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Bhopal Gas Tragedy: Scientific Challenges and Lessons for Future

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ABSTRACT

The Bhopal gas tragedy was the world's greatest industrial accident in 1984. 40 tonnes of Methyl Iso Cyanate were emitted as toxic gas (MIC) This gas is extremely hazardous, and it leaked and spread over the city. 20,000 people have perished as a result of their exposure to the gas. 120,000 are still suffering from the consequences of the exposure. According to ICMR, a sizable portion of those who were exposed to it are still suffering from chronic and long-term illnesses.Recent study findings on the "Health Effects of the Toxic Gas Leak from the Methyl Isocyanate Plant" were given in the organization's first technical report. gathered from the 24 research initiatives conducted between 1985 and 1994' in Bhopal'. The Bhopal tragedy sent shockwaves throughout the chemical industry, both the human heartbreak and the utter technical negligence came as a slap across the face for the chemical industry, provoking wide scale changes and highlighting process safety as a crucial and indispensable element at both the technical and managerial levels. Perhaps it is too late as to search for 'who' was behind such a tragedy, as the balance of power between the poor laborers and the major multinational will just carve another chapter into our book of human misery. Nevertheless, it is crucial to analyze the tragedy and try to overcome all the failures that led to it, something the chemical industry has successfully managed to achieve over the past decades.

Keywords: Affective result and Industrial Clinical Research, Impacts and Effects on Human Health, Animal Study, In vitro Research

INTRODUCTION

The tremendous loss suffered by the state of Madhya Pradesh and its citizens is explained by the consequences of the Bhopal gas catastrophe. (Mehta PS et al;1990) A review of methyl isocyanate toxicity. The published research has generally been restricted to histopathological discoveries, particularly of the lungs, and small cross-sectional studies that outline the symptomatology and clinical morbidity in the survivors. There have been numerous investigations on a variety of topics, but the investigations have largely been unpublished. The Indian Council of Medical Research was one of the first organisations to begin clinical research studies on the affected population (ICMR).The organization's initial technical paper included recent research findings on the "Health Effects of the Toxic Gas Leak from the Methyl Isocyanate Plant". collected from the 24 research projects carried out in Bhopal between 1985 and 1994.As part of the ICMR investigations, 80 000 persons in severely, moderately, and slightly exposed districts took part in epidemiological, clinical, and toxicological research. The results were compared to controls from unexposed regions.According to the ICMR investigation, the first 72 hours following the breach saw nearly three-fourths of the fatalities.

The lack of knowledge on the negative effects of MIC made it difficult to discover a feasible countermeasure to mitigate the impact, which increased the degree of the damage on the survivors' health even though the death toll rapidly fell. The International Commission on Medical Research (ICMR) reports that a large proportion of persons who were exposed to it are still dealing with chronic disorders affecting the reproductive, musculoskeletal, neurological, and other systems.It should be emphasised that scientific writing has subsequently been written that summarises the effects of MIC on human health as well as addressing the claimed research's flaws.

This opinion, as well as a number of others, have emphasised the necessity of keeping a continual eye out for the long-term detrimental effects of MIC.Trimers, dimers, aqueous solutions, and the by-products of thermal breakdown, including HCN, were all components of the aerosol that the tragic victims breathed.The pathological abnormalities in the acute, subacute, and chronic stages of pulmonary edoema and bronchiolitis were discovered by

autopsy investigations, which were then followed by chronic pulmonary fibrosis.The effect of cerebral edoema was "acute histotoxic anoxia."

In-depth experimental research using more modern molecular biology technologies may provide additional insight on the underlying processes and fresh treatment strategies.Initial observations of cherry-red lung discolouration raised cyanide poisoning concerns.Finally, the rapid therapeutic response to NaTS and concomitant rise in urine NaSCN excretion were validated by higher blood and tissue cyanide levels.Periodic clinical recurrences and relapses that pointed to "chronic cyanide poisoning" were still puzzling, nevertheless. (Sriram Chari S. et al;2004)

The N-carbamoylation of the end-terminal valine residues of Hb was used as the foundation for an explanation of specific variations in the 2-3 DPG levels and Blood Gases.Soon, it was discovered that a number of additional end-terminal -amino groups of tissue proteins were likewise N-carbamoylated.If experiments to show S-carbamoylation of glutathione and other tissue enzyme SH radicals, such rhodanese, had been successful, the fundamental mechanism of chronic cyanide poisoning caused by MIC may have been clarified.An effort will be made to describe the important clinical and toxicological findings, followed by a brief summary of the concepts of planned laboratory management for reducing human suffering from future chemical catastrophes, based on the practical lessons learned in Bhopal.

