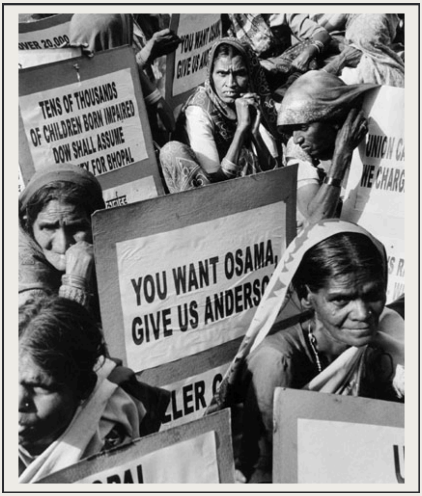

THE BHOPAL TRAGEDY 1984

CHEMICAL CATASTROPHE

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CHEMICAL CATASTROPHE

PUBLISHED BY:

Universiti Teknologi MARA (UiTM)
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Publication Date: 18 August 2025
e-ISBN: 978-967-25930-7-2
National Library of Malaysia

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This e-book offers an analysis and reflective discussion on the 1984 Bhopal tragedy, viewed through the lens of the authors. This e-book aims to provide a comprehensive understanding of the Bhopal Tragedy of 1984, one of the world's worst industrial disasters, through factual accounts, critical analysis, and reflective commentary. Through this work, readers are invited not only to learn from history but also to apply its lessons in shaping safer and more responsible futures.

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SYNOPSYS

THE BHOPAL TRAGEDY 1984

Based on a True Story- A Lesson in Chemical Health and Safety Management

On the night of December 2–3, 1984, a catastrophic gas leak at the Union Carbide pesticide plant in Bhopal, India, released tons of toxic methyl isocyanate (MIC) into the air. Within hours, thousands of people died, and over half a million were exposed to the poison and many suffering long-term health effects, disabilities, or loss of livelihood. The Bhopal disaster remains the world's worst industrial chemical accident.

This e-book presents the true story of The Bhopal Tragedy, examining the incident through the lens of Chemical Safety Management. It highlights how poor hazard identification, lack of risk control measures, insufficient emergency preparedness, and weak regulatory oversight contributed to the scale of the disaster. Key safety failures, such as disabled safety systems, inadequate staff training, and the absence of proper chemical storage protocols, are analyzed to emphasize the critical importance of proactive chemical safety practices.

This case study reinforces the core learning outcomes of Chemical Health and Safety Management courses, encouraging readers to apply best practices and lessons learned from Bhopal to prevent future industrial disasters.

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INTRODUCTION

The Bhopal Gas Tragedy: Revisiting India's Deadliest Industrial Disaster

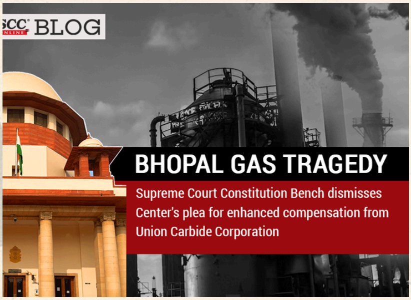
What happened in Bhopal?

On the night of December 2–3, 1984, a highly toxic gas called methyl isocyanate (MIC) leaked from a storage tank at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal. The gas spread rapidly over nearby neighborhoods, killing more than 3,000 people within hours. In total, over 500,000 individuals were exposed, many of whom suffered long-term health effects (Sriramachari, 2004).

Adopted by (Sriramachari, 2004).

Why Bhopal Matters?

What makes Bhopal particularly alarming is the series of failures that led to the disaster: corporate cost-cutting, broken safety equipment, lack of emergency response plans, and government oversight that was either absent or ineffective. It was a disaster that could have been prevented if human lives had been prioritized over corporate savings (Jasanoff, 2007)



Adopted by (Jasanoff, 2007)

INTRODUCTION

The Bhopal Gas Tragedy: Revisiting India’s Deadliest Industrial Disaster

Relevance to Chemical Health and Safety Management

The Bhopal disaster highlights critical gaps in chemical process safety, risk assessment, toxicology awareness, and emergency response preparedness. From a chemical health and safety management perspective, the incident was a result of cumulative failures in **Hazard identification** and **risk control**, Implementation of engineering safety barriers ,Maintenance of process integrity, and Institutional safety culture and regulatory compliance.

Purpose of this e-book

By understanding the failures of the past, this e-book aims to equip future students with the knowledge and awareness necessary to prevent similar tragedies and understand the global culture of chemical safety, and ethical industrial practices.

THE BHOPAL TRAGEDY 1984

CHAPTER ONE

CHEMICAL CATASTROPHE

CHAPTER ONE

BACKGROUND OF UNION CARBIDE AND THE BHOPAL PLANT

Union Carbide India Limited (UCIL) was a subsidiary of Union Carbide Corporation (UCC), a U.S.-based multinational chemical company. The UCIL Bhopal plant was established in the 1970s to manufacture the pesticide Sevin (carbaryl), which required methyl isocyanate (MIC) as a key intermediate (Lapierre & Moro, 2002).

Adopted by (Lapierre & Moro, 2002).

