# Loss Prevention Bulletin

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Issue 240, December 2014

## Remembering Bhopal – 30 years on

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LPB240

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## Loss Prevention Bulletin

*Articles and case studies from around the world*

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Editorial

# Lessons from Bhopal

This issue of *LPB* commemorates the 30th anniversary of the world's worst industrial accident on record. The tragic incident happened at the Union Carbide India Limited (UCIL) pesticide production plant in Bhopal, India in the early hours of the 3rd December 1984.

Many of us recall that this incident was caused by the unintended violent reaction between methyl isocyanate and water, which led to the release of approximately 40 tonnes of this highly toxic gas into the atmosphere. This fateful release caused thousands of deaths and hundreds of thousands of injuries, and an unknown number to suffer continued physical and psychological conditions. An on-going tragedy is that much of the site of the incident remains contaminated and unremediated to this day.

Much has been learned as a result of the terrible accident: A number of countries have taken proactive steps in formulating more stringent controls on the use of land around hazardous industries in light of Bhopal. Anandita Sengupta (see page 17) explains how the experience in land use planning in the Netherlands could equally be applied to similarly densely populated, industrialised areas of India.

Johanna Suikkanan outlines on page 25 how international organisations such the United Nations Environment Programme (UNEP) have been developing policies, programmes and guidance for governments and industry to help reduce industrial and chemical accidents worldwide, as a result of incidents such as Bhopal.

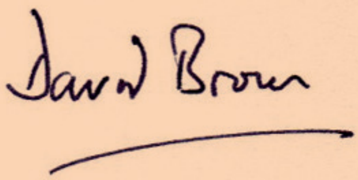
If anything good came out of this tragically fateful accident, it is the realisation of the importance of safety by design. As the late Professor Trevor Kletz said, "what you don't have can't leak" and he urged designers to adopt concepts of inherently safer plants by design. Trevor went on to state that it is devastating that it took such a huge loss of life to shatter the complacent reliance on bolt-on safety systems. Inherent safety is discussed by Graeme Ellis (page 30) and David Edwards (page 21).

Thirty years on, it is imperative for industry to develop a culture that fosters the installation of well-structured inherently safer designed processes and plants. Leaders within these industries should encourage all, including scientists, engineers, managers and operators, to contribute in all aspects of their operations without inhibition or recrimination. Focus should also be given to education and how we train up and coming chemical engineers in our education establishments so that they understand and appreciate the challenges that lie ahead of them in industry.

Finally, I would like to extend thanks to my Editorial Panel colleagues, Fiona Macleod and Mark Hailwood, for the leading roles they have played in enabling this commemorative issue to come to fruition.

**M Iqbal Essa**
**Chairman, LPB Editorial Panel**

Thirty years on, the Bhopal tragedy should give every process industry professional cause for sober reflection. Our industries have brought, and will bring, immense benefits to the world: but that which has potential for much good also has potential for great harm. It is our responsibility as chemical engineers to make safety our top priority, in actions and in resources and not just in words; to place the highest standards of ethics at the core of our professional values; to live those values and to inculcate them in future generations of engineers. The process industries are safer, thirty years after Bhopal – but there is much more to do.



**David Brown**
**Chief executive, IChemE**



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Overview

# Impressions of Bhopal

Fiona Macleod

## Introduction

I had not realised how beautiful Bhopal is.

*View of Upper Lake, Bhopal (FM)*

*Sambhavna Clinic Bhopal (FM)*

When news broke of the Union Carbide accident in India, I had just started my first job as a chemical engineer in Scotland. Many years later, I found myself involved with a major investment program in India along with a team of well-educated, hard-working, ingenious and inventive Indian colleagues. Despite the common language (English), I was struck by the cultural differences and it awoke an intense curiosity to understand what had really happened in the early hours of 03 December 1984 in Bhopal. I read every book that I could get my hands on[1234] and finally visited the capital of Madhya Pradesh in June 2013.

Some Indian friends arranged for me to visit the Sambhavna Trust clinic in Bhopal. Set up in 1995 it provides free treatment to those who need it most. It is a beautiful, tranquil place full of green open spaces, a children's playground, a yoga hall, an open garden meeting room. Alongside conventional medicine, the plants from the large garden are used in complementary therapies. There are people who listen and offer practical support.

I made it clear that I worked for a multinational chemical company and that I did not support the campaign against Dow Chemicals. I was made very welcome, and given the full run of the library and the assistance of a very knowledgeable archivist, who helped me to find all the information that I was looking for.

Reading the eyewitness accounts of the accident and the aftermath so close to where it had happened was a harrowing experience.

Afterwards I went to the factory. It is still there.

What remains of the Union Carbide India Limited (UCIL) pesticide factory is invisible from the road, lost inside a jungle of greenery. It would be easy to miss it, along with the memorial on Kali Parade. The brutalist modern representation of a grieving mother with her dead infant was being used to dry jeans; the squat statue was artistically improved by the denim decoration.

On the wall behind is a colourful mural with a poem:

*History says, don't hope*
*On this side of the grave.*
*But then, once in a lifetime*
*The longed-for tidal wave*
*Of justice can rise up,*
*And hope and history rhyme.*

*Factory complex from Kali Parade (FM)*

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*Bhopal tragedy memorial (FM)*

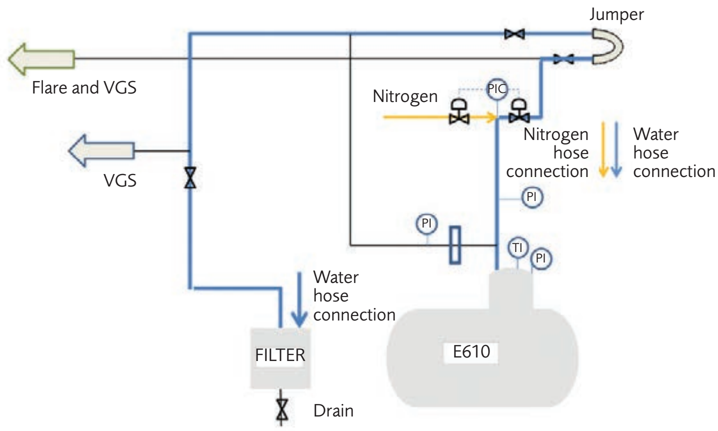


*Figure 1– Water washing theory*

It is strange to see only the work of Dutch sculptor Ruth Waterman and Irish poet Seamus Heaney here because Bhopalis know how to do public art. The 1982 Bharat Bhavan complex above the upper lake in Bhopal celebrates the verbal, visual and performing arts with style and panache. The new tribal museum that opened in June 2013 is simply gorgeous, overflowing with dramatic displays, not just the individual artefacts, but their combination. The concrete memorial on Kali Parade stands in particularly stark contrast to the exquisite stone sculptures in the Bhopal state museum, including a terrifying statue of Chamunda wreaking death and havoc, the perfect symbol for the carnage of the night of 02/03 December 1984.

What really happened to lead up to the world's worst industrial accident? Why is there no proper public memorial? Why has the site not been cleaned up? Why do the victims, relatives and neighbours still feel betrayed?

## The accident

In the early morning of 03 December 1984, a gas cloud was released from the Union Carbide pesticide factory in Bhopal. Within a few hours, thousands of people were dead and hundreds of thousands were injured.

## The cause

Most people agree that the release of toxic gases was caused by a runaway reaction in a tank E610 containing about 40 tonnes of methyl isocyanate after it came into contact with about one tonne of water. There are at least four competing theories as to how this happened.

### *The water washing theory*

Accidental entry of water through a common vent line during a filter washing operation over a hundred metres away on 02 December.

The water washing theory is the accepted explanation in the official Council of Scientific and Industrial Research (CSIR) report.[5] During the routine cleaning of a filter, no physical barrier (spade) was inserted contrary to correct procedure and attributable to the cut backs in maintenance staff on shift. Water found its way back though a common header and travelled up 7m and along 150 metres to E610. This theory is contested on the grounds that there was insufficient pressure of water, there were closed valves in the way, and no water was found in the header when it was drilled at its lowest point two months later. Hydraulics are complex and we have no way of knowing what valves were opened and closed to aid the washing of the filter. In addition a high temperature, high pressure runaway in E610 could have cleared the header, or water could have escaped from leaking flanges (several were reported).

### *The sabotage theory*

Deliberate entry of water by a disgruntled employee connecting a water hose directly to the tank E610 on 02 December.

The sabotage theory was proposed in the Arthur D. Little (ADL)[6] report commissioned by Union Carbide. The evidence is circumstantial (disgruntled employees, a missing pressure gauge, a water hose left running, evidence of altered log sheets and general commotion during a tea break) and is hotly contested by all those on shift at the time. It used to be common practice to blame individual workers for accidents but more sophisticated understanding of process safety, layers of protection and human factors has thankfully reduced this practice. In 1985 this was the company defence – that no safety system can ever be designed to protect against deliberate malicious acts.

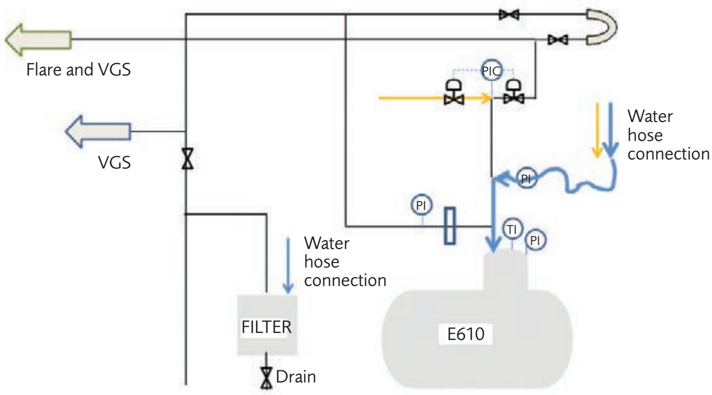


*Figure 2 – Sabotage theory*


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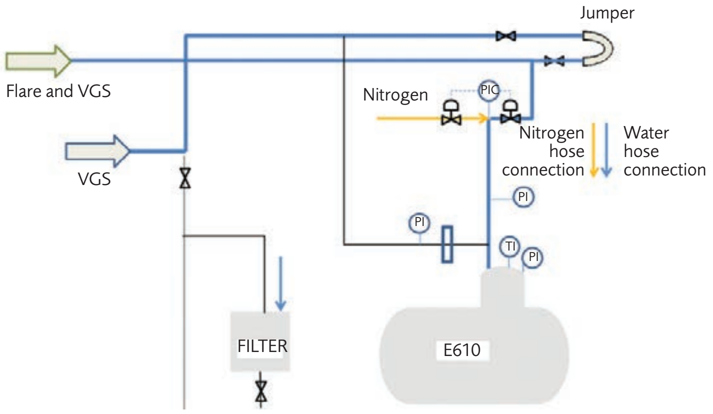


*Figure 3 – Decomposition theory*

## The decomposition theory

Gradual entry of water and other contaminants over many weeks prior to 02 December.

Although extensive trial work was done (based on residues in E610), it is impossible to know the exact composition of the tank contents before the accident, or what happened to it between October (when the last MIC was added) and December (when the runaway reaction occurred). It is known that the composition in E610 was unusual; it contained high levels of chloroform due to distillation to a higher temperature when shutting down and emptying the MIC plant. If E610 was not pressurised with nitrogen it is possible that water or caustic from the scrubber, along with other contaminants, could have entered the tank over the six week period when it sat full and unused. While the chemists were able to replicate the residue found in E610 by adding a single slug of water to a sample of MIC and chloroform, it does not prove that there were no other possible ways to arrive at the same residue.

## The nitrogen mix up theory

Mix up of hose connections leading to accidental entry of water instead of nitrogen on or prior to 02 December.

There is some evidence that repeated attempts to transfer tank E610 had failed because it was not holding pressure. There was chloroform found in the SEVIN feed tank suggesting that some material had been transferred from E610. Could a worker have tried to connect nitrogen directly to the tank and inadvertently connected water instead? This theory was discounted on the basis that "The water lines are blue, nitrogen lines grey and air lines white... They are also labelled. And the nitrogen and water lines have nozzles of different sizes."[7] It is worth noting, however, that despite clear labelling and colour coding and nozzle differences, the Automobile Association (AA) estimate that 150,000 drivers put the wrong fuel in their car every year in Britain alone.

It is now too late to be sure how the accident happened or to know the exact composition of the gases released.

What we do know is that, whatever the cause, had the multiple safety systems been working as designed, then the catastrophe could have been avoided altogether, or had much less severe consequences, i.e.:

- If the tank had been filled to less than 50% full (as designed) instead of over 80% there would have been less material to release.
- If the caustic scrubber had been connected and working continuously, it would have lessened the severity of the release.
- If the refrigeration system had been working along with reliable temperature gauges, there might have been time for operators to react and prevent the release altogether.
- If the flare had been connected and lit, it could have significantly reduced or possibly prevented the consequences of the event.

Also, an emergency water spray could not reach the height of the vent stack, having been designed to alleviate the effects of a ground level spill rather than a high level release.

It is generally accepted that the plant and safety systems were allowed to fall into disrepair while the plant was losing money and closing down. There were a series of cost saving initiatives culminating in the 1983 Operation Improvement Program, which imposed savage cuts in staffing, maintenance and training. The local factory management underestimated the risk of the stored chemicals after the MIC production unit closed down.

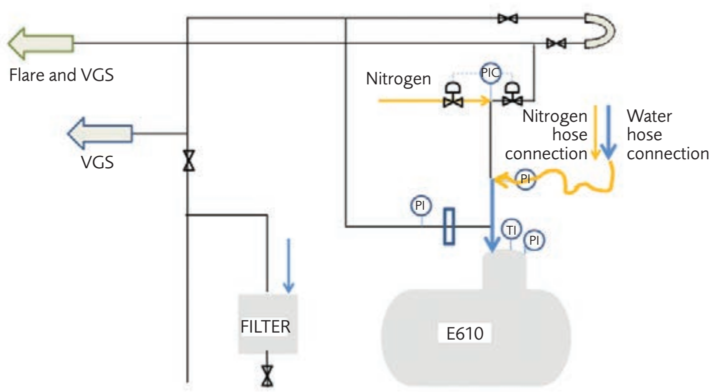


*Figure 4 – Nitrogen mix up theory*

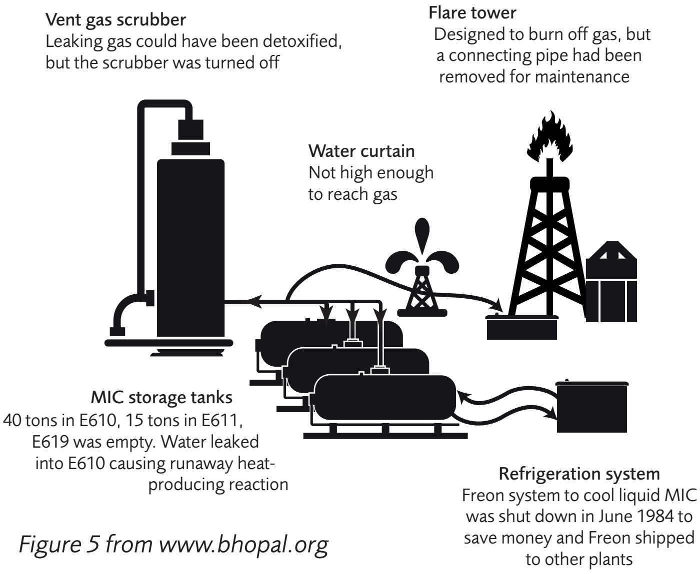


*Figure 5 from www.bhopal.org*

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Several warnings went unheeded:

- The union safety concerns were not addressed and the union leaders who raised them were fired.
- A local journalist, Raj Keswani, repeatedly drew attention to safety issues at the site but was ignored.
- UCC (the parent company) carried out a safety audit in 1982 but did not follow up on the recommendations.