Affective Result and Industrial Reaction Aftermath

The inadequacy of Union Carbide Corporation's response to the 1984 catastrophe involving the leak of the extremely hazardous chemical methyl isocyanate from their factory in Bhopal, India.Since 1984, it is believed that over 20,000 individuals have passed away from exposure to this chemical, leaving over 120,000 survivors with chronic illnesses.Union Carbide wanted to maintain or avoid compensation at any costs.The lengthy, drawn-out procedure of awarding compensation was designed to reduce payments to victims.Key pieces of the safety equipment intended to block the release of the gas were either not functional or were switched off, despite the company's attempts to pin the tragedy on a disgruntled worker.The company has consistently tried to downplay the health risks and has refused to make its study on the effects of the gas on health public which could have helped develop more effective treatment. (Sriram Chari S. et al;2004)

Additionally, Bhopal's medical services haven't been able to create a health care system that provides consistent relief and treatment to the most impacted areas.The Sam Bhavna Trust, a non-profit organisation founded to deal with survivors, is also discussed in this article along with its mission to create straightforward, more efficient, moral, and participative methods of doing research, monitoring, and therapy.Through its programmes, which blend conventional and modern healthcare delivery methods, it makes sure that people and communities are actively involved in all facets of public health.Twenty years after the incident, the Supreme Court's ruling of July 19, 2004, granting redress for Bhopal gas victims is an example of the long arm of justice at work.Methyl Isocyanate (MIC), a deadly gas that leaked from Union Carbide India Ltd.'s pesticide facility in Bhopal on December 3, 1984, caused the deaths of 10,000 people and the lifelong disability of close to 50,000 more.Manufacturing companies need to address some important CSR concerns brought up by this catastrophe in order to fulfil their obligations to the community and environment.The Bhopal Gas Tragedy is examined in this case, and it is explained what happened and why:The bigger challenges that the stakeholders and participants must contend with are covered by the economic, legal, and environmental elements.

Inhaled MIC's acute toxicity or those of its reaction productswas terrible, but the only available treatment focused on the symptoms. Management since it was unclear if the consequences were caused by MIC, phosgene, HCN, or some other responseproducts.It was quite concerning since there was no information available on the toxicity of even the parent chemical, MIC.hindering therapeutic management and interventionof victims of gas.Later, a thorough review showed theup to 21 ingredients, including 9–10 more undiscovered chemicals, may be present.The impacted individuals includereported to suffer from chronic ailments such as pulmonaryasthma, fibrosis, and chronic obstructive pulmonary disease**.** Emphysema, recurring chest infections, illness (COPD),corneal opacities and keratopathy.According to studies, these survivors report having a greater prevalence of febrile diseases, respiratory, neurological, mental, and ocular symptoms, among other health issues.The negative consequences of exposure have also been seen in participants weakened immune systems.Unsurprisingly, a significant pregnancy outcome research involving homes in the severely afflicted areas near the UC plant also discovered a rise in spontaneous abortion rates.

Impacts of respiratory health

The respiratory system was thought to be the most badly damaged by the earliest human autopsy investigations, which showed significant necrotizing lesions in the lining of the upper respiratory tract as well as in the bronchioles, alveoli, and lung capillaries.(Eckerman I et al;2001)According to the ICMR's findings, hypoxia brought on by acute lung damage or acute respiratory distress syndrome (ARDS) may be at the root of the majority of fatalities following MIC exposure.Based on how long these post-trauma symptoms have been present, the clinical state of the victims has been divided into acute, sub-acute, and chronic conditions.A large percentage of people had abnormal