Earlier leaks:

In 1976, two local trade unions complained of pollution within the plant In 1981, a worker was accidentally splashed with phosgene as he was carrying out a maintenance job of the plant's pipes. In a panic, he removed his gas mask and inhaled a large amount of toxic phosgene gas, leading to his death 72 hours later. Following these events, journalist Rajkumar Keswani began investigating and published his findings in Bhopal's local paper Rapat, in which he urged "Wake up, people of Bhopal, you are on the edge of a volcano." Worryingly, the plant was located adjacent to densely populated slums. This made any large-scale gas release potentially catastrophic. Yet, no adequate community warning system or disaster response protocol was ever established (Jasanoff, 2007).

Adopted by (Eckerman, 2005).

Initially, MIC was supposed to be imported in small amounts, but in order to cut costs, the company decided to produce and store MIC on-site in large quantities. This move significantly increased the risk, especially given that MIC is highly toxic and reactive with water (Dhara & Dhara, 2002). By the early 1980s, the plant was operating at a financial loss, which led to reduced maintenance, understaffing, and the shutdown of key safety systems such as refrigeration units, gas scrubbers, and alarms. Despite repeated safety warnings, necessary upgrades and repairs were ignored (Eckerman, 2005).

THE BHOPAL TRAGEDY 1984

CHAPTER TWO

CHEMICAL CATASTROPHE

CHAPTER TWO

CHEMICAL REACTIONS OCCURED DURING BHOPAL TRAGEDY

Bhopal Gas Tragedy Process Flowchart

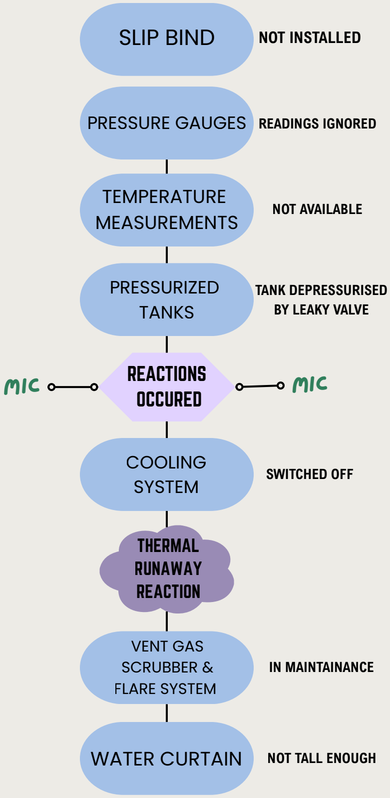


Figure 2.0 Bhopal Gas Tragedy Flowchart

CHEMICAL that involved in this tragedy is methyl isocyanate (MIC) or an intermediate to synthesis a pesticides. To be specific, MIC is highly toxic and volatile chemical compound. Catastrophic event was triggered by an uncontrolled chemical reaction involving MIC and water. Hence, led into a massive toxic gas leak.

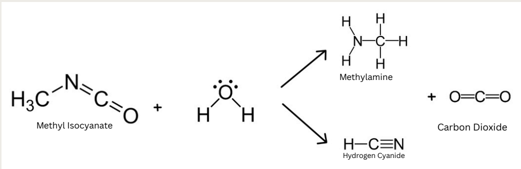


Figure 2.1 Chemical Equation Involved

The water leaks were coming from the flush and cleaning clogged pipes by the staffs. The faulty and clogged downstream valves caused water to backflow into the tank. When MIC reacted with water it formed a toxic gas such as Hydrogen Cyanide and Methylamine. The highly toxic gas were the mail culprit of the tragedy as it can lead into short term sickness and also pro-longed health problems.

The first reactions occured created an exothermic reaction. The intensity of heat rapidly vaporized the MIC, raising pressure until the tank safety valve opened as it depressurized. The secondary reactions included secondary amide formation, polymerization or trimerization of MIC and at temperature 200°C MIC degrades into potential of toxic gases like HCN.

Stage	Reactions	Results
MIC + H2O	$CH_3NCO + H_2O \rightarrow CH_3NH_2 + CO_2$ + heat	Pressure buildup
Secondary amide formation	CH_3NH_2 + MIC → DMU, TMB etc. + heat	Further heating & pressure
Trimerization	MIC —> polymer trimer + heat	Rapid temperature rise
Decomposition above 200°C	MIC → HCN, CO, HCl	Highly toxic mixture

Figure 2.1 Chemical Reactions Stage Summary Table

THERMAL RUNAWAY REACTIONS

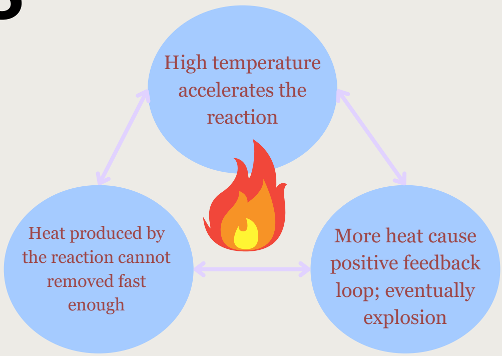


Figure 2.2 Thermal Runaway Reaction Flowchart

What triggered the runaway reaction ?