The number of dead and injured increased because:

- There was no offsite alarm or emergency plan;
- The public and emergency services were not aware of the hazards or safest response;
- The factory was sited close to the old town and to bus and railway hubs;
- Slum dwellings had also grown up around the factory on land zoned as industrial.

It is particularly painful to realise that a wet cloth over mouth and nose might have been enough to save many lives if they had also known to stay indoors or to flee across instead of down-wind.

There are known facts and competing theories, but in the absence of a thorough independent investigation, with forensic preservation of evidence at the time and detailed interviews immediately afterwards, it is impossible to be sure what caused the accident.

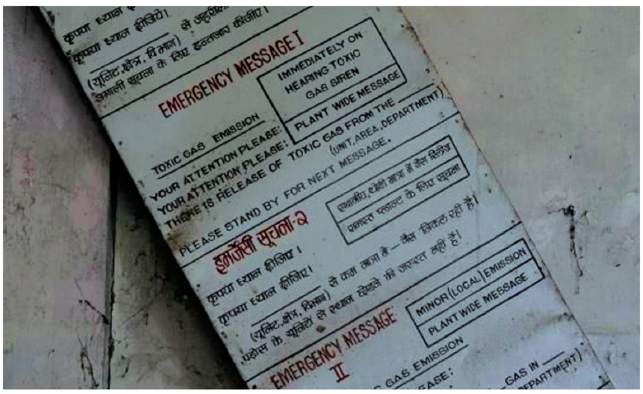
## The aftermath

After the accident, the inadequate response in support of those affected was shocking. There were people in desperate need and there was a rich US corporation willing and able to finance some alleviation of their suffering, but it somehow seems to have all got tangled up in a mess of endless court proceedings.

Others have documented the years of legal wrangles but among them were two key events in 1989 and 2010.

In **1989**, almost five years after the accident, an out of court settlement of US$ 470 million was reached between the Government of India (acting on behalf of the victims) and Union Carbide Corporation (UCC). There are several problems with the settlement:

- It underestimated the number killed.
- It underestimated the number and severity of the injuries.
- It ignored the fact that chronic ill health prevented some from ever returning to work.
- It failed to value the contribution of "non-working" women, children and the elderly within a family unit.
- It ignored mental health injuries.
- It ignored the loss of livelihood for the former workers and the network of small businesses dependent on the factory.
- It ignored inflation.
- Compensation was meagre even by Indian standards*
- Distribution made no allowance for the fact that the worst affected groups were poor and ill-educated, and living at the margins of society.
- The standard of evidence demanded to support claims of death or injury caused by the release meant that much of the compensation money went on medical, legal and loan interest costs. Those providing such services were of variable quality and took a disproportionate amount of the money that should have gone to victims and their families.
- Distribution was slow – in 2004, twenty years after the accident, claims were still being settled.
- Interim relief was deducted from the final settlement.
- No provision was made for the clean-up of the site.
- As a condition of the settlement, all criminal charges were suspended (this was later overturned).




*Emergency sign in 2014 (Julia Green www.bhopal.org)*

In **2010**, over twenty five years later, eight former executives of Union Carbide India Limited (UCIL) – including one who had already died – were convicted of causing death by negligence. The seven surviving defendants were sentenced to two years in prison (the maximum allowed by law) and fined 100,000 rupees, or $2,100. They were given leave to appeal and immediately released on bail.

## Worlds apart

What happened on the night of 02 December 1984 was an unspeakable, terrible tragedy, and the suffering of those who died, were physically injured or mentally traumatised cannot be overstated.

And yet it is still very difficult to write about the Bhopal accident dispassionately without offending or upsetting someone, not least because there was so much suffering and then such polarised opinion, suspicion and hatred.

There are those who believe that Union Carbide in America deliberately allowed an unsafe process to operate in a developing country and that their Chairman, Warren Anderson, personally approved this and was ultimately responsible for everything that happened.

On the other extreme there are those convinced that the process was fundamentally safe but that a single act of sabotage by a disgruntled worker caused the accident. The genuine concern shown by UCC senior executives in rushing to the

**Compensation was ~100,000 rupees (US$3,000 at 30Rs/$) for each certified death and ~30,000 rupees (US$1,000) for proven injury or other loss (livestock etc.), the equivalent of about 5 years' wages for a death (assuming an average annual wage of 20,000 Rs). In the annual UCIL accounts for 1984 the lowest paid full time worker cost the company 32,000 Rs/year and the highest 80,000 Rs/year. The family of the worker Ashraf Mohammed Khan who died after an accident at the factory in 1982 was offered 72,000 Rs in compensation. The family were still contesting this when his three year old son Arshad died in the 1984 accident.*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scene of the accident was met by a lynch mob mentality and things went downhill from there.

*Whatever the cause, the operating company was responsible for ensuring that design, safety systems and community emergency response contained the consequences of any accident to within the site.*

There are those who believe that, after the accident, Union Carbide withheld information that could have assisted in determining the treatment of victims, that they forced the Indian government to halt programs providing effective relief because it might implicate them further and conspired with the government of India to distort the data.

On the other side, there are those who believe that most of the ongoing chronic illnesses, birth defects, disabilities and general poor health of the population is due to socioeconomic factors and no different from any other city slum population.

*No one knows the exact composition of the gas released that night. There is independent evidence of different effects at different distances from the source of the release, suggesting a complex composition. There is no doubt that there was horrific physical suffering and mental trauma in the surrounding population. Help should have been and should continue to be provided unstintingly.*

There are those who believe that the 2007 initiative by the Tata group to organise a "no blame" remediation of the Bhopal site was part of a conspiracy to allow foreign entities to escape any on-going responsibility** and that the only way to prevent a future Bhopal is for justice to be done, and seen to be done. However, as a result of the political and legal impasse, the old Union Carbide site in Bhopal remains rusting and leaking, thirty years on.

## Multinationals

Chemical executives do not spend time stroking white cats and planning ways to poison the planet. The industry is full of intelligent, honourable people whose efforts have helped make the world a better, cleaner place for its ever increasing populations, lifting people out of poverty, providing clean water, improving communication, reducing hunger, preventing and curing disease.

Companies fund innovation and growth by promising a return to their shareholders. The requirement to maximise shareholder value puts increasing pressure on the cost of manufacturing. Together with changing demographics and growing aspirations this means manufacturing in developing countries, largely because that is where the new customers are.

The people who rise to the top of large chemical companies are those who set and meet the most challenging targets. Few are engineers and even fewer have direct experience of the realities of manufacturing. It is not enough to add lagging safety and environmental measures to the financial targets of these top executives; major accidents are thankfully too rare to be a meaningful measure. There is an increasing danger that the

** *In 1986 UCC sold its pesticide division to Rhone Poulenc, acquired by Bayer in 2002. In 1994 the UCC shares in UCIL were sold to McLeod Russel (India) which merged with Eveready Industries India and the proceeds used to found the Bhopal Memorial Hospital. In 1998, Eveready Industries surrendered the lease on the Bhopal factory site to the state government of Madhya Pradesh. In 2001 Dow Chemical acquired the remains of UCC.*

*The MIC Storage tanks E610, 611 and 619 in 2014 (Julia Green www.bhopal.org)*

*MIC Unit in 2014 (Julia Green www.bhopal.org)*

*Sevin Unit in 2014 (Julia Green www.bhopal.org)*

*MIC Unit in 2014 (Julia Green www.bhopal.org)*

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*Control Room Feb 2014 (Credit BMA)*

*Laboratory Feb 2014 (Credit BMA)*

lessons of the past will be forgotten. And accidents repeated.

## Jugaad

Jugaad (pronounced "Joo-gaard") is a Hindi word for a quick fix, a creative way of solving a problem, an improvised arrangement used because of lack of resource, a cost-effective way to solve the issues of everyday life. It is commonly used when describing an innovative workaround to get through commercial, logistical, or legal issues. There are many great examples of frugal innovation where good engineering matches product design to the needs of the market: better, cheaper, faster.

Anyone who has spent time in India cannot fail to come away impressed by the ingenuity and pragmatism, the local ability to do things fast and cheap. But not always well. And not always legally. The theft of electricity by tapping into overhead cables is a prime example of Jugaad.

It is our job as engineers to ensure that risks are quantified and understood. Locally made motor vehicles, a diesel engine lashed onto a wooden cart, may provide low-cost transportation in rural India, but it comes at a price: no crumple zone, no seat belts, no child restraints, no air bags, no anti-skid or pedestrian protection. WHO Global Status Report on Road Safety reveals the staggering number of deaths due to road accidents when pedestrians are hit by unregistered vehicles.

In the Union Carbide plant in Bhopal, the pumps that were designed to transfer methyl isocyanate proved unreliable. A work-around was found that used nitrogen pressure for transfers. In order to do this the nitrogen was diverted from the vents. More than one possible contributing cause of the catastrophe is directly related to this work-around[8].

Jugaad (frugal innovation) is a concept that should never be applied to high hazard chemical plants, or bandied around in the boardrooms of the companies that run them.

## A personal journey

I still remember the response of my industry. In 1984 I was working for ICI in a fertiliser factory in Leith. A few months after the accident my team was gathered in a room with a reel to reel tape recorder and made to listen to a speech by John Harvey Jones, the boss of ICI. The crux of the message was that if we, ICI, could not afford to run a process safely, then we should not run it at all.

Soon after that, in the face of competition from eastern Europe, we began to shut down the plants at the factory one by one. First the sulphuric acid plant, then the phosphoric acid, then the super and triple phosphate. Finally, in the early 1990s, the Leith fertiliser factory closed completely.

I am not suggesting that the cause of my factory closure was simply a heightened safety awareness after Bhopal, but it was made abundantly clear that in the face of huge financial losses, the answer was not to stop training or maintenance or cut costs in ways that would endanger the safety of the workers or the people of Edinburgh. The plants were run properly until the balance sheet (and a bizarre ruling by the UK monopolies commission) meant that they were shut down indefinitely.

I have changed my mind about a few things since visiting Bhopal.

Senior executives should be accountable for the safety of worldwide operations without boundary or border. Alfred Nobel made his factory managers live in the middle of explosive plants. One important way to be sure that the right decisions are taken in boardrooms is to make sure that the decision maker has a personal stake in the consequences.

The social activists are right to fight the removal of the identified toxic waste from the Bhopal site until the wider issue of land contamination is resolved. The waste is packaged and contained; once it is removed, no one will care.

The compensation that was agreed in 1989 by the Indian government on behalf of the victims was too low. Even by local Indian standards it was wholly inadequate. There was no punitive element and no provision for clean up or site remediation.

Ultimately, all individuals and groups are driven by self-interest. It is only by making the consequences of accidents punitively high that companies are forced to take serious and sustainable steps to avoid them. It hurts to realise that each seal in Alaska after the 1989 Exxon Valdez disaster had many times more money lavished on it than any survivor of Bhopal.

## Conclusion

It may be little comfort to the people of Bhopal, but there is no doubt that the Union Carbide accident caused a shift in the way that the industry viewed process safety. There has been a move to safer design, reduced inventory of toxic chemicals (what you don't have, can't leak), a focus on human factors, employee engagement, emergency planning.

Some of those lessons have been institutionalised in developed countries – such as HSE's Control of Major Accident Hazards (COMAH), OSHA's Process Safety Management



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(PSM), EPA's Risk Management Program (RMP) – but 30 years on, it is timely to take a long hard look at the international chemical industry and ask some searching questions.

The interpretation, application and enforcement of environmental and process safety law varies widely from country to country. It is important to design for safety, but the tragedy of Bhopal reminds us that it is not enough. Responsibility for safe operation of high hazard manufacturing assets continues throughout their lifetime.

How do multinationals, headquartered in Western Europe or North America, ensure that their operations in developing countries are designed, commissioned, operated, maintained and closed down safely and responsibly?

The finance director who makes the decisions to cut costs, remove experienced people, take short cuts, may be long gone by the time those decisions come back to haunt the company. There will be senior executives in the chemical industry today who were still at school in 1984. Some may even view government regulation or industry led programs such as Responsible Care as red tape, bureaucracy and additional cost in countries where they are not mandatory.

If a multinational company decides that it will simply obey the local law, it runs the risk (perhaps unwittingly) of taking advantage of poorly drafted legislation full of loopholes, lax enforcement and even corruption[9].

However if a multinational company tries to apply the same European or North American head office standards worldwide, it will run into other difficulties. From engaging with the local communities[10] through cutting scaffolding boards[11] to meaningful SIL verification[12], each country presents different challenges[13]. It is impossible to run a complex project from a distant head office. Nor can key decisions be delegated to an international engineering contractor.

There is no substitute for a mix of a competent, properly trained and fully resourced local team together with on-site head office expertise. That has costs. But if a project cannot be resourced safely, then it should not be done at all. If a plant cannot be run safely, then it should be shut down: responsibly and carefully.

Remember Bhopal.

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Comment

# A call for extending the Safety Case approach

Judith Hackitt CBE
Chair HSE and Immediate Past President IChemE

Significant anniversaries are always a time for reflection. 2014 has seen more such anniversaries which resonate among the engineering community than usual – in June it was 40 years since the Flixborough explosion, in July it was 40 years since the Health and Safety at Work Act came into force here in Great Britain. As the year draws to a close we recognise the 30th anniversary of what is still regarded by most people as the world's worst ever chemical plant incident – in Bhopal, India in December 1984.

Whatever the specific cause of this catastrophic incident, the toll in human suffering was and continues to be truly appalling. The anniversary of this disaster serves as yet another reminder to us all that the same mistakes continue to be made – the high level lessons are still not being learned.

The Bhopal plant was using methyl isocyanate as an intermediate in the production of carbaryl pesticide. Other process chemistry routes existed to produce the same end product which were lower hazard but higher manufacturing cost. Changing the process in Bhopal was unlikely to have been an option that was even considered, but did the management team at the time know what they were dealing with? Did they understand the nature of the risks and what could happen if things went wrong?

Whatever the cause of the ingress of water into the tank, the potential for contamination of the tank with water could and should have been considered. It would be hard to describe it as an unforeseeable event. Cross contamination of materials in storage tanks is a real risk that must be considered as part of any Hazop.

There had been no serious emergency planning to mitigate the consequences or to ensure that emergency systems could cope in the event of an incident. Warning signs that things were not as they should be had been ignored. The flare system was a critical element within the plant's protection system, but it was out of commission.

The plant was designed to run with a refrigeration system to keep the methyl isocyanate cooled but the refrigeration system had been turned off to save costs and the tank was routinely run at ambient temperature despite the design conditions being 0ºC.

When the incident happened, operators quite simply did not know how to respond. People in the locality didn't know what to do even when the alarm sounded. Neither the company nor the local hospitals had information on the hazardous nature of MIC and the appropriate medical response.

It is very easy to look at these failures and say "But that was 30 years ago, we've made huge strides in process safety since then – it couldn't happen here/now". But are we really sure about that? Are our assurance systems good enough to be confident of that? The evidence of further incidents which have continued to happen since Bhopal would tend to suggest that there is still plenty of learning – and action – needed.