pulmonary function testing results (LFTs).According to the ICMR investigations, clinical symptoms did not totally go away. Additionally, autopsies revealed anoxic brain injury, cerebral edoema, and generalised visceral congestion.It's interesting to note that during the course of the 2 years of observation, both forced vital capacity (FVC) and forced expiratory flow (FEF25-75 percent of FVC) decreased gradually.According to Vijayan et a examination's of bronchoalveolar lavage (BAL) performed 1-2.5 years after exposure to the 'toxic gas' at Bhopal, there was an increase in cellularity in the lower respiratory tract (alveolitis) of the severely exposed individuals (in both smokers and non-smokers).In severely exposed non-smokers, aberrant macrophage accumulation was the cause of the increase in cellularity, whereas in heavily exposed smokers, macrophages and neutrophils were the cause.The bulk of subjects among the Bhopal victims had reduced vital capacities. The clinical, functional, and radiological data show that these people had a picture of acute extrinsic allergic bronchiole-alveolitis owing to exposure, which has entered the chronic phase of the pathogenesis, despite the fact that the diffusion tests could be done.

Table 1: Clinical symptoms seen between 1-6 months after exposure to methyl isocyanate in the acute and subacute phases

Impacted Physiological Systems	Clinical Signs
Ocular	Photophobia, corneal ulcer, conjunctival and circumcorneal congestion, intense burning, and tearing.
Respiratory	Pneumonitis, pulmonary edoema, chest discomfort, a strong dry or wet cough, and breathlessness.
cognitive and neurological	Anxiety, neurotic sadness, difficulty adjusting to new situations, poor auditory and visual memory, attention span and alertness.
Gastrointestinal	Abdominal discomfort, anorexia, and persistent diarrhoea
Immunological	Lowered T cell count, downregulation of lymphocyte phagocytic activity, and suppression of cell-mediated immunity.
Genetic	A rise of chromosomal anomalies.
Reproductive	Menstrual abnormalities, spontaneous miscarriages, and perinatal and neonatal deaths
General	Weakness in the muscles, fatigue, lack of appetite, nausea, vomiting, and fever.

Health implications on the eyes

The patients had significant ocular burning, wetness, discomfort, and photophobia within the first two months following the exposure. These results coincide with those of the clinical trials published by the ICMR in its most recent report. (Eckerman I;2004).

With the exception of a few numbers of cases where damage was done to the posterior ocular chamber and needed surgical replacement of corneal tissue, the majority of the victims' acute phase ocular symptoms appeared to have resolved.According to a comparison of the frequency of ocular symptoms in respondents living at different distances from the factory, 80 percent of subjects living at a distance of 0.5 km and 40 percent of subjects living at a distance of 8 km reported having problems. In all groups, the results of the distance vision test indicated that individuals with vision between 6/12 and 6/60 were somewhat impaired, while those with vision lower than 6/60 were more seriously affected. In neither group of patients were there any complaints about colour vision issues. All participants' ocular movements were normal.

Table 2: Clinical symptoms seen after exposure to methyl isocyanate during the chronic period (6 months and beyond)

Physiological Systems were Affected	**Clinical Signs and Symptoms**
Ocular	Damage to the posterior ocular chamber, corneal opacity, conjunctivitis, chronic lesions, and tear secretion deficit.
Respiratory	Chest discomfort, dyspnoea, wheeze, impaired lung function, obstructive and restrictive airway disorders, acute extrinsic allergic bronchi-alveolitis, cough (with or without expectoration).

Cognitive and neurological	Muscle pains, related learning, faulty standard progressive matrices, and tests for motor speed precision.
Cancer	Almost little change in oropharynx cancer cases.
Immunological	Immune system hyperresponsiveness in those exposed in utero.
Pattern of Adolescent Development	exposure-related growth retardation in male adolescents
Reproductive	reduced placental/fetal weight, increased new-born mortality, and pregnancy loss.

Implications on mental and physical health

There have been reports of substantial neurological, neurobehavioral, and psychological impacts in the Bhopal gas catastrophe survivors.The ICMR report demonstrated how anxiety and sadness were caused by psychological consequences in the exposed population.3 to 5 months after the tragedy, a randomised assessment of outpatients at eleven government-run clinics revealed that 22.6% of them had psychiatric illnesses.Similar numbers had social adjustment issues, anxiety, and neurotic depression.