The water that ingress into MIC tank initiated exothermic reactions with MIC. All the reactions cascade, rapidly escalating heat and pressure in loop. The failures of equipment lead into serious crisis. Based on the flow chart (Figure 2.0) previous page, the refrigeration meant to maintain low MIC temperature was offline, vent gas scrubber that was designed to neutralize escaping gas was malfunction and flare tower was disconnected for maintainance. Hence, the heat buildup accelerated leading into thermal runaway reaction.

Enormous toxic cloud gases occurs during the tragedy. This is the main route of the accident by inhaling the environment air and limitless exposure affecting the whole nearby residents leading to deadly and lethal level. Numerous patient could not be tend as during that era, the lack of knowledge due to the toxic gases were worsening the situation.

HAZARD SAFETY DATASHEET REVIEWS

SDS ELEMENT	BHOPAL FAILURE	MODERN SDS REQUIREMENT
Hazard Classification	Underplayed MIC's extreme toxicity	Emphasize H330, H318 and H335
Exposure limits	Not monitored, high exposure occured	Enforce TLV = 0.02 ppm, continuous air sampling
Reactivity data	Did not highlight MIC + water reaction hazard	Detailed reactivity warnings and safe segregation
Safety systems	Cooling, scrubbing, venting were offline	Mandatory redundant system with maintenance schedule
Storage requirements	Stored in carbon steel at ambient temperature	Require low temperature stainless or glass storage
Emergency planning	No public alert, medical unprepared	Include community notification, PPE protocols and safety zone

HAZARD SAFETY DATASHEET REVIEWS

Section 2: Hazards identification

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008 (CLP)

Section	Hazard class	Category	Hazard class and category	Hazard statement
2.6	flammable liquid	2	Flam. Liq. 2	H225
3.1O	acute toxicity (oral)	3	Acute Tox. 3	H301
3.1D	acute toxicity (dermal)	3	Acute Tox. 3	H311
3.1I	acute toxicity (inhal.)	2	Acute Tox. 2	H330
3.2	skin corrosion/irritation	2	Skin Irrit. 2	H315
3.3	serious eye damage/eye irritation	1	Eye Dam. 1	H318
3.4R	respiratory sensitisation	1	Resp. Sens. 1	H334
3.4S	skin sensitisation	1	Skin Sens. 1	H317
3.7	reproductive toxicity	2	Repr. 2	H361d
3.8R	specific target organ toxicity - single exposure (respiratory tract irritation)	3	STOT SE 3	H335

For full text of abbreviations: see SECTION 16.

Section 6: Accidental realease measures

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures

For non-emergency personnel

Remove persons to safety.

For emergency responders

Wear breathing apparatus if exposed to vapours/dust/spray/gases.

6.2 Environmental precautions

Keep away from drains, surface and ground water. Retain contaminated washing water and dispose of it.

6.3 Methods and material for containment and cleaning up

Advices on how to contain a spill

Covering of drains

Advices on how to clean up a spill

Wipe up with absorbent material (e.g. cloth, fleece). Collect spillage: sawdust, kieselgur (diatomite), sand, universal binder

Appropriate containment techniques

Use of adsorbent materials.

Other information relating to spills and releases

Place in appropriate containers for disposal. Ventilate affected area.

6.4 Reference to other sections

Hazardous combustion products: see section 5. Personal protective equipment: see section 8. Incompatible materials: see section 10. Disposal considerations: see section 13.

HAZARD SAFETY DATASHEET REVIEWS

Section 7: Handling and storage

SECTION 7: Handling and storage

7.1 Precautions for safe handling

Recommendations

- Measures to prevent fire as well as aerosol and dust generation

Use local and general ventilation. Avoidance of ignition sources. Keep away from sources of ignition - No smoking. Take precautionary measures against static discharge. Use only in well-ventilated areas. Due to danger of explosion, prevent leakage of vapours into cellars, flues and ditches. Ground/bond container and receiving equipment. Use explosion-proof electrical/ventilating/lighting/equipment. Use only non-sparking tools.

- Specific notes/details

Places which are not ventilated, e.g. unventilated below ground level areas such as trenches, conduits and shafts, are particularly prone to the presence of flammable substances or mixtures. Vapours are heavier than air, spread along floors and form explosive mixtures with air. Vapours may form explosive mixtures with air.

Advice on general occupational hygiene

Wash hands after use. Do not eat, drink and smoke in work areas. Remove contaminated clothing and protective equipment before entering eating areas. Never keep food or drink in the vicinity of chemicals. Never place chemicals in containers that are normally used for food or drink. Keep away from food, drink and animal feedingstuffs.

7.2 Conditions for safe storage, including any incompatibilities

Managing of associated risks

- Explosive atmospheres

Keep container tightly closed and in a well-ventilated place. Use local and general ventilation. Keep cool. Protect from sunlight.

United Kingdom: en   4   Page: 4 / 12

CHEMOS solutions through service

Safety Data Sheet

according to Regulation (EC) No. 1907/2006 (REACH)

Methyl isocyanate

Version number: GHS 1.0   Date of compilation: 2019-03-12

- Flammability hazards

Keep away from sources of ignition - No smoking. Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking. Take precautionary measures against static discharge. Protect from sunlight.

- Ventilation requirements

Keep any substance that emits harmful vapours or gases in a place that allows these to be permanently extracted. Use local and general ventilation. Ground/bond container and receiving equipment.