I do not doubt at all that we have learned a great deal from the tragic incidents of the past. Our focus on accident prevention measures, risk mitigation and emergency response is enshrined in robust regulation. Most, but still not all, parts of the world have specific regulation to cover major hazard operations. In countries where major hazard regulations exist there remain differences of approach – some of which are entirely understandable given a variety of factors including culture, system maturity, experience.

But the 30th anniversary of Bhopal is surely a time for us all to reflect on whether or not we are doing as much as we could or should to share knowledge and to raise everyone's game everywhere in the world.

I am personally a very strong believer in the robustness of the safety case approach. The UK has a long history of delivering effective and balanced regulation of major hazards built upon principles of pre-operation regulatory permission coupled with active audit and inspection. The safety case is more than a documentation report to fulfil regulatory requirements. It should be a living document requiring the business to systematically assess the risks associated with their activity, and to identify the most critical control measures that need to be in place. It enables the regulator to assess whether things will really operate in practice and focus their inspection efforts on the most important aspects.

The safety case is also a powerful tool for communication with the emergency services, who will need to respond in the event of an incident, and local residents, who need to understand what action to take if the alarm sounds.

Would a safety case regime have prevented the tragedy in Bhopal? An impossible question to answer – not least given that the actual cause of the incident is still the subject of much debate. Safety case regimes coupled with open and transparent enforcement, do not offer any guarantees – but they can offer a very high degree of protection to people and the environment, especially in comparison to other regulatory approaches. Safety cases cannot stop deliberate acts of sabotage or even mistakes being made, but they can ensure that their consequences are mitigated by whatever means are practicable. They can also ensure that process safety is properly understood and managed and that response in the event of an incident is predetermined and effective.

We must never stop reminding ourselves that the lessons from the past are there to be learned from and acted upon. The 30th anniversary of Bhopal is yet another date where we should all take time to reflect and feel the unease.



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Comment

# Thinking about Bhopal – the role of education

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In its quest to make the country self-sufficient in food, the Indian government in the 1960s promoted high-yielding varieties of grain. The ensuing 'green revolution' transformed India from a country with chronic shortages into one that grew all the food it needed. For its success, the 'green revolution' required a massive increase in the indigenous production of chemical fertilisers and pesticides. This was the context in which Union Carbide Corporation was permitted to set up an insecticide manufacturing plant at Bhopal, setting in motion a chain of events that led to the tragedy thirty years ago–the worst industrial accident in history. A real tragedy of Bhopal was that it could have been avoided with better education and better awareness of safety measures among the workers.

In the immediate aftermath of the tragedy, there was sharp criticism of the Indian government: that it did not properly scrutinise the chemical processes involved before sanctioning the plant, that it did not examine the alternative less-hazardous routes for the production of Sevin, that it erred in locating such a potentially hazardous plant so close to a population centre, and afterwards that it did not exercise due diligence in carrying out its regulatory and supervisory functions. On its part, Union Carbide was accused of putting up a plant of unsafe design and adopting unsafe operating procedures once it became clear that operations were not profitable, of refusing to take any responsibility for the accident and withholding information and spreading disinformation about the nature and the toxicity of the gases released during the leak. Both the government and Union Carbide were accused of collusion in the matter of compensation.

As India matures as a nation, we have to realise that all technologies carry risks and the assessment of such risks is an important component in the choice of the particular technology we adopt. There are however, many competing considerations – technical, political, economic and social that feed into any such decision-making, and safety does not always get the emphasis it deserves.

The growing chemical pollution of our environment and the alarming increase in the incidence of cancer and other life-threatening diseases, are indications that we may not be on the right path. We need to rethink our policies of development, and not only because of what happened in Bhopal. Higher economic growth does not necessarily translate into a better life for the people at the margins—the ones who are most affected by tragedies like Bhopal. Working with NGOs we have seen that those who already have some resources benefit more from development projects than those who have none or very little. This is supported by the recent work of Piketty[1], who using long-term economic data across many countries, has shown that periods of economic growth are invariably accompanied by an even greater growth in inequality.

Post-independence, in large part due to the charismatic leadership of Jawaharlal Nehru, India enthusiastically embraced the concept of development based on industrialisation. It is time to question the universality of such a concept. We need to educate our population to become informed citizens so that they can play a critical role in influencing and re-formulating national policy. We need to revisit models of development so that they proactively help the poor and the marginalised.

Two other issues need our attention. With depleting fossil fuels and natural resources, the world is going to be increasingly dependent on nuclear energy. How well are we prepared to handle accidents in the nuclear industry? A particularly worrying element is the recent rise in sea levels with the melting of the polar ice caps allied with the fact that many nuclear power plants are sited close to seas to satisfy their huge demand for water. Another consideration is what is driving this growing demand for resources, for energy, for food, for a better quality of life—the increasing population of the world. People generally need to be educated about the gravity of the situation and the necessity for immediate corrective action.

To be blessed with such citizens will require a major reformulation of our education policy and the aims it is expected to serve. We need to educate our children to be sensitive to their own physical and mental wellbeing, to take care of the world they inhabit, to the importance of responsible citizenship. We need a system that teaches our children not only the skills of scholarship but also educates them to become more responsible, tolerant and respectful of others so as to function harmoniously in the increasingly plural society that they inhabit. We need to educate them about personal health, safety, the pollution of the environment, the finiteness of our natural resources and the absolute necessity for sustainable models of development, but most of all we need to extend the reach of education in India. If half of our children are not being educated beyond middle school, then we are tackling our problems with only half our intellectual potential—for talent resides as much among the half we are not educating as the half we are.

If we wish these not to remain mere rhetorical injunctions but to become the guiding principles for a better system, then we have to ensure equity and access for the marginalised while maintaining and improving the quality of what we deliver in the name of education. The state of education in India, in general and science education in particular, especially in rural schools, whether public or private, apart

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from being of limited reach remains pathetic in quality. The emphasis is on rote learning. There is no attempt at developing critical thinking, and schools lack even basic facilities like libraries and laboratories. Science is taught as a compendium of laws, as if answers to all possible questions that a pupil could ask are already known and there is no room for investigation or experimentation in the classroom.

The Hoshangabad Science Teaching Programme was an attempt, starting in 1972 and lasting 30 years, to teach science for better understanding in government middle schools in predominantly rural areas of the state of Madhya Pradesh, whose capital city incidentally happens to be Bhopal (see references 2 and 3 for a detailed account of the programme, its beginning and closure). It was organised by voluntary agencies (in later years Eklavya) with resources drawn from universities and research laboratories. In the Indian context where students have little exposure to observation, experimentation or investigation in science classes, teaching science for better understanding translated into teaching using suitably chosen experiments that children performed themselves. The revision of the middle school curriculum, preparation of new workbooks based on experiments that were low-cost and could be performed by students in rural settings, training teachers, regular school follow up, an innovative system of assessment – all followed as consequences of this basic objective. The curriculum was not only driven by the demands of the discipline but was also responsive to the environment of the child and the needs of good citizenship. It tried to teach children how to learn for themselves, to encourage them to develop enquiring minds and to find answers to their own questions by designing suitable investigations.

After running for about 30 years and having spread to some 800 schools the programme was abruptly closed down by the government, because government policies can change not only when a new party wins an election or a new minister for education is appointed but even when a new bureaucrat assumes office in the department of education.

Nevertheless the dream of a better future, of a better life for the poorest in society, is not likely to come true unless we shed the cynicism that such events breed, and work concertedly for a better quality education which is accessible to the children of the poorest in our land.

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Bhopal legacy

# Understanding the impact of unreliable machinery

Kenneth Bloch and Briana Jung

A common misconception lingering today is that the toxic chemical release in Bhopal, India, was an extreme, outlier event. However, when the public record is considered, a different picture emerges. What follows is a careful and recent evaluation of information that has slowly been released into the public domain over a twenty-seven year period. The warnings this assessment offers should be of poignant interest and concern for all organisations responsible for the lives of others.

## Methyl isocyanate release

Union Carbide began producing methyl isocyanate (MIC) in Bhopal, India, on February 5, 1980.[1] MIC is a highly reactive intermediate chemical that Union Carbide used to manufacture various pesticides. It is also a very lethal substance that can be harmful or fatal if inhaled or absorbed through the skin.[2] MIC reacts exothermically with a variety of potential contaminants including rust and particularly water.[2]

Routine maintenance activities were taking place in the factory on the evening of December 2, 1984. Sometime around 10:45 p.m., a large quantity of water began entering a chemical storage tank containing over 40 tons of MIC. The reaction mixture inside the tank progressively warmed as conditions moved closer to a thermal runaway reaction.

Water continued entering the tank until shortly after midnight (December 3, 1984), when the thermal runaway reaction took place. This caused the MIC storage tank's pressure gauge, shown in Figure 1, to suddenly spike above scale.[3] Although this drew attention to the tank, it was too late to stop the catastrophic loss of process containment.

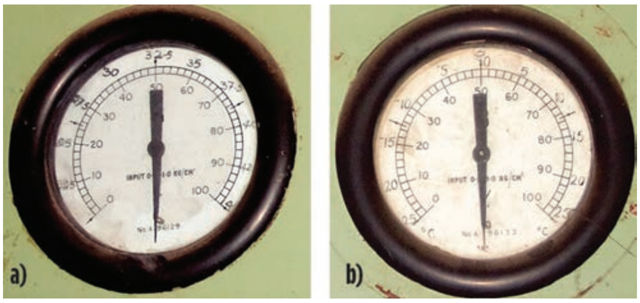


*Figure 1. a) MIC storage tank 610 control room pressure gauge. b) MIC storage tank control room temperature gauge*

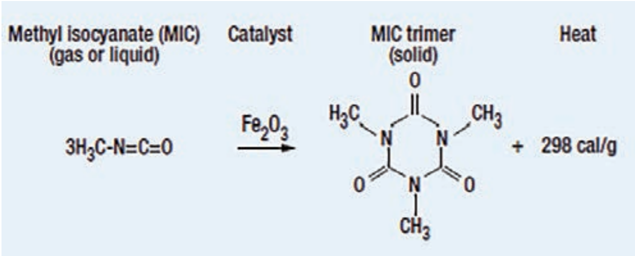


*Figure 2: MIC trimerisation reaction*

Shortly after the runaway reaction occurred, hot MIC vapour burst through the tank's automatic pressure relief system and into the relief valve vent header (RVVH).[3] Although this prevented an explosion, a major release involving up to 40 tons of toxic MIC drifted downwind into the surrounding community. By morning, thousands of people and animals were dead.[4]

Systems that should have prevented the release, including a refrigeration unit and alarms, failed. None of the safety equipment capable of containing the potential release or at least minimising its consequences had worked either. The factory never reopened and Union Carbide, once an undisputed leader in the chemical manufacturing industry, struggled to survive before selling off its remaining business in 1999.[5]

## About MIC

Carbon steel is incompatible with MIC.[4] Rust ($Fe_2O_3$) catalyses the exothermic MIC trimerisation reaction shown in Figure 2.[4] This reaction forms a nuisance deposit that can clog pipes.[6] Therefore, stainless steel is recommended in MIC service.[6] In theory, more economical carbon steel components could be substituted when protected by a corrosion inhibitor[4] such as nitrogen. If so, then the inert gas would be critical for mechanical integrity (corrosion and fouling resistance). However, stainless steel represents an inherently safe choice that eliminates the reactivity hazard associated with carbon steel.[4]

## Designing the disaster

In March 1985, Union Carbide issued an investigation report[3] that included the piping and instrumentation diagram (P&ID)

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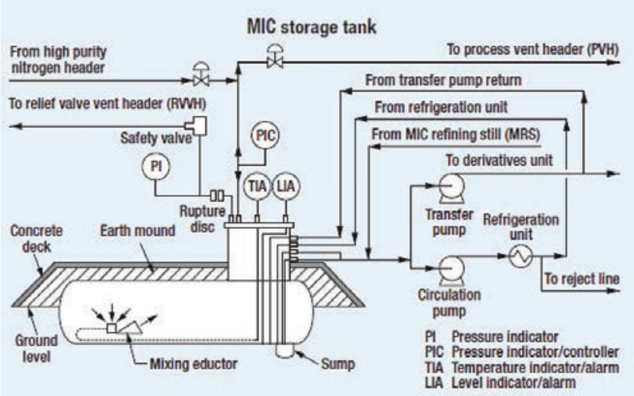


*Figure 3: Original MIC storage tank P&ID*

shown in Figure 3. The P&ID shows the MIC storage tank design. Figure 3 provides design information that explains how equipment reliability contributed to the Bhopal disaster.

The MIC produced at the factory was stored in two stainless steel storage tanks, designated as Tanks 610 and 611.[4] An identical tank (Tank 619) received contaminated material from either Tank 610 or 611 on an emergency basis only.[3] This tank provided extra storage volume to allow for an adequate response to a potential thermal runaway reaction.[3] A nitrogen blanket[4] was used to maintain slight pressure[6] inside the MIC storage tanks while continuously purging MIC vapour into the process vent header (PVH).

The tanks were equipped with the two centrifugal pumps appearing in Figure 3. Each of the pumps had a specific function. The "transfer pump" exported stored MIC into the derivatives unit as needed to produce pesticides. The "circulation pump" processed MIC through a fluorocarbon-based refrigeration system.[7] The refrigeration system kept the stored MIC temperature near 0°C[3] to prevent a thermal runaway reaction.[2]

The pumps were connected to four flanged nozzles on the side of each tank head. Figure 4 shows how these nozzles were configured on Tank 610. Both pumps circulated MIC through internal pipe extensions that dropped to the tank bottom, as shown in the P&ID. The discharge lines returning to the tank were provided so that the pumps would operate continuously.

*Figure 4: MIC storage tank 610 side-head nozzle configuration.*

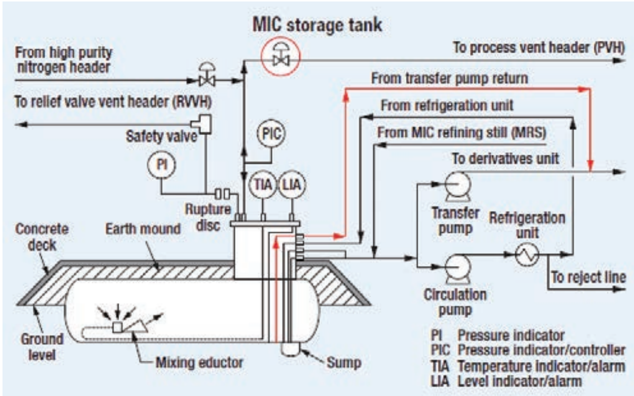


*Figure 5: Alternative MIC storage tank operating method.*

## Procedures

The factory suffered from a series of chronic MIC leaks.[8] MIC is a highly volatile compound that represents an immediate exposure hazard upon its release.[2] For reference purposes, the eight-hour threshold limit value (TLV) for MIC is 0.02 ppm[5] compared to a 10 ppm TLV for $H_2S$. MIC could therefore not safely be released into the environment.[2]

Although the transfer pumps were provided to export MIC into the derivatives unit, there is no record of their use at any time while the factory was in operation. Instead, an alternative transfer method was developed that excluded the pumps. This method involved raising the MIC storage tank pressure to at least 14 psig with nitrogen.[9] Under these conditions, the MIC would reverse-flow directly into the derivatives unit through the alternative pathway shown in Figure 5. This practice minimised the potential for transfer pump seal failures to expose factory workers to the lethal process.[6]

However, nonstandard operating procedures[10] may address one hazard while introducing others. In this case, pressurising the tanks in order to bypass the transfer pumps required isolating the tanks from the PVH. As the P&ID shows, this interrupted excess nitrogen flow into the PVH.[4]

Loss of excess nitrogen flow was an issue because the PVH and RVVH were made of carbon steel.[4] Figure 6 shows the vent gas scrubber (VGS) piping configuration. The photograph shows that the vent header inlet pipes enter above the VGS caustic overflow line. Therefore, air migrated into the

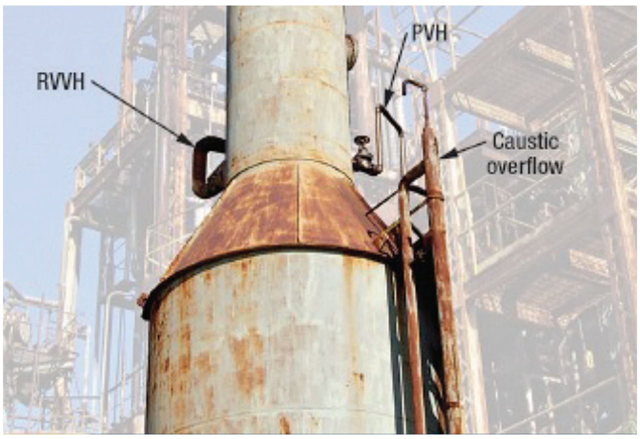


*Figure 6: Vent gas scrubber pipe configuration*


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atmospheric VGS when nitrogen was isolated to pressurise the tanks. Afterward, the inert environment inside the PVH and RVVH ceased to exist. The vent lines started to corrode,[4] which produced rust. Rust catalyses the formation of MIC trimer deposits, according to Figure 2.