According to the ICMR, neuromuscular abnormalities in the patients' limbs, such as tingling numbness, pins-and-needles sensations, and muscle pains, persisted following exposure. Inhibiting the development of muscle fibres in the culture at low concentrations and killing fibroblasts and myoblasts at higher doses are two possible explanations for these effects of MIC exposure.It was shown that out of 208 people with psychological issues, neuroses affected 45% of them, anxiety states affected 35%, and worsening of existent adjustment responses affected 9%.A few months after the accident, an observation found impairment in attention reaction time, alertness, and auditory and visual memory.Associates learning and motor speed and precision were noticeably hampered in afflicted patients in follow-up investigations after a year.Irani and Mahashurnoted notable psychiatric issues in certain youngsters older than 7 years old, including anxiety, jitteriness, despair, and verbosity. (Crabb C;2004).

Effects on Reproductive Health

Menstrual irregularities, vaginal discharge, and early menopause have become widespread issues among Bhopal MIC exposed women and their female offspring/girl children twenty years after the gas tragedy. (Gupta JP.et al;2004).Inaddition to having an impact on women's reproductive health, these situations are causing social issues in conservative neighbourhoods.Retrospective cohort studies have been used to highlight maternal-foetal, gynaecological consequences.Clinicians in Bhopal have noticed that the girls who were exposed as infants and those who were carrying them now have "menstrual chaos".A comparative study was conducted to explain the impact of exposure to the poisonous gas on pregnant women in both exposed and unexposed areas of Bhopal during the early stages of recovery.Pregnant women exposed to the hazardous gas experienced a higher rate of spontaneous miscarriages (24.2%) than those in the control (unexposed) region (5.6 percent).There were no differences in the rates of stillbirth and congenital abnormalities, two additional indicators of poor reproductive outcomes.In comparison to the control region (5.0 and 4.5 percent, respectively), the perinatal and neonatal mortalities were considerably higher in the afflicted area (6.9 and 6.1 percent, respectively).

In addition to increased menstruation abnormalities and heavy bleeding among residents who were exposed to gas, the final technical report of the ICMR also noted elevated miscarriage rates in the early years following the tragedy."Post-disaster trauma" has been linked to this trend.observed a disproportionately greater frequency of abnormal pap smears and uterine haemorrhage in exposed women 15 weeks following the exposure.In males, but not in girls, who had been exposed to MIC when they were toddlers or those born to exposed parents, there was a selective retardation, according to anthropometric research on exposed teenagers conducted nearly sixteen years after the tragedy.

Immune-toxic effects

In contrast to what was anticipated given that the poison had entered the bloodstream, no significant haematological or biochemical abnormalities were found in the Bhopal disaster population. Several studies on the survivors of the Bhopal disaster suggest long-term immunological effects, including the potential for MIC to cause hypersensitivity reactions.The two clinical results on how MIC affects immune function showed a considerable delay in the cell cycle and a reduced responsiveness to mitogen-activated stimulation of proliferating cells in vitro.Sera from 99 persons and sera from guinea pigs exposed to MIC were analysed in order to gauge the development of anti-antibodies in the exposed participants.Only eleven human individuals developed specific antibodies that belonged to the IgG, IgM, and IgE classes, compared to all guinea pigs who received reactive isocyanate injections, which produced specific antibodies in titres ranging from 1:5120 to 1:10 240.These results show that a distinct immunologic response was induced by a single massive exposure to MIC, despite the titres being modest and temporary (declining after several months).Following MIC exposure, this occurred concurrently with persistent

respiratory consequences.The Indian Toxicology Research Centre (ITRC) examined immune function in exposed individuals 2.5 months after exposure.Comparing mean immunoglobulin levels to controls, no differences were discovered.Less than half of what is typically found in the Indian population made up the T-cell population (28%) (65 percent).Comparing lymphocyte phagocytic activity to controls revealed a significant decline, pointing to a possible reduction of cell-mediated immunity by MIC.In a recent study by our team, we compared the immunological state of two groups of 50-year-old, gender-matched, unexposed individuals with that of a group of 50 young people who were exposed to MIC gas while in utero (first trimester). (Naik SR et al;1986).