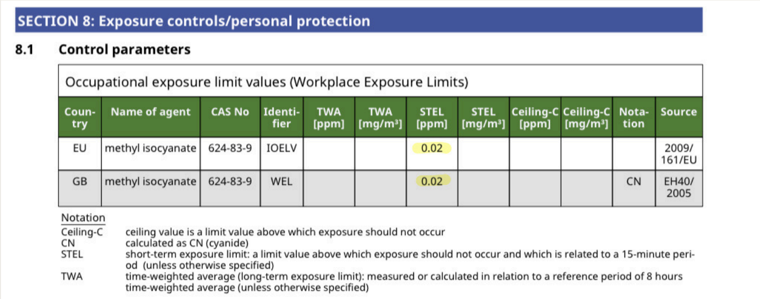
- Packaging compatibilities

Only packagings which are approved (e.g. acc. to ADR) may be used.

CHAPTER TWO

HAZARD SAFETY DATASHEET REVIEWS

Section 8: Exposure controls/personal protection



SECTION 8: Exposure controls/personal protection

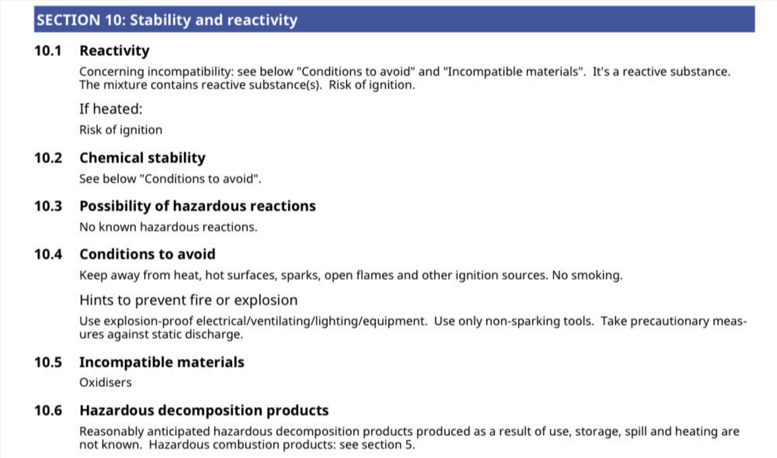
8.1 Control parameters

Occupational exposure limit values (Workplace Exposure Limits)

Country	Name of agent	CAS No	Identifier	TWA [ppm]	TWA [mg/m³]	STEL [ppm]	STEL [mg/m³]	Ceiling-C [ppm]	Ceiling-C [mg/m³]	Notation	Source
EU	methyl isocyanate	624-83-9	IOELV			0.02					2009/161/EU
GB	methyl isocyanate	624-83-9	WEL			0.02				CN	EH40/2005

Notation
- Ceiling-C: ceiling value is a limit value above which exposure should not occur
- CN: calculated as CN (cyanide)
- STEL: short-term exposure limit: a limit value above which exposure should not occur and which is related to a 15-minute period (unless otherwise specified)
- TWA: time-weighted average (long-term exposure limit): measured or calculated in relation to a reference period of 8 hours time-weighted average (unless otherwise specified)

Section 10: Stability and reactivity



SECTION 10: Stability and reactivity

10.1 Reactivity

Concerning incompatibility: see below "Conditions to avoid" and "Incompatible materials". It's a reactive substance. The mixture contains reactive substance(s). Risk of ignition.

If heated:

Risk of ignition

10.2 Chemical stability

See below "Conditions to avoid".

10.3 Possibility of hazardous reactions

No known hazardous reactions.

10.4 Conditions to avoid

Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.

Hints to prevent fire or explosion

Use explosion-proof electrical/ventilating/lighting/equipment. Use only non-sparking tools. Take precautionary measures against static discharge.

10.5 Incompatible materials

Oxidisers

10.6 Hazardous decomposition products

Reasonably anticipated hazardous decomposition products produced as a result of use, storage, spill and heating are not known. Hazardous combustion products: see section 5.

CHAPTER TWO

HAZARD SAFETY DATASHEET REVIEWS

Section 11: Toxicological information

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Classification according to GHS (1272/2008/EC, CLP)

Acute toxicity

Toxic if swallowed. Toxic in contact with skin. Fatal if inhaled.

- Acute toxicity estimate (ATE)

Oral	100 $^{mg}/_{kg}$
Dermal	300 $^{mg}/_{kg}$
Inhalation: vapour	0.5 $^{mg}/_{l}$/4h

Skin corrosion/irritation

Causes skin irritation.

Serious eye damage/eye irritation

Causes serious eye damage.

Respiratory or skin sensitisation

May cause allergy or asthma symptoms or breathing difficulties if inhaled. May cause an allergic skin reaction.

Germ cell mutagenicity

Shall not be classified as germ cell mutagenic.

Carcinogenicity

Shall not be classified as carcinogenic.

Reproductive toxicity

Suspected of damaging the unborn child.

Specific target organ toxicity - single exposure

May cause respiratory irritation.

Specific target organ toxicity - repeated exposure

Shall not be classified as a specific target organ toxicant (repeated exposure).