After sealing the tanks, other MIC vapour sources continued venting into the PVH.[3] This prompted the creation of a maintenance procedure to remove MIC trimer deposits polymerising inside the PVH and RVVH. The procedure involved flushing out the MIC trimer deposits with water.[11]

Although MIC could still be exported without the transfer pumps, there was no way to refrigerate MIC without operating the circulation pumps. A seal failure on or before January 7, 1982,[8] provided a maintenance opportunity to "upgrade" the original metallic seal with a more fouling resistant, but weaker ceramic seal.[6] In MIC fouling service (reactive environment), using a ceramic seal may seem logical. But if a force-related failure mechanism is causing unacceptable seal performance, then a lower strength ceramic material may not be the best choice.[12]

On January 9, 1982, the fragile ceramic substitute seal was shattered in an unprecedented catastrophic failure.[8] This failure produced a massive MIC release that sent about 25 workers to the hospital with serious injuries.[13] On January 12, 1982, a formal notice was issued to declare that the refrigeration system was being shut down.[8] In doing so, a third non-standard operating procedure was introduced: running the plant without MIC refrigeration.

## Disabling instruments and alarms

After shutting down the refrigeration system, the MIC storage temperature varied from about 15°C to 40°C.[14] This new operating range exceeded the 11°C MIC storage tank high temperature alarm[14] in the control room. Therefore, the high temperature alarms were disconnected.[3] Likewise, the actual temperature inside the tank was unknown[8] after shutting down the refrigeration system because the control room temperature gauge (Figure 1) was not scaled for operation above +25°C. Similarly, the normal operating pressure inside the tank increased from less than 2 psig[2] with an unobstructed tank vent open to the PVH[6] to about 25 psig[3] after bypassing the MIC transfer pumps.

In April 1982, factory workers printed hundreds of handouts expressing their concern about decisions being made inside the factory that might influence the community outside the factory.[8] In May 1982, an independent audit team from the US arrived in Bhopal to perform a safety audit.[6] The audit report formalised several recommendations that might improve managing the MIC pump hazards. For example, it was recommended that a nitrogen purge system with low flow alarms as an *alternative* MIC system venting into the PVH[6] should be installed (this would restore the inert environment inside the PVH and RVVH without operating the transfer pumps). Installing dual seals on centrifugal pumps[6] was also recommended. Another recommendation was to provide water spray protection for the MIC pumps in the storage area, for vapour cloud suppression.[15]

The audit team complimented the factory's creative approach to improving workplace safety with nonstandard operating and maintenance procedures.[4] It is, therefore, understandable why the decision to shut down the refrigeration system was not questioned.[8] Accordingly, the factory's safety manuals were rewritten in 1983 and 1984 to reflect actual operation without MIC refrigeration.[8]

## The fateful night

On the evening of December 2, 1984, the vent lines were corroded and choked with MIC trimer deposits.[4] The pipes were being flushed with water to remove the MIC trimer deposits.[13] MIC trimer deposits form in the presence of rust. Rust forms on carbon steel pipes not protected by an inhibitor. The inhibitor (nitrogen) was isolated from the PVH and RVVH in order to pressurise the MIC storage tanks. The MIC storage tanks were pressurised to bypass the transfer pumps.

Somehow, water entered Tank 610, which contained over 40 tons of MIC. Under normal circumstances, this would have activated the tank's high temperature alarm. But the high temperature alarm was disconnected when the refrigeration system was shut down. Likewise, the control room MIC temperature gauge could not be trusted because it normally read above scale without refrigeration. The refrigeration system was shut down almost three years before the incident[4] because pump seal failures exposed factory workers to the hazardous process. The contamination event inside Tank 610 remained hidden while the reaction mixture temperature continued rising.

Tank 610's vent valve was leaking on the evening of December 2, 1984.[4] The MIC storage tank pressure increased as the reaction mixture evolved more vapours into the PVH.[3]

Although the control room pressure gauge seemed to be within normal range for a sealed tank,[3] the tank was not sealed.[3] Therefore, contamination was not detected until a thermal runaway reaction took place, which sent the tank's pressure gauge off scale.[13] Although factory workers responded immediately, by that time it was too late.

The refrigeration equipment and process alarms were provided to prevent a thermal runaway reaction should the MIC be contaminated by any means. But process safety was compromised in an attempt to manage personal exposure hazards represented by potential pump seal failures.

## Can we learn more from Bhopal?

Bhopal forever changed the way industry approaches process safety management (PSM). Increasing clarity around the events leading up to the release complements and reinforces these important lessons. Time has allowed us to take an even closer look at regrettable decisions that resulted in disabling the system whose purpose it was to prevent the scenario that resulted in the release. Most industry professionals no doubt plainly see from this examination that we confront the same decisions at work every day. Perhaps this is the message contained in "recognised and generally accepted good engineering practices." The decisions we make throughout the life of a process, especially before its construction, can and will affect us as well as all those who follow.

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*Editor's note: The accident on January 9 1982 was on a phosgene pump, not on the MIC refrigeration pumps. The release was phosgene not MIC. However, this does not alter the conclusions of this valuable paper.*

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As an industry professional you will make decisions daily that as a whole define your process safety identity. We can't tell you what the right answers are. It is therefore important to allow your conscience be guided by what took place in Bhopal. This is where Bhopal has even more redeeming value. With these thoughts in mind, the focus is on insightful advice:

- When you choose not to investigate a chronic failure, remember Bhopal.
- When the right choice is not the most economical choice, remember Bhopal.
- When choosing to accept actual operation because you cannot get expected or design operation, remember Bhopal.
- When designing a solution that manages a hazard instead of eliminating it, remember Bhopal.
- When tempted to execute a procedure the way you think it should be written instead of how it is actually written, remember Bhopal.
- When thinking about substituting engineered equipment with people, remember Bhopal.
- When you perform a safety audit, remember Bhopal.
- When redesigning a system to make it "safer," remember Bhopal.
- When operators have concerns with a decision you are about to make, remember Bhopal.
- When making changes for the sake of improving personal safety, remember Bhopal.

## Finding your identity

After 27 years, there are two prevailing theories that may explain how water entered the MIC storage tank. An examination of the events preceding the incident supports the argument that this detail is irrelevant.[5] However, the explanation you favour is governed by your process safety identity. If you believe that a single event can cause a process safety incident of extraordinary magnitude, then the cause was probably sabotage. But if you believe that significant process safety failures result from a complex series of interacting events that may include design defects, repeat failures and missed warning signals, then maybe the cause was inadequate process isolation during a routine maintenance procedure (perhaps even during a maintenance activity required to contain the process in a factory like yours).

## What can you do?

When you report for work tomorrow, remember Bhopal. And when you return to the comfort of your home, convince yourself it is because you did.

*Photo credits: Figures 1 and 6: Dennis Hendershot. Figure 4: Paul Cochrane*

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Bhopal legacy

# Land use planning in India

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## Summary

This article introduces the current situation on regulations and risk acceptability criteria on land use planning in India, 30 years after the Bhopal accident. A number of developed and developing countries have taken proactive steps in formulating more stringent controls on the use of land around hazardous industries in light of Bhopal. The paper discusses the challenges that India faces to develop land use methods that are already in place in other countries.


**Keywords:** Bhopal, risk assessment, land use planning decisions, India

## Introduction

After the independence of India in 1947, Bhopal became the state capital of Madhya Pradesh. The city started attracting new industries and government institutions and this growth continued throughout 1960s. From 50,000 people as a base in the mid-50s, the city grew to 102,000 in 1961 up to 670,000 in 1981. However, the rapid growth of Bhopal was not supported by adequate basic services or urban infrastructures and the situation led to haphazard urbanisation. Nearly 20% of the total population lived in the slum colonies within 5 km of the pesticide plant (Figure 1). Due to lack of development restrictions in place, many of these colonies encroached up to the site boundaries of the plant. Some of these experienced the direct influence of the gas leak.

A good number of studies can be found in the literature[1-7] discussing the numerical dispersion of MIC, role of urbanisation or the meteorological conditions during the accident. However, not many studies have been placed so far investigating how the unplanned development around the plant also contributed significantly to the vast number of fatalities.

The combination of rapid development of these densely populated slums, with minimal infrastructure and hygienic supplies, poor infrastructure, and limited capacity to cope with the crisis and mitigate the damages, exacerbated the incident[8]. Referring to the case histories compiled by Lees[9], Bhopal accident was somehow a foreseen disaster.

One of the key reasons for the high number of fatalities in Bhopal accident was the lack of land use restrictions, resulting in the co-existence of densely populated residential areas in close proximity to a highly hazardous industry. Following the disaster in Bhopal, many national governments and inter-

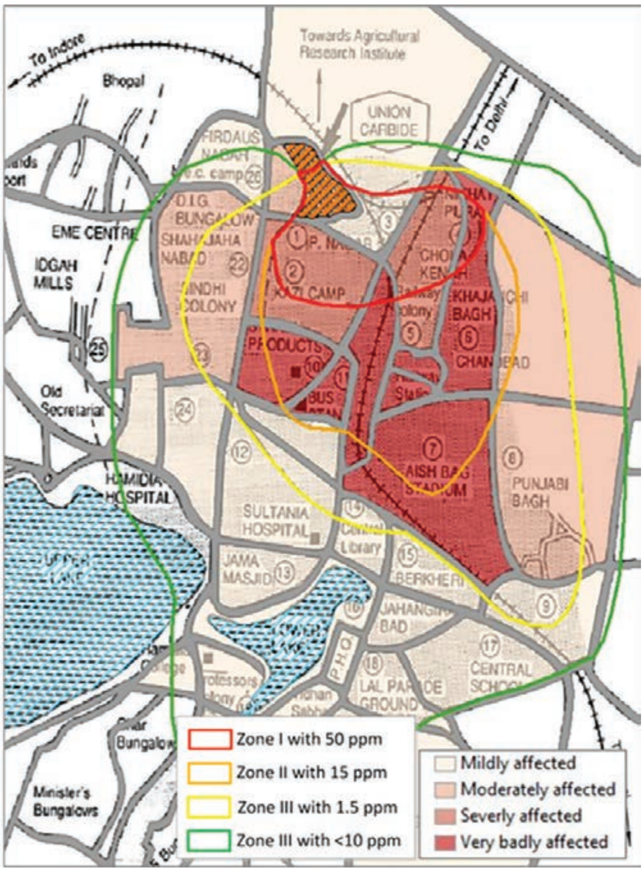


*Figure 1: The gas affected areas of the Bhopal City - showing in different shades of red determined on the basis of mortality statistics as extracted[1]. Source: Layout map of Bhopal city. Bhopal disaster - a personal experience; J. of Loss Prevention in the Process Industries; vol. 18: 261–263.*

governmental organisations recognised the need for land-use planning to restrict and control the use of land in the vicinity of hazardous installations. Nonetheless, no significant improvement has been made in India so far to incorporate 'risk assessment' into land use planning decisions[10]. At this time there are about 1489 Major Accident Hazardous (MAH)* industries in India. Many of these hazardous industries often concentrated in clusters to take advantage of common infrastructural facilities as well as availability of skilled manpower. The number of hazardous industries in such clusters is anticipated to go up significantly with the current policy focus of the Government. Furthermore, acting as engines of industrial and economic growth, these areas often

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witness a steady influx of population resulting from migration of people to take advantage of jobs and other livelihood opportunities generated by these industries. Absence of an appropriate regulatory requirement for land use restrictions results in the close proximity of hazardous industries.

Despite all of these applied changes in other countries, 30 years after the Bhopal accident, India is still far behind due to deficiencies in legislation and the lack of guidelines. So far no provision has been made in India to link two traditionally independent domains of 'risk assessment' and 'land use planning' decisions. As a result, continuing with earlier practices, risks from these hazardous industries continue to increase in certain clusters where development is on-going. Therefore, it is important to adopt simplified methods for estimating spatial measures of risks originating from hazardous facilities.

In India, certain regulations including the Section 41A of Factories Act[11], the Environmental Impact Assessment (EIA)[2] Notification[12] ; the Zoning Atlas for Siting of Industries by Central Pollution Control Board (CPCB)[13] deal with the safe siting of hazardous industries. However, these legal provisions do not provide any specific criteria or mechanism which can guide land use planning decisions. For instance, the Zoning Atlas for Siting of Industries was prepared taking into account environmental considerations only, but risk is yet to be factored as a criteria for zoning of an industrial area. Moreover, the Atlas also fails to provide a linkage to the existing land use planning framework as proposed by the UDPFI guideline[14]. During discussions at the Second India Disaster Management Congress (2009), a consensus was reached on the need for adoption of land use planning principles based on scientific rationale as a strategy for risk reduction and mitigation.

> *"Land-use and location planning is the first level risk reduction in industrial disaster management and has to be highlighted in the regional developmental planning and spatial environmental planning of urban or industrial areas. Zoning atlas and environmental risk mapping approach have to be revisited in the context of disaster risk reduction…."* [15]

The above mentioned issues thereby provide an opportunity to appraise the existing land use planning decisions around the hazardous industries of India. From this perspective, the authors evaluated the present situation with the example of Haldia, one of the emerging petro-chemical hubs of India, and compare the Indian approach with one of the best practices as established in the Netherlands, to identify the gaps that need to be bridged. More importantly, the choice of the Dutch system for evaluation and comparison was made because the situation in India and in the Netherlands shows similarities in many aspects. The Netherlands is by far one of the most densely populated (488 people per sq. km) and industrialised countries in Europe, and due to its geographical location, available land is very limited in the Netherlands – as is also the case in India. In fact, India supports almost 17% of the worlds' population in 2% total area available on Earth. Most importantly, because of its limited land resource in the Netherlands, a relatively large population lives close to one of the largest industrial areas in Europe[16]. In spite of encountering similar challenges, the Netherlands has evolved a systematic framework for assessing risk from hazardous industries using quantified risk analysis and criteria, which then led to the adoption of suitable risk reduction strategies[17]. All considered, after 30 years after the tragic accident in Bhopal, the method which was developed in the Netherlands is still missing in India.