Our research provided the first evidence that the Bhopal gas tragedies in utero MIC exposure resulted in afflicted people developing a chronically hyperresponsive cellular and humoral immune response.Higher levels of immunoglobulin in this cohort and enhanced cytokine release by activated lymphocytes in vitro provided evidence for this.Another notable finding was the significant incidence of anti-nuclear antibodies in the group exposed in utero.An immune system that is chronically hyperresponsive has been brought on by MIC exposure while a person is pregnant during the first trimester.

Effects of toxicity on DNA

Sister-chromatid exchanges (SCE) frequency in lymphocytes were shown to be enhanced more than three times in MIC-exposed individuals, according to a preliminary investigation by Goswami.Additionally, chromosomal breaks were found in 10 out of 14 afflicted individuals (71.4%) studied, compared to just 6 out of 28 (21.4%) controls.Even chromatin bodies were seen in some of the survivors in addition to the typical 46 chromosomes.Goswami et al. have created a chromosomal profile for 154 people they studied between 1986 and 1988 in different research.

Robertsonian translocation was often seen in the exposed participants' at least two kinds of chromosomal abnormality, particularly in the acrocentric chromosomes 13 and 21.Such findings point to possible DNA damage caused by MIC.At least 50% of the patients with such severe chromosomal anomalies are known to be at risk for developing malignancies, experiencing recurrent miscarriages, or passing on problems to their progeny. Ground-breaking research from 1990 conclusively links MIC exposure to the genetics of cancer patterns among the tragedy's gas victims.These tests, which may have helped identify persons with chromosomal abnormalities and at a high risk of getting cancer, were not carried out until the late recovery phase.

Experiment Results

Approximately 25 years have passed since the occurrence, yet additional work has to be done to thoroughly assess the hazardous consequences of MIC utilizing experimental modalities.The evaluation of exposure and toxicity is viewed as being insufficient by the scientific community at large.International organizations that support studies on the toxicogenomic consequences of MIC utilizing cutting edge technologies have made similar arguments.Since any changes at the genomic and/or epigenetic level may have long-term health effects, including accelerated aging, cancer development, immuno-compromised states, and, more importantly, vertical transmission of genetic aberrations, the significance of such experimental studies cannot be overstated.(Dhara VR et al; 2002)

Animal Research

Alveolar membrane and tracheobronchial epithelial cell "particular vulnerability" to MIC exposure has been demonstrated in animal studies.It is known that MIC is a very irritating substance that damages the lungs by causing bronchial lesions and, in extreme cases, pulmonary edoema.Overall, mice who survived the initial exposure shown amazing recovery, despite the fact that there were still lesions in the airways, including what may have been obliterative bronchiolitis.In rats, the pathogenic consequences of a single exposure to MIC and its aqueous derivatives, Methyl Amine and Di-Methyl Urea, have been investigated by Jeeva Ratnam and Sriram Chari.After 24 hours, oedematous fluid was seen filling the alveoli and the bronchial epithelium had developed eosinophilic necrosis.In an animal model of MIC exposure, Bucher et al. attempted to comprehend the pathophysiology of acute inhalation.(Acquilla SD et al;1996)

A reddish-white encrustation around the mouth and nose, a small thymus, distension of the gastrointestinal tract with gas, consolidation and haemorrhage of the lungs (middle and median lobes), and failure to deflate were some of the early gross pathologic changes. Microscopic changes in the upper respiratory tract included marked erosion and separation of olfactory and respiratory epithelia from the basement membrane with accumulation of serofibrinous fluid.The late phase is characterized by granulomatous inflammation and It was discovered that the airways had intraluminal fibrosis.Exfoliated cells, mucous plugs, and/or intraluminal fibrosis may clog lower airways.By adopting murine models, the research teams at the Industrial Toxicology Research Centre (ITRC), India, have also advanced our understanding of how MIC exposure affects the components of BALF, reproductive health, and germ cell mutagenicity.Following MIC exposure, a significant rise in the overall number of BALF cells was observed.The total protein, sialic acid, and lactic acid content of cell free BALF increased, whereas macrophages' capacity for phagocytosis reduced.In these experiments, the mutagenicity of MIC to germ cells could not be established.because it does not biodistributed well to the target areas.Animal studies have shown demonstrated toxic consequences of MIC exposure on the respiratory system.The guinea pig airway tissues' autoradiographic tests revealed that after