Aspiration hazard

Shall not be classified as presenting an aspiration hazard.

Section 16: Other information (Abbreviation and acronyms)

Code	Text
H318	Causes serious eye damage.
H330	Fatal if inhaled.
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled.
H335	May cause respiratory irritation.
H361d	Suspected of damaging the unborn child.

	tions concerning the International carriage of Dangerous goods by Rail)
STEL	Short-term exposure limit

THE BHOPAL TRAGEDY 1984

CHAPTER THREE

CHEMICAL CATASTROPHE

CAUSE OF THE ACCIDENT

1) HUMAN ERROR

2) CORPORATE NEGLIGENCE

3) OVERSIGHT OF RISK AND SAFETY PROTOCOLS

1) HUMAN ERROR

overlooked to insert a device that is designed to prevent the water from getting in the underground chemical tank, which is known as Tank 610

water flow through the valve during the cleaning operations and leak into the chemical tank that consist of a substantial amount of MIC (Hanley, 2021)

produced an exothermic reaction with enough energy to release tons of the dangerous chemical into the atmosphere.

Pressure inside the tank has increased

vent gas scrubber and a flare tower were switched off at the time of the occurrence.

MIC was held at ambient temperatures resulted in increase of its reactivity.

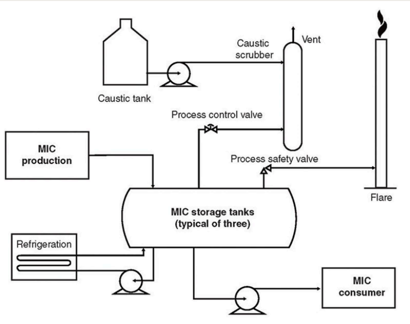


Figure 3.0 : Available Safety Components and System

Figure 3.1 : The site of the Tragedy

CAUSE OF THE ACCIDENT

- 1)HUMAN ERROR
- 3) OVERSIGHT OF RISK AND SAFETY PROTOCOLS
- 2)CORPORATE NEGLIGENCE

2)CORPORATE NEGLIGENCE

- cost-cutting measures that threatened the plant's safety.
- the duration of on-site safety training was lowered from six months to 15 days.
- Manpower in safety and maintenance was also drastically reduced to save money.
- The number of trained personnel was reduced
- Experienced engineers have been replaced with underqualified staff.
- operator performance had declined beyond basic regulations in a very hazardous plant.

Figure 3.2 : Survivors stage a protest march

Figure 3.3 : Protest on further compensation and a clean up of the area

Figure 3.4 : Activists of All India Youth Federation raise slogans against America, Indian government and Warren Anderson, the head of Union Carbide Corp. at the time of the gas leak

CAUSE OF THE ACCIDENT

1)HUMAN ERROR

2)CORPORATE NEGLIGENCE

3) OVERSIGHT OF RISK AND SAFETY PROTOCOLS

Several small gas leaks and technical faults occurred at the plant in the years were disregarded by management.

3) OVERSIGHT OF RISK AND SAFETY PROTOCOLS

Workers had expressed major worries about leaking valves, corrosion, and poor maintenance standards

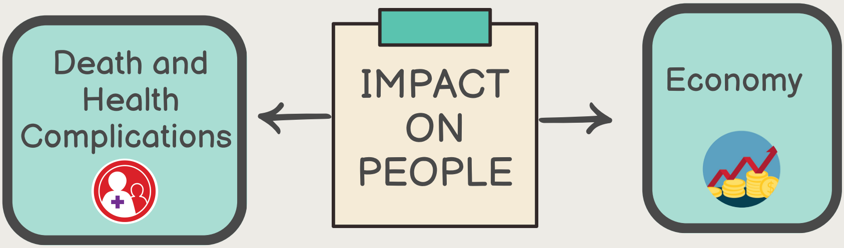
their objections were consistently rejected.

Internal safety audits and external assessments identified risky practices and the potential for catastrophic failure

corrective measures were never completely implemented

Figure 3.5 : A person with full Personal Protective Equipment (PPE) due to safety hazards

Figure 3.6 : Safety slogans at the Union Carbide factory were in English



Death and Health Complications

The Bhopal Gas Tragedy was one of the most significant industrial disasters in history, killing 2500-6000 people and disable over 200 000. The township's citizens experienced various degrees of exposure with over 500 000 registered victims surviving the disaster (Goldman & Gaviola, 2022).The Indian Council of Medical Research (ICMR) research found that most deaths happened within 72 hours of the leak. Although the number of deaths decreased, the impact on survivors' health was severe due to a lack of knowledge about the harmful effects of MIC. Many the exposed population suffers from chronic illnesses in several systems, including respiratory, gastro-intestinal, reproductive, musculoskeletal, and neurological.