## Present status of India – case study of Haldia, West Bengal

In line with the objective, the study involves the application of the contemporary quantitative risk assessment (QRA) methodology, to calculate a measure of risk to communities and to assess the effectiveness of such a risk measure for guiding the land use planning or zoning decisions in the area. For this purpose, the case study was carried out in Haldia, one of the largest industrial areas in the eastern part of India, supported by a large port complex and other infrastructural facilities. Presently, there are 42 industrial units, out of which 17 are notified as MAH units. Several new industries including a chemical hub under Petroleum, Chemicals and Petrochemicals Investment Region (PCPIR) is being planned in the area. At the same time, the region is also witnessing a steady growth of population resulting in increased potential (industrial) risk to communities with many people living in close proximity to hazardous installations.

To demonstrate the practical applicability of the QRA method, we have considered several accident scenarios as 'reference scenarios' of VCE, BLEVE and toxic release events originating from different hazardous industries located in the study area (Figure 2). After scenario selection, the next step in QRA requires the estimation of their frequencies. However, a review of several industry-specific risk assessment reports of MAH units in Haldia point to an absence of any definitive estimate of failures that could result in a major accident with potential offsite consequences. Even at a broader level, no such failure frequency statistics is known to exist in India. As an alternative, the frequency of each scenario was estimated using the international generic failure-frequency databases like the TNO's Purple Book, the UK HSE's Failure Rate and Event Database (FRED). However, whether these levels of failure frequency will be viable for the Indian MAH installations has to be discussed and agreed upon, given the fact that the frequency of an accident in India might be different from those in the Western European countries because of factors like enforcement of the regulations on maintenance, replacement, inspection and safety management etc.

Subsequently, physical effects of the reference scenarios were estimated for 1, 5, 10, 20 and 50% fatality, based on facility-level information and the most frequently occurring atmospheric condition of the area. Finally, Individual Risk (IR) and Societal Risk (SR) in terms of Potential Loss of Life (PLL)

** Major Accident Hazards (MAH) Installations means isolated storage and industrial activity at a site, handling (including transport through carrier or pipeline) of hazardous chemicals equal to or, in excess of the threshold quantities specified in column 3 of Schedules 2 and 3 respectively in the Manufacture, Storage and Import of Hazardous Chemical (MSIHC) Rules, 1989 and subsequently amended in 2000 under Environmental (Protection) Act, 1984*



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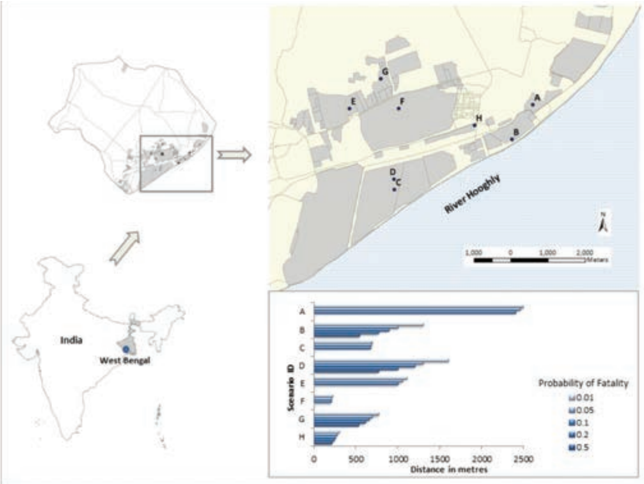


*Figure 2: Location of Haldia (Left); Selected storages used for reference scenarios with calculated effect distances for different threshold values (Right)*

were calculated which are demonstrated on Figure 3, using the Dutch criteria for land use planning decisions[16].

Studying the land use planning policy situation in India, the following gaps were identified:

- First of all, it was found that there is no integrated system for assessing and managing risks in place. Even though current regulations addressed some of the issues of risk assessment, they do not seem to blend these rules together into a cohesive system. For example:
  - There is no common guideline for risk assessment methods for how risks should be assessed;
  - A specific risk acceptability criterion is not defined. The authors made an attempt to compare the results with the Dutch criteria used for land use planning decisions;
  - There is no national-level accident database or a failure-frequency database for probability calculation;
  - There are significant weaknesses in the institutional framework to implement any of the above issues.
- There is no regulatory requirement to link the risk assessment process with land use planning decisions, and no standard criteria for risk assessment results which can be translated into land use planning criteria. On the other hand, planning agencies are well trained to comprehend the results of 'risk assessment' because of the technicalities involved in it.
- Planners do not have access to risk information and so the planning agencies often fail to consider the risk factor in the planning decisions of land around the hazardous industries.

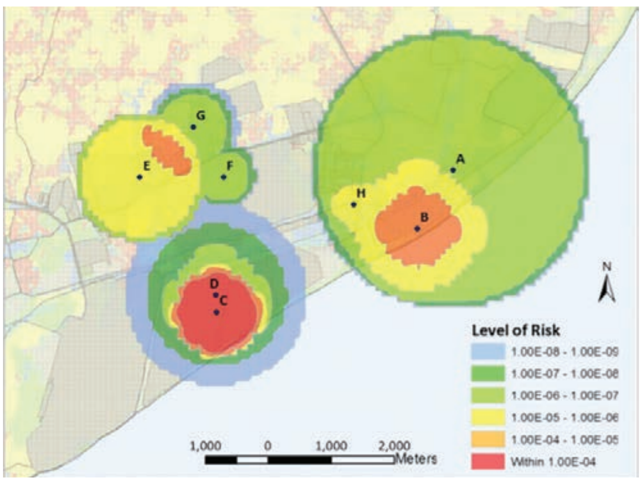


*Figure 3: Application of Dutch approach in the study area*

| Iso-risk contour | Area (sq. km) | (%) | Residential (%) | Industry (%) |
|---|---|---|---|---|
| Within $10^{-4}$ | 1.67 | 5.92 | 0.00 | 5.93 |
| $10^{-4}$ to $10^{-5}$ | 1.84 | 6.53 | 0.46 | 4.18 |
| $10^{-5}$ to $10^{-6}$ | 5.48 | 19.44 | 2.32 | 7.29 |
| $10^{-6}$ to $10^{-7}$ | 12.70 | 45.05 | 11.39 | 13.43 |
| $10^{-7}$ to $10^{-8}$ | 3.58 | 12.70 | 0.93 | 2.07 |
| $10^{-8}$ to $10^{-9}$ | 2.92 | 10.36 | 0.93 | 6.07 |

*Table 1: Area-affected under different level of iso-contours*

## Conclusions

As demonstrated, India faces a complicated situation regarding land use planning given the fact that no standard criteria for risk assessment is in place so far. Through this case study, it is concluded that a simplified, but reliable methodology for QRA can be adapted for estimating spatial risk categories originating from a number of hazardous facilities using reference accident scenarios. On one hand, one outcome could be the possible backward linkage towards harmonization of industrial risk assessment methods based on standards and criteria acceptable to risk management actors. It has been noted that in the absence of standard criteria for risk endpoints or sufficient guidance on model input conditions and variables, risk or hazard analysis undertaken for MAH industries in the past exhibit substantial variations in results of the consequence scenarios from similar events. Standardisation of the risk analysis procedure may lead to the generation of uniform risk scenarios using an accepted tool, which could be summed using this method to obtain a measure of cumulative individual or societal risk prevailing in an industrial cluster.

On the other hand, planners often do not have access to risk information and as a result, the planning agencies fail to consider risk into the planning uses of land around the hazardous industries. Therefore, it seems that the problem could be partly or entirely solved if land use planners could get access to the risk information.

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# Export inherent safety – not risk

David W. Edwards

Evidence is presented that production and handling of bulk chemicals and the attendant risks are being transferred from industrialised to developing nations. The transferred risk is increased because larger plants are built in localities that are less able to cope with the increased hazards. Bhopal was an example of an inherently unsafe plant, with major hazards that could have been avoided or drastically reduced by design. New plants ought to adopt inherently safer philosophy and practice in order to prevent another 'Bhopal'.

## Introduction

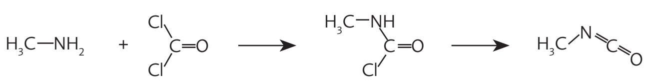
The release of toxic gas at Bhopal, which caused thousands of deaths and hundreds of thousands of injuries, remains the world's worst industrial accident.

Bulk chemicals production and handling has been moving to developing countries, and with it the attendant risks to people and the environment. This export of risk is neither ethical nor good business, and could be avoided if we built inherently safer plants.

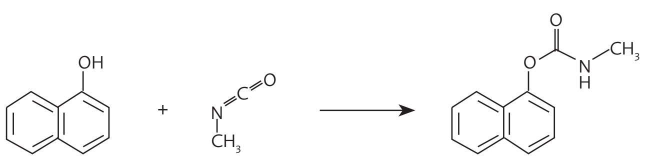
## Bhopal and inherent safety

The deaths and injuries at Bhopal were caused by the release, through an unintended reaction, of methyl isocyanate (MIC) from a storage tank containing 40 tonnes of it. On a number of counts the Bhopal plant was inherently unsafe. The MIC was neither a raw material nor a product, but a reaction intermediate. Therefore, it should not have been stored at all and certainly not in such quantities. Worse, there is an alternative way of making the final product, carbaryl, from the same raw materials: merely reacting them in a different sequence avoids the production of any MIC at all[1].

## Bhopal plant – the chemistry

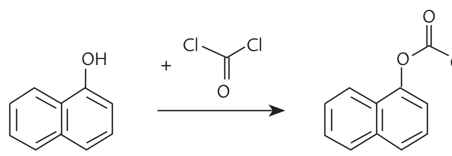


Methylamine + Phosgene Methylisocyanate

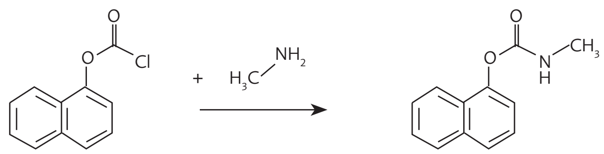


α-Naphthol + Methylisocyanate Carbaryl

## Alternative carbaryl chemistry



αNaphthol + Phosgene Chloroformate



Chloroformate + methylamine Carbaryl

In conventional plant, control of risks is achieved through protective systems, which reduce the likelihood of hazards being realised, and mitigating systems, which reduce their severity. As is well known, the conventional layers of protection in place at Bhopal were either ineffective, disabled or failed: the release was uncontrolled and unmitigated.

In an inherently safer plant, the hazards – and thus the risks – are identified early and avoided or minimised by design. There have been many advances in process safety since Bhopal. However, inherent safety remains a philosophy that is much admired but not always practised.

## The changing geographical distribution of chemicals production and risk transfer

Looking back to the Bhopal accident it is worthwhile for the reader to consider the current context of the worldwide chemical business. In 2010 for the first time, chemical sales in Asia equalled that of Europe and the US combined and capital investment in chemicals for the same year for Asia -Pacific (Japan excepted) was five times that for the whole of Europe. The inescapable conclusion is that emerging economies are now and will be into the future outpacing industrialised nations in the production of chemicals[2].

Although these new plants are built and operated to the same high standards that the companies insist upon worldwide, the hazards are greater, because the plants are often larger than those previously in existence in the developing country in question while most of the designs have not changed from the original implementation in the industrialised world. Effectively a design is exported "because it works", not necessarily because it has been adapted and optimised for the location in which it is to be implemented. In fact often it is the case

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that a producer is looking to move production either to an economically more beneficial location or simply closer to end users, perhaps because the original benefits of production in the industrialised world have ceased to exist. Further, piping inventories increase more than linearly with capacity[3]. Again, if equipment, for example columns, heat exchangers and flare systems, has to be duplicated or tripled, etc the inventory and therefore the hazard will rise more than in proportion to the capacity increase. However, the risks are increased even more than the hazards.

Windhorst and Koen[3] have made quantified risk assessments of ethylene plants. They concluded that the individual risk of the most exposed person increases with the capacity raised to the power of 1.33, and with the square of capital investment.

Some reasons suggested for this effect are:

- larger equipment and nozzle sizes result in larger releases and release rates and increased probability of ignition;
- larger rates of energy release following ignition;
- lower rates of heat loss, resulting in higher temperatures during process upsets and runaway reactions;
- management of change is more complex because of the greater number of support systems, including special safety systems for larger reactors; and
- duplicated, triplicated, etc equipment requires much more complicated piping, many more valves, flanges, welds, etc – all of these increase the probability of a release.

In addition to the increased risk posed by the larger capacity plant, other factors compound the increased risk for plant built in developing countries. Many of these are to do with people, their culture and history.

In most of the industrialised world, the chemical industry has a very long history, resulting in a comprehensive body of regulations, a low tolerance of risk, and an enviable safety record. In the UK, for example, the fatal accident rate is lower in the chemical industry than in most other sectors and there have been no offsite fatalities for over a hundred years from a chemical accident in peace time.

However, in developing countries, the regulations may be inappropriate or non-existent, or there may be insufficient resources for enforcement; it is inconceivable that people would have been allowed to live as close to a major hazard site in the UK as they were at Bhopal. There may be a total lack of emergency response planning and provision of information to people living near the plant (again as at Bhopal).

These deficiencies may be less of a problem when the plant is new, profitable and run by well-trained local people and expatriates – chemical companies insist upon the same good standards world-wide. However, when the plant is ageing and losing money (as the Bhopal plant was), problems are likely to occur due to reduced staffing and skipped maintenance, for example. Maintenance is a particularly critical aspect if spare parts need to be imported due to the level of import duties which are often levied and also the fact that these parts must be paid for in foreign currency. If the design has not been properly assessed for conditions under which it should operate then the original maintenance planning may be wholly inadequate for the climate and operating conditions. The chances of safety suffering on a very large plant (as Bhopal was) are greater when demand for the product drops, because the loss due to closure would be higher and the break-even production is large.

Companies can underestimate the difficulties of operating in countries with different cultures and traditions, for example, where loss of face is an important issue. Serious safety incidents have been caused by local personnel denying there was a problem – when there was.

Risks can increase when ownership is transferred to local companies or to the state, particularly if the experience and safety culture brought by the expatriate experts is lost. An exception to this may be if the people who run the plant are employed by the new owners

If inherently safer plant were the norm for developing countries, risk control would not be so dependent upon regulation, operator training, protective systems etc. The risks would be low because the hazards would be low. Finally, building inherently safer plant is a 'no-brainer' for countering terrorism targeted at chemical plant, particularly in those regions where security and counter-terrorism resources may not match the threats.

However, inherently safer plant are not the norm, as discussed below.

## The barriers to inherently safer plant and how to overcome them

Perversely, it seems that the widespread adoption of inherently safer design, the best available technique for reducing risk to people and the environment, has been prevented by the inherent aversion to commercial risk and the conservatism of the chemical industry. This aversion and conservatism finds expression most often in the approach to process development (with its overriding focus on time-to-market), cost estimation, evaluation of projects and business risk. Competitive pressures and emphasis on speed to market make inherently safer designs too (commercially) risky.

Several barriers to inherently safer plant have been identified[4]. These may be summarised as follows:

- inadequate project evaluation, because of lack of appropriate and tested tools for assessing inherent safety;
- inflexible methods, for capital and operating cost estimation and economic feasibility assessment, that do not credit inherently safer designs with their cost advantages;
- no enforced legislative requirements for inherently safer plant; and
- no incentives for implementing inherently safer designs.

Let us examine each of these barriers in turn.