being exposed to 14C-labeled MIC by inhalation, the airway tissues had the highest level of radioactivity.The covalent alteration of airway macromolecules and the persistence of airway radioactivity throughout the 48-hour post-exposure period are related.Additionally, the cellular localization in the tracheobronchial area revealed dose-dependent epithelium and subepithelial deposition with label accumulation at the subepithelial region.Additionally, animal studies have shown that MIC's fetotoxicity is concentration-dependent and influences placental and fetal weights.

In vitro research

Only a few data based on conventional cytogenetic profiles of exposed people are known about the genotoxic consequences.Although these publications show a strong correlation between MIC exposure and somatic mutagenesis, the methodological quality of these few research was questionable, and as a result, they did not get the attention of the scientific community at large.Despite these drawbacks, a compelling argument can be made for thorough study and research into the long-lasting genetic consequences of MIC when the results are paired with the evidence from animal studies.Consequently, it has become required to carry out the MIC's molecular toxicological effects are investigated utilizing whole genome scanning techniques.This has been accomplished by combining both traditional and contemporary technologies, which harness the strength of cutting-edge equipment and methods.By examining the toxicogenomic potential of MIC, the Research Department at the BMHRC in Bhopal, India, has helped to further our understanding of the impacts of MIC exposure.Comprehensive research has been done on immunotoxin effects, cytotoxic effects, inflammatory responses, development of mitochondrial oxidative stress, and chromosomal and microsatellite instability. (Bucher et al ;1987).

After exposure in vitro, the genotoxic potential of MIC in cultured mammalian cells has been evaluated.Through the examination of DNA cell cycle, measurement of the cellular apoptotic index, and qualitative and quantitative measurements of the phosphorylation statuses of the ATM, H2AX, and p53 proteins, studies were conducted to better understand how cells respond to DNA damage.Methyl isocyanate has been shown to increase cell cycle arrest and death in cultured mammalian cells, suggesting that it may cause genetic changes, via adversely affecting the DNA damage response mechanism.Investigated was the induction of genomic instability in cultured human colonocytes after exposure to methyl isocyanate.Numerous treated cells displayed higher apoptotic indices, raised levels of inflammatory cytokines, and cell cycle arrest in the G2/M phase.Numerous chromosomal aberrations were discovered during cytogenetic analysis, along with aberrant pericentrin protein production. Increased microsatellite instability was discovered by ISSR PCR analysis as a result of erratic simple inter sequence repeat amplification. In order to understand how isocyanate-mediated mitochondrial oxidative stress contributes to chromosomal instability in cultured human kidney epithelial cells, research was conducted. Methyl isocyanate at a concentration of 0.005 M caused morphological changes and stress-induced senescence in the treated cells. Superoxide dismutase (SOD) and glutathione reductase (GR) depletion, an increase in DCF fluorescence indicative of oxidative stress, and steady build-up of 8-oxo-dG were seen throughout time. Thus, endogenous oxidative stress resulted p53, p21, cyclin E, and CDK2 proteins exhibit aberrant expression, which is indicative of an unbalanced cell cycle, chromosomal abnormalities, centromeric amplification, aneuploidy, and genomic instability.

It has been determined that MIC is capable of undergoing biotransformation reactions in human peripheral blood lymphocytes, causing DNA damage through phosphorylation of ATM and H2AX indicative of DSBs at damaged sites, according to an assessment of the immunotoxic response of cultured human lymphocytes isolated from healthy human volunteers.When exposed, it was found that there was a dose- and time-dependent increase in intracellular ROS generation through increased DCF fluorescence and accumulated 8-oxo-dG, as well as a simultaneous depletion in glutathione reductase, an elevated pro-inflammatory cytokine response, and ultimately an irreversible cellular death.Experiments on cultured human neutrophils derived from healthy human volunteers were carried out to clarify the consequences of isocyanates on the regulation of neutrophil activity and its influence on immune system at the molecular level.Through increased annexinV-FITC/PI and active caspase-3 staining, as well as the typical apoptotic DNA ladder assay and increased mitochondrial depolarization, it has been shown that isocyanates cause neutrophil apoptosis via activating a mitochondrial-mediated mechanism.