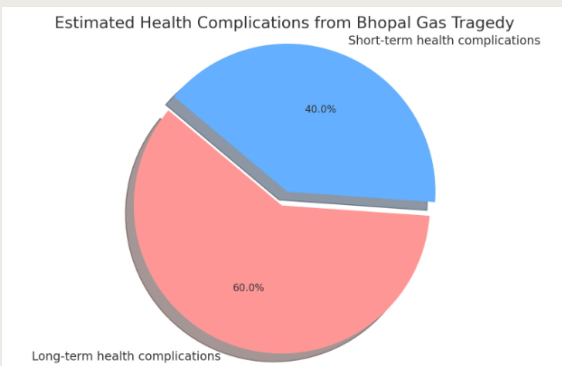


Figure 3.7 : Pie chart of the Short-term and Long-term Health Complications of survivors from the tragedy

Figure 3.8 : News on the Bhopal Gas Tragedy after 30 years

Death and Health Complications

Respiratory Health Effects | **Reproductive Issues** | **Relation of Psychological and Neurological Health Effects**

Autopsy Findings	• Complex respiratory system damage • Necrosis in lungs, airways, and capillaries • Organ congestion • Cerebral enlargement • Oxygen deprivation in the brain
Cause of Death (ICMR)	• Acute lung damage • Acute Respiratory Distress Syndrome (ARDS)
Health Phases	Victims categorized as: • Acute • Sub-acute • Chronic (based on duration of symptoms)
BAL (Bronchoalveolar Lavage) Results	• Increased lung inflammation (alveolitis) • Non-smokers: High macrophages • Smokers: High macrophages & neutrophils

Figure 3.9 : Observation of a patient's respiratory health

Figure 3.10 : A patient has an X-ray to monitor his respiratory problems.

Death and Health Complications

Respiratory Health Effects

Reproductive Issues

Relation of Psychological and Neurological Health Effects

Women and their kids exposed to methyl isocyanate (MIC) were still experiencing abnormalities in menstrual cycle, vaginal discharge, and premature menopause two decades after the Bhopal gas tragedy occurred.These reproductive health issues have not only had an impact on physical health, but they have also resulted in social shame and problems, particularly in conservative cultures. According to past cohort research and clinical observations, girls who were exposed in infants or in the womb are now experiencing "menstrual chaos."

Figure 3.11 : A child that is born after the leak

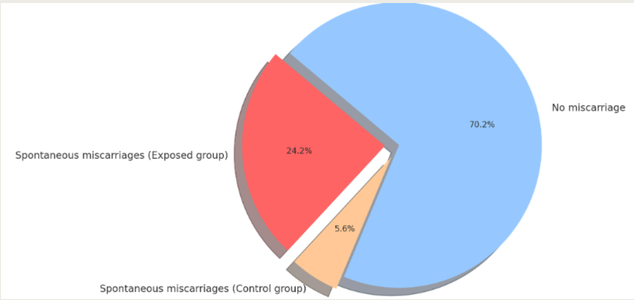


Figure 3.12 : Pie chart of spontaneous miscarriage rates related to Bhopal gas exposure

Figure 3.13 : A baby from the effect of the leak

Surprisingly, the incidence of premature babies and birth defects were not statistically different between the two groups. The ICMR's final report also indicated increased miscarriage rates, monthly abnormalities, and heavy bleeding in the early years after the tragedy. Many women continued to have miscarriages in the years following the tragedy and some struggled with infertility (Khan, 2024). It was also found that there is an increase in abnormal uterine bleeding instances and abnormal Pap tests in exposed women within 15 weeks after the gas released.

Death and Health Complications

Respiratory Health Effects

Reproductive Issues

Relation of Psychological and Neurological Health Effects

EMOTIONAL & MENTAL HEALTH

- Depression
- Anxiety
- Social adjustment problems
- Psychiatric disorders in 22.6% (3–5 months after tragedy)

NEUROMUSCULAR SYMPTOMS

- Tingling and numbness
- Muscle pains
- "Pins and needles" feeling

COGNITIVE DISORDERS

- Memory issues
- Shorter attention span
- Slower response time
- Poor learning and motor skills

EFFECTS ON CHILDREN

- Anxiety
- Sadness
- Excessive talking

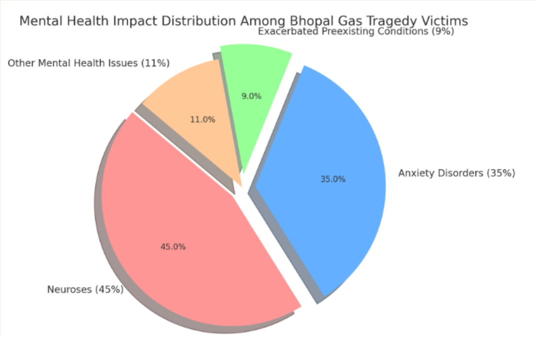
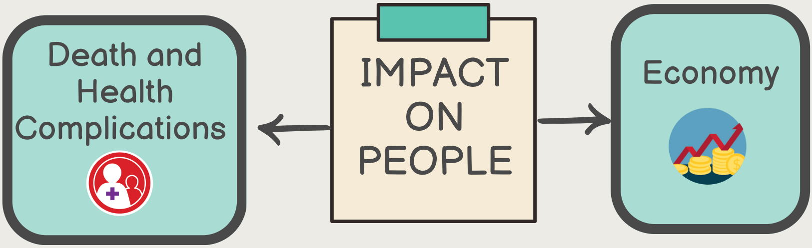


Figure 3.15 : Pie chart of the distribution of mental health impacts among Bhopal Gas Tragedy survivors..