### *Project evaluation*

One of the biggest barriers to the implementation of inherent safety is not that engineers do not understand how to design according to inherently safer principles, but in the way engineering projects are often conducted. In a globalised economy very often sites around the world within a multinational corporation bid against each other for the


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execution of a production project. This means that within the pre-production timeframe a large portion of the time is not spent developing the engineering, but in deciding on the economics and logistics of where the plant is to be located. A further aspect, particularly true for industrialising and developing countries is that the parent company is not usually looking to develop new technology, but instead to have a production location with economic advantage. This means that "tried and tested" technology (often grown over many years) is copied across to the new location. Whilst this can have advantages in terms of running in the plant, training, etc., it is not necessarily the safest engineering design or the design most suited to the local conditions. Shinnar[5] comments that whereas the first fluid catalytic cracker went from initial design to full production in only 18 months in 1938, it might take 18 months today to pass a management decision to build a pilot plant. The need for more decision-making time by management can have negative implications for engineering, particularly for inherently safer engineering.

## *Cost estimation*

There should be a return on this commercial risk, because inherently safer designs offer savings in both capital and operating costs:

- inventory reduction will reduce costs because smaller vessels cost less;
- simpler plant costs less because there is less equipment and ancillaries;
- avoiding hazards also avoids the costly hazard control measures; and
- reducing count, size and complexity of equipment reduces utilities, labour, testing and maintenance costs – as Henry Ford succinctly put it: "what you don't fit costs you nothing and needs no maintenance".

Industry insiders claim that equipment related to safety, health and environmental protection represents 10-50% of the capital cost of conventional plant. On operating cost, achievable reductions with inherently safer plant are 10% for maintenance and 20% for downtime. Payback times are typically less than two years for projects involving inherent safety.

Such economic benefits are not apparent at the point that the major project decisions are made. This is because early economic estimates do not allow for the decreased capital and operating costs of inherently safer plants. For example, the need for standard safety equipment is seen as inevitable. Therefore, in the absence of a compelling argument for doing otherwise, the conventional design will normally be chosen.

## *Inherent safety legislation*

Inherent safety is not yet compulsory in most safety legislation but it is mentioned or described in existing regulations and guidance, for example in the UK, where an inherently safer approach is recommended. There is a trend towards regulation that focuses on reducing the size of hazards and the possible consequences, particularly to offsite populations, rather than reducing the statistical risk of harm. This trend favours the adoption of inherent safety and it is likely that it will appear in future legislation. Therefore, companies ought to adopt an inherently safer approach to ease current and future regulatory compliance.

## *Forthcoming legislation?*

Currently in the USA, both OSHA and EPA are carrying out public consultations concerning the review and modification of the PSM and RMP regulatory programmes. Within this consultation "inherent safety" has been raised, particularly following major accidents in the petroleum refining industry and requirements by some local authorities for the adoption of inherent safety concepts in particular industries. There is however a need for caution as some political voices categorise all engineered risk reduction measures as "inherent safety" without considering how the measures actually take effect.

## *Inherently safer plants are safer*

Beyond this, adoption of inherent safety can improve a company's reputation. The public understands that low probability events can happen – people do win lotteries. The absence of hazards is far easier to communicate than acceptability of risk.

## Summary and the way forward

The Bhopal plant was a large, inherently unsafe chemical production facility in a developing country, which was majority owned by a company from an industrialised country, although day to day operations were locally organised. An accident on the plant caused the world's worst industrial disaster, wherein thousands died.

The current transfer of production of bulk chemicals from developed to developing nations appears to pose unacceptable risks to the people and the environment. This is because the risks increase more than linearly with the on-going capacity increases of the plants and developing countries are less able to cope with the increased risks.

The Bhopal plant could readily have been designed to be inherently safer, in such a way that the disaster would have been completely prevented. The paper makes the case for building inherently safer plant, especially in the developing world, to reduce the hazards and risks. Beyond the safety benefits, there are compelling economic, security and reputational advantages of inherently safer designs for new facilities. Even so, as plants increase in size, they continue to be built to conventional designs.

The industry needs to make inherently safer plants a reality, rather than a much-lauded ideal. This strategy might seem commercially risky, but the risks of not following it are greater. The chemical industry survived the appalling loss of life at Bhopal, but the Union Carbide Corporation did not.

Two bodies were set up in response to disasters due to inherently unsafe plant. The International Process Safety Group was set up after the Flixborough disaster that prompted Trevor Kletz to establish the principles of inherent safety[6] – coincidentally, 2014 is the 40$^{th}$ anniversary of Flixborough . The Centre for Chemical Process Safety was set up by the AIChE in response to the Bhopal disaster. However, the membership of these bodies consists mostly of safety professionals.

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A similar forum should be established for decision makers in the process industries, where they could be informed of and discuss risk issues and formulate an industry response. Would the Chief Executive of Union Carbide have allowed the Bhopal plant to continue operating as inherently unsafely had he known about the size of the hazard and that all the risk to his company was concentrated in that one loss-making plant in India? Hopefully, such a forum of chief executives would decide to:

*Export Inherent Safety NOT Risk*


## Acknowledgements

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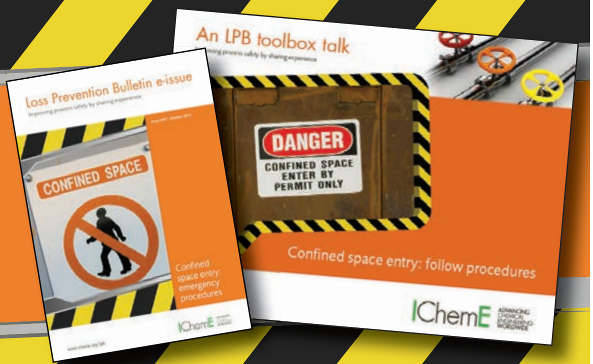


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# A review of UNEP programmes on industrial risk reduction

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## Introduction

With the shift of industrial operations, many countries are becoming more industrialised and often new installations are being located in communities that had not previously faced industrial risks. Urban and rural areas alike, particularly in low and middle-income countries, experience regular small disasters that undermine local development as well as national competitiveness[1]. Along with increased quantities of chemicals being moved across national boundaries and continents and insufficient risk information, promoting cooperative risk awareness and risk reduction has taken on ever increasing importance.

### *The global challenge*

Emerging economies have already surpassed Europe and the United States of America in total chemicals production, with twelve out of the top 30 biggest producers located in Asia[2]. According to the Global Chemicals Outlook[3], significant growth rates of chemicals production in developing countries are expected from 2012 until 2020 (Asia Pacific 46%, Africa/ Middle East 40% and Latin America 33%) leading to growth in markets for upstream suppliers, transporters, distributors and clients in these regions.

Although increased knowledge and governance have improved the management of risks, many countries continue to struggle with accidents. The International Labour Organisation reports that hazardous substances are estimated to cause 651,000 deaths annually, mostly in the developing world[4]. Rapidly industrialising countries are often at greater risk because of:

- limited regulations or incomplete enforcement of existing rules including land use planning;
- inadequate resources for prevention, preparedness and response;
- limited staff in government and industry with the specific skills and knowledge required to manage risk;
- rapid pace of changes in industrialisation and difficulty of managing changes; and
- increasing complexity of supply chains involving operations handling chemicals.

### *UNEP's contribution to industrial risk reduction*

UNEP provides leadership and encourages partnership on environmental sustainability, setting the global environmental agenda, and leads the implementation of the environmental dimension of sustainable development within the UN system. For almost three decades, UNEP has been developing globally applicable and adaptable guidance for governments and industry aiming to help reduce industrial and chemical accidents.

At a global level, binding agreements on the regulation of chemicals and of waste have been reached through a number of conventions, e.g. Ozone, POPs, Mercury and these conventions are being applied and enforced. However in the field of chemical accidents, the ILO Convention on Major Accidents[5] (agreed in 1993 and entered into force in 1997) has only been ratified by 18 countries; the UNECE Convention on Transboundary Effects of Industrial Accidents[6] only applies within a certain group of nations and the EU Seveso Directives[7] only apply within the EU. Not only is the lack of binding regulation an obstacle to good governance in the field of chemical accident prevention, in many countries there is a lack of awareness and understanding as regards to what measures can be undertaken by various stakeholders and how to structure these activities, including those of

## UNEP programmes

UNEP programmes promoting a participatory and multi-stakeholder approach to chemical accident prevention and preparedness:

- **Awareness and Preparedness for Emergencies at Local Level (APELL)**: Promotes multi-stakeholder preparedness to industrial accidents and disasters through community participation **(www.apell.eecentre.org)**
- **Flexible Framework for Addressing Chemical Accident Prevention and Preparedness (CAPP):** Focuses on support to national governments wanting to develop, or strengthen their industrial chemical accident prevention and preparedness policies and regulatory frameworks **(www.capp.eecentre.org)**
- **Responsible Production – Chemical Hazard Management for SMEs:** Engages business in safer production, risk communication and emergency preparedness with a focus on SMEs that handle hazardous materials **(www.unep.org/responsibleproduction)**

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chemical accident prevention and preparedness policies and regulations. This is where the focus of UNEP's work lies.

### *Multi-stakeholder collaboration as a starting point*

At a global level, numerous initiatives addressing safety are promoted by government agencies and industry association, often targeted at a specific group: either industry itself (such as the Responsible Care Programme), or governments (Policy Guidelines, Conventions). UNEP programmes and initiatives, based on a multi-stakeholder approach, provide an enabling environment conducive to open dialogue, building mutual understanding, and forging consensus between multiple stakeholders. The following sections explore the practical application of these approaches with the different stakeholder groups.

Taking existing local capacities as the starting point, building on the strengths of individuals, and local institutions, and pooling all available resources is necessary for ensuring the sustainability of the initiatives and effective implementation.

## Responsible Production — targeting SMEs

Small companies, often family owned, and frequently outside the formal economy, contribute significantly to the economic development of many countries. According to the Organisation for Economic Co-operation and Development[8], 90% of industry, outside the agricultural sector, in developing countries is formed of SMEs. In China, 99% of chemical companies are SMEs, accounting for 80% of the chemical industry accidents[9].

The question of SMEs does not only affect the owners, operators, workers or neighbours of the company. Many SMEs are involved in intricate supply chain relations that may be at risk if one small company has an accident. To this end, large companies are adopting product stewardship principles, through initiatives such as the ICCA's Responsible Care Initiative (see **http://www.icca-chem.org/en/home/responsible-care/**), and are increasingly monitoring the performance of their suppliers from a lifecycle perspective under the scope of Corporate Social Responsibility programmes.

UNEP has developed guidance called *Responsible Production Handbook – A Framework for Chemical Hazard Management in SMEs*[10] in collaboration with the Chemical and Mining Industry Associations to provide guidance for SMEs. This experience shows that SMEs needs simplified process safety management approaches[9, 11]. An SME can implement the Responsible Production Toolkit to improve safety, through guidance that supports understanding hazards, controlling and preventing exposure to hazardous substances, reducing accident risks and engaging stakeholders. Its support for risk planning, management and communication is of interest to large companies, business partners and local authorities alike.

### SME partnerships

Thailand was the first country to pilot test the Responsible Production Toolkit. The pilot at the Bangpoo industrial estate involved the Industrial Estate Authority, five pilot companies, the Office of Disaster Prevention and the Bangpoo Municipality. Parallel factory and community hazard assessment led to hotspots being identified and a group being set up to identify further hotspots along transport routes, through a method called 'town watching'.

Responsible Production has been implemented in ten countries since the Thailand pilot. The UNEP publication *Responsible Production for Chemical Hazard Management in SMEs: Lessons Learned from Implementation*[11] demonstrated that SMEs are rarely accustomed to working with their stakeholders to reduce the risks related to their onsite and offsite operations and engaging partners is a challenge for SMEs. Further tools and practical guidance are needed to enhance the practices.

## APELL – a community based process

Local governments have a lead role to play in dealing with risk reduction to build resilient communities and nations. Community safety in the face of emergencies is often determined by the effectiveness of emergency management and services, the awareness of the individuals, organisations and industries of the risks they are exposed to, and the actions taken to mitigate and prepare for such emergencies[12], making the local authorities, industrial sites and communities key players in improving accident preparedness.

In 1988 in the wake of the devastating Bhopal accident, UNEP published the *Awareness and Preparedness for Emergencies at Local Level Handbook - A process for responding to technological accidents*[13], updated in 2014 to *A Process for Improving Community Preparedness for Technological Accidents at Local Level*. To date, APELL projects have been introduced in at least 80 communities.

Initially, the focus of APELL was on industrial accidents that threatened to extend beyond the boundary of a hazardous installation. Since 1996, the scope of the APELL process has expanded to address accident risks in other contexts, such as transport of hazardous goods, port areas, mining operations,


*An APELL project group*

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## APELL coordination groups – the heart of the APELL process

In India, an APELL pilot project in six industrial areas in the early 1990s led to the 'Chemical Accident (Emergency Planning, Preparedness and Response) Rules, 1996' that gives the legal backing for APELL-like coordinating groups called 'local crisis groups'. These groups are present in all industrial areas. The Guidelines on Chemical (Industrial Disaster) Management issued by the National Disaster Management Authority of India in April 2007 recommend the APELL process.

In Sri Lanka, a demonstration project in two industrial areas showed the effective participation of representatives of the industrial community, the local level government institutions and the local community. The demonstration led to the establishment and training of Local Coordinating Groups (LCGs) at ground level, the development of Integrated Emergency Preparedness Plans through a consultative process by LCGs and linking APELL into District & Divisional Level Disaster Preparedness and Response Plans developed by the Disaster Management Center.

In Peru, the NGO RAPID LA is working with communities and mining and transport companies through the creation of Local Civil Defence Committees. In coordination with the community members the Committees carry out community based multi-hazard risk assessments and develop emergency plans that are tested through practical drills with different groups, including school children. The dissemination efforts include campaigns in the cinema – the CinemAPELL.

tourism and multi-hazard considerations. APELL provides guidance for local authorities and plant managers for:

- establishing well co-ordinated actions of individuals and institutions;
- building awareness of hazards among all members of a community; and
- preparing appropriate emergency plans.

## UNEP guidance on policy development on CAPP

Although APELL continues to play an important role in raising awareness and improving risk communication and community preparedness at the community level, there is a significant need for national governments to provide leadership and guidance related to disaster risk reduction as well as preparedness for and response to chemical accidents. This includes appropriate regulations, along with adequate enforcement. To address this need, UNEP published guidance for governments in 2010, titled *A Flexible Framework for Addressing Chemical Accident Prevention and Preparedness*[14]. This guidance builds on several international agreements as well as a number of other international initiatives.

This guidance is 'a flexible framework', not a legal text. It helps prioritise, and then establish appropriate (legal)

## Multi-agency taskforce driving CAPP

In the past five years UNEP has supported six countries through the process set out in the guidance – of which, three have been in Asia (Cambodia, Philippines and Sri Lanka) and three in Africa (Mali, Senegal, Tanzania).

In Sri Lanka, a national CAPP taskforce was established consisting of ten national agencies, and an advisory support group of academia, technical institutions, industry and civil society. Since the inception of the UNEP supported project, the taskforce has been meeting on a monthly basis. In addition, through UNEP coordination, a partnership between the taskforce and the relevant government agencies in Thailand has led to two study visits on legislation, management of industrial marks and the implementation of the Globally Harmonised System for Classification and Labelling of Chemicals (GHS)

In Tanzania the existing Emergency Response Committee took on a new role and met seven times in 18 months to assess the current situation and decide on national priorities in the implementation of CAPP. The Committee has decided to continue its expanded function after the UNEP supported project and will continue having a leading role in supporting the lead agencies in revising the national legislation appropriately.

instruments adapted to the local conditions. The guidance instructs government agencies to adapt the framework in light of factors such as the size and nature of its chemical risks, its legal and administrative structures, local culture, local language(s), and available resources. The challenge often is to enhance focus on prevention of accidents, and not just preparedness.