The generation of reactive oxygen species, a reduction in the antioxidant defence state, and an increase in pro-inflammatory cytokine response were further signs of the immunotoxic reaction of isocyanates in neutrophils.In cultured IMR-90 human lung fibroblasts, the molecular processes behind isocyanate-mediated inflammatory responses have been investigated, as has their potential significance in the development of genomic instability.Elevated expression levels of ATM, ATR, H2AX, and p53 as well as an increased apoptotic index were indicative of induced inflammation that caused significant DNA damage.Isocyanate-induced genomic instability is further demonstrated by chromosomal abnormalities in treated cells, which comprised the overexpression of centrosomal proteins and varied amplification of simple inter sequence repeats.

A Looking Head of Bhopal Gas Tragedy

Unquestionably, one of the greatest industrial catastrophes in human history was the Bhopal gas tragedy.The incident sparked interest from business, academia, and government, and it is widely regarded as one of the pivotal

moments in the development of process safety.With a gross domestic product (GDP) per capita of US$ 2900 in 2004 and an annual economic growth rate of more than 7-8 percent, India has been rapidly industrializing.Rapid industrial expansion has made a considerable economic contribution, but at a price in the form of environmental deterioration and elevated hazards to public health.A significant concern for this century will be raising awareness of potential exposures to exogenous non-biological substances resulting from human activity.Numerous considerations about health safety, the safety of future generations, difficulties with compensation and penalties, and other topics arise as a result of these exposures and their effects.

Dissecting the long-lasting effects of the disaster will be of immense value and significance when dealing with future chemical disasters, even though accidents involving MIC or an accident of similar magnitude may or may not recur in a country like ours that is rife with human, environmental, and economic perils.Despite the fact that there is global agreement that the type, extent, and suffering of the accident survivors are of the highest order, academic and industrial efforts to comprehend the persistence of long-lasting consequences are behind.The investigation into the human side of the catastrophe may have lingered, and there hasn't been any systematic planning to institutionalize investigations into the event's effects on long-term health.The length of time that gas victims would continue to have multiple system diseases and if these abnormalities would also influence their progeny are new questions that have been highlighted by the investigations thus far.If we want to comprehend the scope and severity of the disaster's long-term impacts, extensive molecular investigations of ophthalmic, respiratory, reproductive, immunological, genetic, and psychological health must be carried out.

The authors strongly emphasize the need for long-term surveillance of the afflicted community to hide the deficiencies in medical care. and employing appropriate investigative techniques, such as well-designed cohort studies for these conditions, characterizing individual exposure, and accident analysis to identify potential toxic cloud components, as the researchers have identified a number of clinical and epidemiological deficiencies, including flawed study design, bias, and incorrect exposure classification.Studies on cultured cellular model systems to understand the increasing morbidity of MIC exposure will offer a framework for understanding the potential mechanism of toxicity of a variety of other exposures and may also reveal distinctive abnormalities in the survivors, stimulating efforts to develop newer and more efficient diagnostic and therapeutic approaches for aiding the survivors. Although the disaster is extremely regrettable, it has provided a tremendous chance to learn about the negative impacts of MIC.In reality, the implications of such discoveries would help to refine threats that mankind confronts from chemicals and other environmental hazards as well as measures for the preventative management of future industrial disasters.