Figure 3.14 : Vikas Yadav, 19, and Aman Yadav, 17, brothers, have muscular dystrophy and are being cared for by their mother at their home.

Figure 3.16 : A child affected by the toxic gas leak



Economy

The economic consequences of the Bhopal gas tragedy were closely linked to Union Carbide's financial issues and uncertain choices prior to and during the disaster. In the first 10 months of 1984 alone, UCIL lost more than Rs. 5 crores, causing Union Carbide Corporation (UCC) to close the factory and prepare it for sale (Ipe, 2005). The corporation planned to shut down and relocate the factory because there are no buyers interested in buying it. By November 1984, shutdown negotiations had begun. These measures to cut expenses and employment reductions compromised plant safety and maintenance that directly contributed to the gas leak. Following the tragedy, the economic responsibility was shifted to the Indian government, which passed an ordinance establishing itself as the sole legal agent of the victims and eventually filed a compensation action in US courts.

Figure 3.17 : Condition of the land and home of the residents

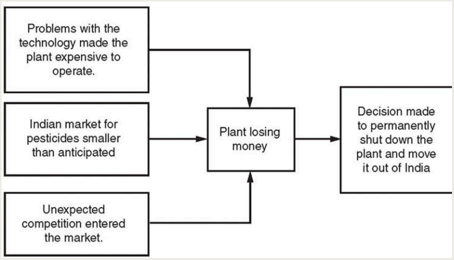


Figure 3.18 : The economic situation during the tragedy

However, the government's claim registration process was badly managed, causing victims to wait longer for financial assistance. Union Carbide promptly shifted blame and settling with the laid off employees for a minimal $1.8 million (Sharma & Umekar, 2019). Meanwhile, the business faced a takeover effort by GAF, which many viewed as a strategy to reorganize assets and protect itself from potential liabilities. Union Carbide eventually used this circumstance to file for protection against bankruptcy, perhaps preventing future payments. Despite the catastrophic event, shareholders gained from higher earnings, but sufferers received little or no financial support.

Judge J.F. Keenan asked UCC to grant immediate relief of $5-10 million as a matter of a fundamental human right, but administrative delays prevented the aid's payments (Sharma & Umekar, 2019). The agreed-upon $5 million was eventually transferred through the American and Indian Red Cross, but a year later, no victims had benefited, and relief operations were unknown.

Figure 3.19 : The Union Carbide site

contamination of water

Toxic substances like pesticides, heavy metals, and volatile organic compounds progressively dissolved into the soil

The existence of carcinogens and other hazardous chemicals in the water.

Residents are at risk for major health problems like skin conditions, and digestive disorders (Prakash et al., 2020).

The Indian government does not supply safe drinking water to all impacted residential areas

Figure 3.20 : residents collected water from hand pumps for their daily needs.

Figure 3.21 : A boy drinks water from a hand pump near the plant

ENVIRONMENTAL IMPACT

Figure 3.22 : Protest march due to the pollution and climate change

Figure 3.23 : Toxic waste left around the tragedy area

land pollution

Dangerous compounds were disposed of in open-air landfills and unsecured evaporation ponds or kept in leaking containers

Area's soil is unsuitable for safe reconstruction, agriculture, or habitation

Local livelihoods have been severely impacted especially for those who relied on farming, as the land has become poisonous and abandoned.

The possibility of direct chemical exposure for kids playing on contaminated land.

Figure 3.24 : People rushed to leave Bhopal in trains and buses

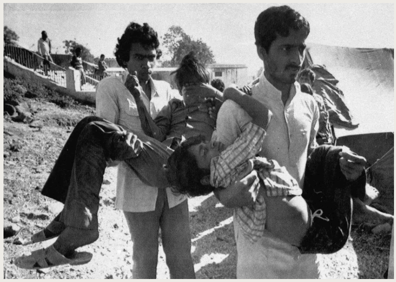


Figure 3.25 : Two men carry children blinded by the Union Carbide chemical leak in Bhopal, India, to a hospital.

RESPONSE AND MANAGEMENT

- there was no emergency alarm system in place in the hours after the methyl isocyanate (MIC) gas leak on December 2-3, 1984.
- People ran aimlessly through the streets after waking up coughing, choking, and blinded.
- the medical professionals at nearby hospitals were unprepared and overwhelmed as they had no idea what the gas was or how to treat its symptoms.
- antidotes were not available, and there were no protocols for MIC poisoning (Goldman & Gaviola, 2022).
- Rs. 1 crore provided in immediate financial support and declared a relief fund of Rs. 36.03 crores
- the Indian Supreme Court authorized that Union Carbide Corporation Limited (UCIL) compensate the victims of the Bhopal gas tragedy with $470 million.
- the number of deaths and ijnured people increased quickly in the first 72 hours tinuously disabled.
- the Department of Bhopal Gas Tragedy Relief and Rehabilitation was established as a special unit to manage all rehabilitation initiatives.

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CHAPTER FOUR

CHEMICAL CATASTROPHE

LESSONS LEARNED

Sytemic Safety Culture Over Blaming Individuals

Systemic safety culture views accidents as failures in organizational systems, not individual errors. It emphasizes structured decision-making, feedback mechanisms, and accountability across all levels to prevent recurring risks.