## Conclusions

So what can our experience tell us?

### *No one-size-fits-all*

Firstly, that flexibility is a key attribute when designing guidance with global relevance. There is no one-size-fits-all,

*Emergency drill taking place in an APELL-implementing community in India.*

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and it is practically impossible to 'export' regulations to a different context. The unique vulnerabilities, risks, value systems, capabilities, risk perceptions, infrastructure, resources and cultural and regulatory contexts must be recognized and respected. Nevertheless, experiences from other countries can be used to develop effective guidance.

### *Local ownership and leadership*

Secondly, chemical accident programmes must be locally 'owned' and led, whether this is at the national or at the community level. It is important for the country or the community to define its own strategies, goals and frameworks for measuring success. In this process, sharing lessons learned and experience from other countries is of crucial importance, and UNEP's role is to facilitate sharing of experience from others who have successfully addressed the same issue.

### *Multi-stakeholder collaboration*

Thirdly, to successfully improve chemical accident prevention and preparedness, there is a crucial need for effective leadership that requires coordination and consultation. A multitude of agencies and other stakeholders need to be involved and take responsibility for various aspects of prevention, preparedness and response. This coordination and collaboration needs to be fostered, and its importance needs to be emphasized during any capacity building effort.

### *Mindset change*

Finally, moving from a pure response perspective to preparedness and eventually prevention requires a significant change in mindset. It can be difficult to ensure the appropriate commitment of all involved for various reasons: for example, they may be overconfident and assume that safety is assured with the preparation of a response plan, they may consider it impossible for an accident to happen, or they may simply have cost concerns or not recognise their responsibilities. All in all, improving awareness, capacities, providing leadership and channels for sharing of experience and learning from the past can provide good means for overcoming some of these barriers.

### *Linking chemical accident prevention to sustainable development*

Social pressures such as urbanization, population pressures, and changing land use patterns and industrial landscape are introducing new and continuously changing challenges related to the management of industrial risks. Ensuring chemical safety is a concern for sustainable development, increasingly considered by decision-makers. The global chemical industry is expanding with more and more production and distribution facilities located in developing countries and emerging economies. Although there is a shift in production and use patterns of chemicals towards developing countries, only 10% of national development plans in 2009 prioritised sound chemicals management. This lack of priority may expose populations to unnecessary risks and may result in risks for sustainable development.

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Bhopal legacy

# Site contamination threat remains for Bhopal

Centre for Science & Environment, India

Three decades after being shut down, the Union Carbide factory continues to be a real danger to the people of Bhopal. Almost every study done to measure the impact of the waste dumped within and outside the site by UCIL has come up with one conclusion — there is large-scale contamination in the soil and water of the area where the factory is located.

In the first initiative of its kind, New Delhi-based research and advocacy body Centre for Science and Environment (CSE) has analysed all the studies and their conclusions. CSE released the key findings of its analysis and a comprehensive action plan for ridding the site of this contamination[1].

Between 1969 and 1984, Union Carbide India Limited (UCIL) had produced carbamate pesticides and organochlorine formulations. Throughout these years, the toxic wastes and products were being dumped at several locations inside the plant and in the solar evaporation pond (SEP) outside. After the plant was shut down in 1984, this highly toxic waste was left lying on the plant premises and SEP. Over the years, this waste has been a continuous source of soil and groundwater contamination and therefore, a cause of serious public health concern for residents in the surrounding areas.

CSE has analysed about 15 studies conducted over the last 20 years to assess soil and groundwater contamination in and around the UCIL site. These studies were conducted by several non-government organisations, Madhya Pradesh state agencies, the Central Pollution Control Board (CPCB), and Council of Scientific & Industrial Research (CSIR) institutes such as the National Environmental Engineering Research Institute (NEERI), the National Geophysical Research Institute (NGRI), the Indian Institute of Chemical Technology (IICT) and the Indian Institute of Toxicology Research (IITR). Most of the studies confirmed contamination. The nature of contaminants found in the soil and the place from where they were found are similar in several studies. Contamination of groundwater has also been reported in most studies.

In April 2013, CSE held a stakeholders' meeting in New Delhi focussing on developing a road map on remediation of soil and groundwater, disposal of toxic chemical waste, remediation of plant machinery and the fate of the site. Expert representatives attended from scientific institutions such as NEERI, IITR, IICT, NGRI, IIT-Bombay, IIT-Kharagpur, IIT-Madras and IIT-Roorkee; regulatory bodies such as CPCB; industry including those with expertise in remediation of contaminated sites; and organisations from Bhopal.

The expert group concluded that 350 tonnes of stored waste is a small part of the total waste that is still dumped at the site and the SEP area. The bigger challenge is to decontaminate the soil and groundwater.

## Action plan

The expert group suggested a range of measures for remediation and waste disposal. Based on the criticality and required time-frame for implementation, the measures were divided into two sections – immediate and medium/long-term.

### *Immediate measures*

1) Securing the site and SEP area by fencing and guarding to prevent access of people, especially children, hence their exposure to toxic chemicals; stopping construction in the SEP area; and protecting annual surface water runoff from the site during monsoon.
2) Excavation and recovery of all the waste from the site; Characterisation and inventorisation of the collected waste for proper treatment and disposal.
3) Characterisation of the 350 tonne wastes that is stored at the site and the results to be shared in the public domain. Under the supervision of the CPCB and affected community, incinerable waste is to be incinerated after the stabilisation of the trial results at Pithampur.

### *Medium and long-term measures*

1) Groundwater contamination assessment through detailed field investigation and laboratory analysis to develop a remediation plan. Possibility of hydraulic containment is to be explored as an interim containment measure.
2) Characterisation and remediation of the waste dumped in SEP area, particularly the landfill, to prevent continued contamination of the groundwater in the local area.
3) Detoxification, dismantling and decommissioning of the plant after preserving structures such as MIC plant including the vent, vent scrubber, storage tanks and control room.
4) Remediation of the UCIL site that involves building a memorial and centre of excellence for industrial disaster management after decontaminating the site.

The expert group agreed that it was high time to break the existing institutional logjam and called for the government of Madhya Pradesh to swiftly act and solve this public health concern.

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Bhopal legacy

# Are we doing enough to reduce hazards at source?

Graeme Ellis, principle lead consultant
ABB Consulting, UK

Two events have reminded me about the importance of inherent safety and how the principles should be more widely applied by engineers across the process industry. Firstly, the sad loss of process safety guru Trevor Kletz last year, widely recognised as the father of inherent safety in the chemical industry, who coined the phrase "What you don't have, can't leak". Secondly, the 30th anniversary of the tragic accident at Bhopal in India that cost thousands of lives, and could have been avoided if simple inherent safety principles had been applied. Hazard and Operability (HAZOP) studies have been adopted throughout the process industry, whereas inherent safety principles aimed at reducing process hazards 'at source' have not landed on such fertile ground.

## Learning from accidents

The UK's most deadly process accident remains the explosion at Flixborough in 1974. A massive loss of cyclohexane at 150 °C and 9 barg occurred, believed to be caused by the rupture of a temporary line, resulting in a vapour cloud explosion. The accident investigation focussed on poor control of temporary modifications. A more fundamental question is the wisdom of a process with 400 tonnes of highly flammable material at elevated temperature and pressure, as the result of an inefficient reaction that required a large internal recycle. The inherent safety principle of minimisation or intensification would have encouraged a more efficient process, for example using oxygen rather than air to reduce the overall inventory and hence hazard potential.

The principles of inherent safety did not prevent the worst accident in the global process industry at Bhopal in 1984. An intermediate storage tank containing reactive and highly toxic methyl iso-cyanate (MIC) came into contact with water. This led to an exothermic reaction and release of MIC via the pressure relief system causing a large cloud of toxic gas to be dispersed into the local community. The key findings from the investigation pointed to failures in the layers of protection or barriers that should have halted escalation of this event. A refrigeration system to keep the tank contents cool had been taken out of service, the pump on a scrubbing system had been stopped during normal operation, and a flare that should have safely combusted the MIC was on a long term outage for repair. Like the accident at Flixborough, there are many inherent safety learnings from Bhopal as summarised in the table.

| Inherent Safety Principle | Learning |
|---|---|
| *Substitution* | The Bhopal process reacted methylamine with phosgene to make MIC, this was then reacted with 1-Naphthol to make the fertiliser product carbaryl. An alternative chemistry route using the same raw materials, produced chloroformate as the intermediate, a toxic material but less hazardous than MIC |
| *Minimisation* | The Bhopal facility included intermediate bulk storage of MIC in two 40 tonne storage tanks, providing a convenient production buffer between upstream and downstream plants. If the site owner Union Carbide had questioned the need for a large inventory of highly toxic material these tanks could have been emptied and the upstream plant operated on demand, as happened on other Union Carbide plants after the accident. |
| *Segregation* | When the Bhopal MIC plant was built in 1979 it was located in an area zoned for industry. A lack of planning controls allowed highly populated settlements to develop around the site boundary, greatly increasing the scale of the disaster, particularly when coupled with a lack of public information on suitable action to take in the event of a release. |

## The case for inherent safety

It is helpful to define an inherent safety approach and how this differs from traditional proces safety, captured by the following definition from a UK HSE publication.

> *"An 'inherently safer' approach to hazard management is one that tries to avoid or eliminate hazards, or reduce their magnitude, severity, or likelihood of occurrence, by careful attention to the fundamental design and layout. Less reliance is placed on 'add-on' engineered safety systems and features, and procedural controls, which can and do fail".*

International standards and codes of practice do not generally encourage inherent safety, mostly accepting the inherent hazards of the process and minimising the likelihood using well engineered and maintained equipment. Regulators provide encouragement when assessing safety reports, as they look for a 'hierarchy' of risk management controls where inherent



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safety features are favoured over prevention, control and finally mitigation measures. The need to demonstrate a proactive approach during the design process has been strengthened in the recent EU Offshore Safety Directive 2013, which requires regulators to confirm "*how the design decisions described in the design notification have taken account of risk management so as to ensure inherent safety and environmental principles are incorporated*".

There is growing evidence of a focus on inherent safety during accident investigations carried out by regulatory authorities. The US CSB investigation into the 2012 Richmond refinery fire found that serious sulphidation corrosion was the root cause of the accident due to the wrong material of construction for a pipe. The report states that "*Chevron did not regularly or rigorously apply inherently safer technology, which provides an opportunity for preventing major accidents, in its PHAs, MOCs, incident investigation recommendations, or during turnarounds*".

## Why a reluctance to change?

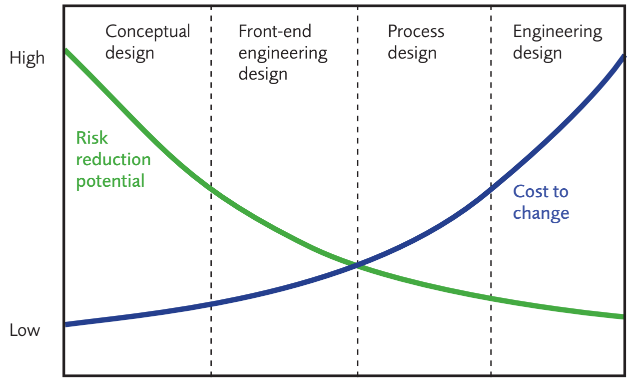
There are many examples of inherent safety being applied across the process industry. One example is the move away from flammable solvents in the paints sector, not only reducing health hazards during use of paint products but also eliminating the fire and explosion hazards during manufacture. The oil and gas sector has less opportunity to avoid or minimise hazardous materials, but there are many good examples of applying inherent safety principles. For example the use of low design temperature steel to protect against Joule-Thompson cooling and embrittlement hazards. Design engineers may claim that such improvements are part the normal development process, but I have seen many cases where inherent safety opportunities have been missed, and facilities left reliant on safety systems that are costly to install and maintain.

It may be argued that opportunities to apply inherent safety are limited in cases where the chemistry is fixed or where the process design is being provided under licence. There may also be a reluctance to change a proven process design, especially where the project is under time and cost pressures. Whilst these concerns are valid, a change in mind-set is needed such that all options for inherently safer processes are explored and either adopted or discounted for valid reasons. The additional effort at the early design stage can be justified by the potential for significant reductions in the lifecycle costs for the facility, by avoiding unnecessary equipment and 'bolt-on' safety systems that require costly testing and inspection throughout the operational phase.

## Guidance from the Energy Institute

The UK Energy Institute recently released, *Guidance for Inherent Safety in Design: Reducing process safety hazards whilst optimising CAPEX and OPEX*. This guidance is aimed at the energy sector but is applicable to the wider chemical industry. The objective is to raise awareness of the benefits of adopting inherent safety in design, and the need for strong leadership to ensure that all opportunities are recognised and assessed. Whilst this approach can be applied throughout the design process, the greatest potential for benefits is during the early conceptual design stage as shown in Figure 1, as subsequent decisions become more difficult and costly to reverse.

*Figure 1: Benefits of Inherent Safety early in project*




A formal and structured Inherent Safety workshop is recommended during the conceptual design stage based on process block diagrams for all viable process routes. This is similar to a Hazard Identification (HAZID) study during the later FEED stage, except focussing on changing the basic process design to eliminate or minimise hazards, rather than providing 'bolt-on' safety systems to reduce the likelihood. Inherent safety guidewords are systematically applied to each hazard to identify options for improvement, to be assessed for practicality, cost effectiveness and availability of technology. The workshop will improve the project team's understanding of inherent safety principles that will benefit the later stages of design where there are further opportunities to design out hazards and simplify the design.

A lack of inherent safety thinking during detailed design was a contributing factor to the UK Buncefield accident in 2006. A gasoline tank was overfilled and the independent high level trip failed to operate due to a test lever on the float switch being in a 'disabled' position. A procedural control requiring a padlock to hold the lever in the 'armed' position was cited as the cause, but an inherently safe design would have mechanically prevented the lever being in a 'fail-to-danger' position.

## The future

Inherent safety is a topic that has been recognised in the process industry for nearly 40 years. We must therefore question why project design teams continue to miss opportunities to design out hazards, relying instead on multiple barriers to reduce risks to an acceptable level. It is a trait that I have seen many times with HAZID and HAZOP study teams making recommendations for costly safety systems.

The Energy Institute guidance highlights the need for a culture change in process design teams, strong and committed project leadership. A current lack of tools to identify inherent safety options early in the project cycle has been addressed by defining a structured workshop, and it is hoped that this will be adopted in a similar manner to HAZOP studies during the later stages of design.

Where can we take the inherent safety message in the future? Hopefully the inventive minds of process designers will be encouraged to create facilities where the potential for process safety accidents have been eliminated or minimised at the drawing board, rather than relying on safety systems that all too regularly let us down.

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Bhopal legacy

# Medical comment on the Bhopal tragedy

Professor Paul Cullinan

It is unlikely that we will ever know exactly what constituted the gas cloud released over Bhopal from the Union Carbide plant in December 1984; but much of it was almost certainly methyl isocyanate (MIC), a pungent gas of low boiling point (39$^{0}$C) and high vapour pressure that readily reacts with water. This combination of physical properties makes MIC a devastatingly toxic irritant to any mucous membranes with which it comes in contact; survivors of the disaster recall intense irritation of their eyes, nose and upper airway (likening it to 'burns from chilli'). More significantly, the readiness with which MIC vaporises and its high concentration in the plume led to penetration deep within the lower airways for those with the heaviest exposures, and it is likely that most early deaths, which numbered many thousands, were the result of pulmonary oedema and asphyxiation.