(Carayon et al., 2015; Xu et al., 2024; Ismail et al., 2024; Kuçük et al., 2020)

Robust Training and Equipment Training

The lack of structured training and regular equipment maintenance contributed significantly to the Bhopal disaster. Inadequate staffing and poor technical knowledge led to undetected system failures, while neglected maintenance compromised critical safety equipment.

(Joseph et al., 2005; Di Nardo et al., 2020)

Mandatory Emergency Planning and Community Drills

Emergency plans must involve regular, realistic drills supported by proper resources and leadership. Effective response requires coordination across agencies and the community to uncover and fix communication gaps or procedural weaknesses before a crisis occurs.

(Russell & Simpson, 2010)

Safe Plant Sitting to Protect Population

Plant location plays a critical role in public safety. Risk models show that hazardous zones can extend kilometers beyond chemical sites, making distance from residential areas essential. Strategic siting must consider threat zones, land use, and long-term exposure risks.

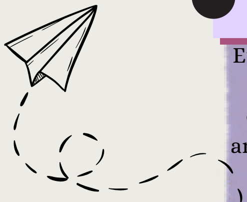
(Ahmad et al., 2021; Choi & Byeon, 2020; Syeda et al., 2017)

CHAPTER FOUR

RELEVANCE OF CHEMICAL HEALTH AND SAFETY MANAGEMENT (CHSM) TO THE TRAGEDY

Integrated Maintenance and Training

CHSM emphasizes how routine maintenance and structured employee training are essential to prevent system degradation. In Bhopal, the failure to maintain critical equipment such as refrigeration units and alarms which combined with undertrained staff led to cumulative faults that triggered the disaster (Di Nardo et al., 2020).

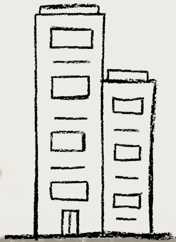


Systematic Documentation and Hazard Assessment

Effective CHSM includes accurate chemical inventories, hazard reports, emergency protocols, and safety data. This documentation ensures all workers are informed about risks and how to act during abnormal conditions, reducing confusion and miscommunication.
(National Research Council, 2012)

Stakeholder Participation and Accountability

When organizations link safety investment to measurable outcomes such as training effectiveness and maintenance performance, their ability to detect and respond to problems improves significantly. CHSM aligns leadership, staff, and external stakeholders through clear accountability and shared responsibility (Di Nardo et al., 2020).



Interconnected Safety Ecosystem

CHSM is not a set of isolated actions but a unified framework connecting hazard identification, operator preparedness, documentation, incident response, and community engagement. It reduces dependency on individual vigilance by building a structured, adaptive, and transparent safety system.
(Di Nardo et al., 2020)

MODERN REGULATION INFLUENCED BY BHOPAL TRAGEDY

HOW A SINGLE TRAGEDY LED TO GLOBAL SAFETY REFORMS

Emergency Planning & Community Right-to-Know Regulations

The Bhopal disaster prompted legislative action such as the U.S. Emergency Planning and Community Right-to-Know Act (EPCRA), mandating public disclosure of hazardous chemical inventories, community emergency planning, and coordination between agencies and residents. (National Research Council, 2012)

Figure 4.1: Bhopal survivors demanding answers and reforms in chemical safety governance

Adoption of Comprehensive Process Safety Standards

The catastrophe accelerated adoption of country-level process safety reforms and standards, especially in the United States, embedding principles such as hazard analysis, management of change, and process hazard review into official regulation and industrial practice (Joseph et al., 2005)

Industry-Wide Acceptance of Safety Culture Metrics

Journals analyzing post-Bhopal reforms document how safety culture became a central performance indicator in chemical regulations, with audits, incident investigations, and safety leadership integrated into compliance protocols across industries (Joseph et al., 2005)

International Occupational Health Legislation Reforms

In India, Bhopal catalyzed creation of new occupational health provisions and institutional mechanisms focused on hazardous industries, including mandates for worker health monitoring and stronger enforcement of industrial hygiene standards (Tulchinsky & Varavikova, 2014)

DID YOU KNOW?

- ECPRA was passed just 2 years after Bhopal (1986)
- Many countries modeled regulations after OSHA's Process Safety Management
- India created environmental courts and new licensing after Bhopal

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CONCLUSION

CHEMICAL CATASTROPHE

The Bhopal Gas Tragedy was one of the worst disasters in history. A poisonous gas leak from a factory killed thousands of people and left them to have many side effect. People in Bhopal are still suffering until today.

In our local context, Malaysia has established frameworks such as Occupational Safety and Health Act (OSHA) 1994, Environmental Quality Act 1974, and CIMAH regulations (Control of Industrial Major Accident Hazards) to prevent similar disasters. However, regulations alone are not enough. As future scientists, engineers, educators, and safety officers, students must develop a deep understanding of risk management, ethical responsibility, and the importance of safety culture.

By studying true events like the Bhopal disaster, we are reminded that chemistry is not just about reactions and formulas, it is about people, lives, and the environment. Let the tragedy of Bhopal serve not only as a warning but also as a guide to building a safer, more responsible future for Malaysia and the world.

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e ISBN 978-967-25930-7-2

UiTM NEGERI SEMBILAN, KAMPUS KUALA PILAH

(online)