Since the event, considerable heat – but very little light – has been generated over the extent and nature of any long-term, adverse health effects in survivors. Indeed, one of the lesser known tragedies of the incident has been the failure of any systematic public health response – a failure which is manifestly unjust and has cost the people of the city dearly. What we know of MIC (above) suggests that residual damage to the lower airways in a proportion of those exposed would be expected and there is reasonable evidence that this is so, at least in those who were adults at the time of the disaster. This damage is manifest as a fixed scarring of the small airways ('obliterative bronchiolitis') which causes those affected to be more or less breathless on exertion or even at rest; it is not amenable to drug treatment. Survivors with the most severe bronchiolitis are likely to develop a secondary cardiac failure. Whether those who were children in 1984 risk similar outcomes is not known, but it seems very probable. Scarring of the external parts of the eye, in particular the cornea but perhaps also the lens, resulting in a reduction in or loss of vision, would also be anticipated but has not been properly studied. Unsurprisingly, the event in 1984 was extremely traumatic to those who were caught up in it and long-term, in some cases severe, psychological consequences would be anticipated – but, again, these have not been systematically examined.

Far more controversial has been the question of whether exposures have resulted in more 'systemic' damage as a result of absorption, through the lungs, of MIC and/or other constituents of the plume into the circulation. Most toxicologists think this very improbable but there is a vocal lobby that attributes a wide range of adverse health effects to exposure; these include neurological diseases, infections such as tuberculosis, pregnancy failures, birth defects, growth reduction in children and even DNA damage. None of these has been investigated in any meaningful manner and it is unclear whether their reportedly high incidence can be attributed to gas exposure or to the confounding effects of poverty.

It would not be especially difficult to address most of these issues using standard epidemiological approaches. If done carefully and sensitively these would very probably result in improved outcomes and care for the survivors of the disaster. Shamefully, however, it seems that the required degree of high-level institutional commitment is wanting. In the meantime, very large sums of money have been directed towards the building of expensive hospital facilities where therapies of dubious value are administered. These contrast starkly with the several community-based organisations (notably the Chingari and Sambhavna clinics) where large numbers of people from the most marginalised and needy sectors of the city are offered care in an environment of extraordinary tenderness. While there is no proof that the conditions being treated in these settings are a direct result of the 1984 accident, or from ongoing contamination from abandoned pesticide, there is no proof that they are not. In a story that has few heroes, those who tirelessly work there are worthy of our support.

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**Paul Cullinan is Professor in Occupational and Environmental Respiratory Disease at the National Heart and Lung Institute (Imperial College, London) and Honorary Consultant Physician in Respiratory Medicine at Royal Brompton Hospital, London. In 1994, Paul was a member of the International Medical Commission on Bhopal.**



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Interview

# A local perspective from the Chingari Trust

Syed Tabish Ali

## About the Chingari Trust

The Chingari Trust is a non-profit, non-political organisation that uses all of its available resources for the welfare of community members. As a charitable trust, Chingari does not participate in political activities as its main purpose is to work with the victims of the Bhopal gas disaster and local communities that are affected by the continuous industrial hazards present as a result of the abandoned Union Carbide factory.

More specifically, the Chingari Trust supports marginalised sections of society, including women and children, without discrimination on the basis of caste, creed or religion. For further information, see **www.chingaritrustbhopal.com** and **www.bhopal.org/the-clinics/the-chingari-trust/**

## Perspectives of a Chingari patient

In this article, Mr Tabish interviews Mohammed Shifon, a teenager (born 12th October 1998) who has been attending the Chingari rehabilitation centre since its inception in 2007.

On being questioned about his experiences at Chingari, Shifon replied:

> *"I am coming to Chingari from beginning with other children like Aman, Vikas, Suraj, Karthik etc. ... Initially I was not able to stand properly and used to fall down while taking a step forward. But now I am able to stand properly and walk also....Later on therapy was started here ... which was given by Sanjay Sir (Physiotherapist) after which my knees and fingers have become comparatively straight and I have started walking. Later on Tarique Sir and Bindya Madam (Special educators) have also joined Chingari and we started studying and have learned things like English-Hindi alphabets, mathematics tables etc. Now I am able to do multiplication and division also. Vidya Didi (Community health worker) has helped me and other children in getting admission in Birjisiya Government School in fourth standard and now I have reached seventh standard. My speech is clear so I have not received speech therapy, but I have seen other children getting speech therapy here. I have also participated in sports events from Chingari and have one gold medal and Certificate in football. My other friends from Chingari have also won medals in different sports."*

On being asked about the changes he has observed in other children coming to Chingari his reply was:

> *"Earlier Shyam Babu* (pictured right) *used to stammer while talking but now his speech has become clear and even Payal and Ankada have started talking. Mannanhas now has started standing. Earlier Ashish's foot was also tilted but now it has become straight. Earlier Zehra also used to slide on the ground but now she is able to stand and walk on her own. Minakshi was not able to walk earlier but now she has started walking. Earlier Shyam Babu also used to fall down while walking but now he is able to walk without falling down."*

Shifon is sad to see so many children with disabilities coming to Chingari and feels that the number of children at Chingari has increased a lot, but at the same time he also feels happy when he sees any of them showing improvement, starting to sit or walk. On being asked about his future plans and hobbies, he explains:

> *"I would like to become completely cured and would like to go in Jamaat (to live in a mosque for some days) so that my Namaz (prayer) becomes proper. Sunny Deol (Bollywood actor and action hero) is my favourite – I like his fighting. Khuda Gawha is my favourite movie because in that movie the hero said in the song that he would come to meet you even if he dies – and then in the end, when he became unconscious by getting hurt by a bomb, he rose up to fight. I also like playing hide and seek, and play with my friends in the night."*

This was my short interview with Shifon. At present there are more than 600 such special children registered with Chingari Trust but because of resource limitations, we are only able to treat 180 children regularly, providing them with physiotherapy, speech therapy, special education, sports, mid-day meals, pick-up and drop-off facility, occupational therapy and other facilities free of cost. If these 180 children can show improvement then the other 420 children registered with us and many other such children born in gas and water affected families but not yet registered with Chingari Trust could also show improvement if provided with proper treatment, love and care.

**Syed Tabish Ali (Mr.Tabish) was brought up in Bhopal and graduated in Biotechnolgy with a post graduate qualification in Management. He joined the Chingari Trust as a Public Relations Officer in August 2011.**

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Review

# Bhopal literature review

Mark Hailwood and Fiona Macleod

## Journal and conference papers

There are very many papers written about the Bhopal disaster, written from a wide range of disciplines and standpoints. These cover not only the chemistry and chemical engineering professions but also the medical, legal, political and social sciences. Writing about Bhopal has not been an easy task from the outset and continues to remain fraught with difficulties. Establishing the facts and then interpreting these within the context of an industrialising nation in the 1980s is complicated and at a distance of 30 years, expectations and behaviours with regard to chemical process safety are generally much different.

The following text does not cover the large number of medical and toxicological studies and publications. These include discussions of the toxic effects of MIC as well as the possibility that cyanide poisoning had also occurred. There are also detailed discussions of the consequences of eye and respiratory irritation as well as considerations of potential carcinogenic effects. This expanse of literature is beyond the scope of a detailed review within *LPB*.

The articles listed below attempt to show a cross-section of the themes addressed. No single article covers every aspect of information on the occurrences in Bhopal. Readers also need to be aware of the context in which the articles were published or presented. Conference papers have a somewhat different context to scientific journal papers. Authors speaking from an industrial background will have a different standpoint to academic authors. One of the earlier papers which discusses the technical causes of the disaster is a conference paper by Kalelkar at an IChemE conference on major accidents. The author was involved in the investigation of the accident on behalf of Union Carbide Corporation. Carrying out an investigation for an accident in which the operating company was effectively a joint venture between a major multi-national corporation and local state agencies and with limited access to the facility, is unlikely to lead to undisputed and unbiased results. When it is considered that the operating environment, whilst theoretically English language based, in reality was Indian language and probably of limited literacy then the adherence to rules and regulations, together with operator understanding of process control cannot be seen solely in the context of a multi-national corporation based in the USA. In addition the facility in Bhopal was being run down and significant, safety critical equipment was no longer in operation. In the 21st century process safety professionals would generally find this an unacceptable form of operation, however accident investigation reports of incidents in industrialised nations show that maintaining the operation of safety critical equipment (particular in economically challenged industries) remains a problem.

The papers have been written over a number of years. However it is noticeable that the anniversaries of Bhopal generate retrospectives and reflections. Particularly poignant is that some of the problems that led to the Bhopal disaster are still not solved today. It is still a challenge for multi-national corporations to ensure that their subsidiaries are operated in the same way in which they would be run in an industrialised country, and that the reporting to the corporate management is open and transparent. Understanding the local culture in which joint-ventures are run, including the culture and expectations of the corporate partners (which in many cases are local state owned operations) is still underestimated by many companies looking to invest in developing and industrialising countries. It should also not be forgotten that the UCIL site in Bhopal remains contaminated and the ruined buildings and plant have yet to be safely demolished, removed and the site returned to a safe environment.

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## Books

### Five Past Midnight in Bhopal

*Domanique Lapierre and Javier Moro*
*978 074322 035 4, 2003*

A partly fictional recreation of the events leading up to the tragedy, providing context and history, the novel tells the stories of the engineers who built the Union Carbide plant in Bhopal and follows the lives of the poor and dispossessed living beside it.

When the green revolution lowers food prices, agricultural labourers working on uneconomic smallholdings face destitution and move to the city slums to survive, only to become victims a second time.

This book was recommended to me by my Indian colleagues when I was working in Utter Pradesh. It is difficult to make sense of the aftermath of the tragedy without some understanding of Indian culture and politics.

This book manages to give a balanced, moving and human account, despite some major inaccuracies in the science.

### The Black Box of Bhopal

*Themistocles da Silva*
*978 141208 412 3, 2006*

Themistocles da Silva was a research chemist working for Union Carbide, and his book concentrates on the chemical clues left in the residue of tank E610 to explain what caused the runaway reaction.

The author looks at the underlying causes of the tragedy, showing how the green revolution led to a rising demand for chemical fertiliser and pesticide production in India to feed its growing population. National governments are rarely best placed to decide the capacity and technology of chemical plants, but the Indian Government's inflexible industrial policy, strict rules on foreign exchange and a lack of market realism led to flaws in the India plant that contributed to the size of the disaster.

Although the process technology for MIC was the same as that used by Union Carbide in the USA, the Indian plant had fewer automatic controls, relying on more manual operation. The alpha napthol technology was developed in India, untried at large scale and never worked properly. The plant was too big and lost a spectacular amount of money.

Themistocles da Silva unearths a wealth of fascinating detail. Union Carbide ran a shrimp boat in the bay of Bengal; the export of prawns earned foreign exchange to pay for the import of raw materials to the Bhopal factory.

While Themistocles da Silva remained convinced that sabotage was the only possible explanation (a conclusion that I cannot agree with), he does not pull his punches in highlighting the general mismanagement of the factory, and this is a well-researched and thoughtful book.

### Bhopal the inside story

*TR Chouhan and others*
*978 094525 722 6, 1995*

TR Chouhan worked for Union Carbide India Limited (UCIL) from 1975 until after the accident in 1984. His version of events (a set of interviews with workers) was written mainly in response to the accusation of worker sabotage by Union

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Carbide, and so is highly defensive, focusing mainly on proving why the company theory was impossible.

The book includes a diatribe against capitalism, multinationals, government, lawyers, journalists – all understandable given his direct and horrific personal experience. He also makes a plea for a return to low technology cottage industries, indigenous agricultural methods, horse-drawn transport and ayurvedic medicine – a refreshingly honest understanding of the consequences of rejecting technology.

He gives some fascinating insights into the culture at UCIL, including the fact that many of the process operators employed had been highly qualified (TR himself had been studying for a diploma in Pharmacy when he took the factory job) and when they found themselves required to do manual work, they left as soon as they could to find better jobs, or remained, openly resentful.

Descriptions of the work practices and lack of industrial hygiene paint a grim picture of the safety culture long before the 1984 accident.

### Behind the Poison Cloud

*Larry Everest*

*978 091665 025 4, 1986*

The author spent several weeks in India in February 1985 and collected valuable information and eyewitness accounts in the immediate aftermath of the accident. There is a useful section on the state of safety and environmental regulation in India in the 1980s. However, I found it a difficult read as the author filters everything though the lens of a "mammoth cover up" and summarises the tragedy as "a horrifying and concentrated illustration of the essential operation of imperialism, not so much an accident as a massacre."

### Animal's People

*Indira Sinha*

*978 141652 627 8, 2008*

Up close and personal, the grim story of a crippled boy searching for a cure is brought to life by a truly gifted writer, allowing an unexpected beauty to shine through. The fictional story, set in the imaginary town of Khaufpur, deals unflinchingly with the aftermath of a chemical accident. The power struggle between rival activists, the tussle between local and western medicine and the suspicion of foreigners and officials is vividly portrayed with real humanity.

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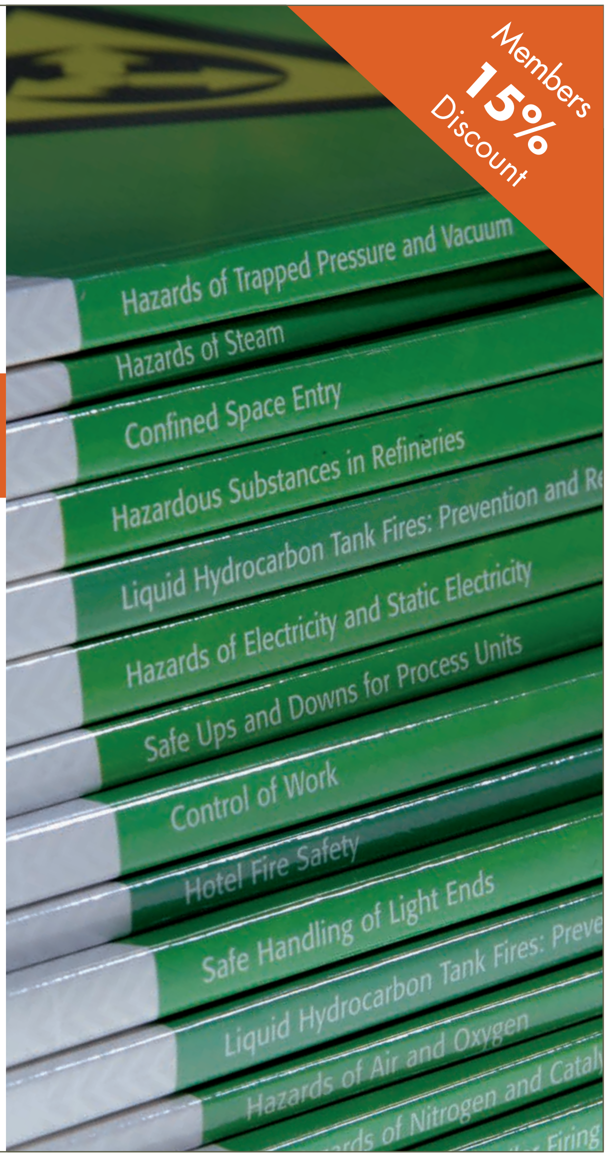



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