CONCLUSION

In the midst of the night of 3rd December 1984,40 tonnes of methyl isocyanate (MIC) which was released from the union carbide plant caused a chaotic and alarming situation in the city of Bhopal. More than 3000 deaths were reported within a week and till date more than half a million case has been encountered for non-fatal injuries and serious ailments. Though the incident is now almost 37 years old but the gruesome and scars of the incident still cripples us in the form of mutation which has been carried by the next generation from the parents.The people who have been directly exposed to the gas now inhibits fewer abnormal cells but the frequency of aberrations within these cells have increased in due course of time. Another severe affect was growth in chromosomal aberrations even in the people who were not Directly exposed or mildly exposed to the gas. The scholars explain the reason behind this as “A number of confounders, including adaptive lifestyle of the people, environmental factors, nutritional factors, hygienic drinking water, occupational exposures, and inherent genetic conditions interact.

Moreover, ceaseless contamination of soil by chemical wastes that are dumped in the site of Union Carbide India limited that might have supplemented the genetic changes through interaction with other biological and biological factors,”.Even though more than three decades have passed, there is still the question of providing rehabilitation and proper health monitoring to the children who have been born disabled due to the gas tragedy and also to the parents who live in water contaminated areas. The Chemical Industry and Government needs to properly monitor the maintenance and check-up in regular intervals of chemical technology machineries and refineries running in entire country and a setup is required from the initiative of government to clean the toxic place. It is considered as one of the most dreaded industrial disasters in the world history but the city of Bhopal is still grieving in its pain. A completely new generation born to the ones who have survived this tragedy has been afflicted and contemplated with birth defects. It would not be wrong to deduce that the surviving generation has inherited the poisoned genes of the Bhopal Gas Tragedy.

Fig.1: A Photo that depicts the tragedy and its consequences that is followed within couple of days.

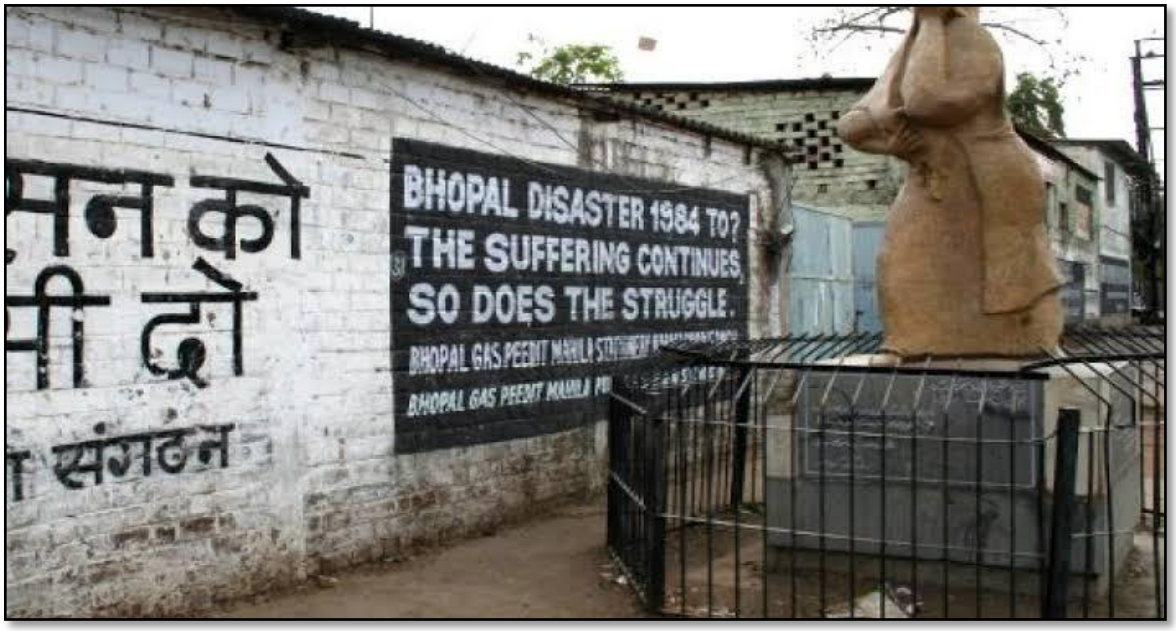

Fig. 2: A Memorial Built in remembrance of the Tragedy.

Fig. 3: The Tragedy cause loss of 8000 lives within Two weeks

Fig. 4: A Photo that shows that Industrial waste is still not cleaned up even after 37 years of the Tragedy.

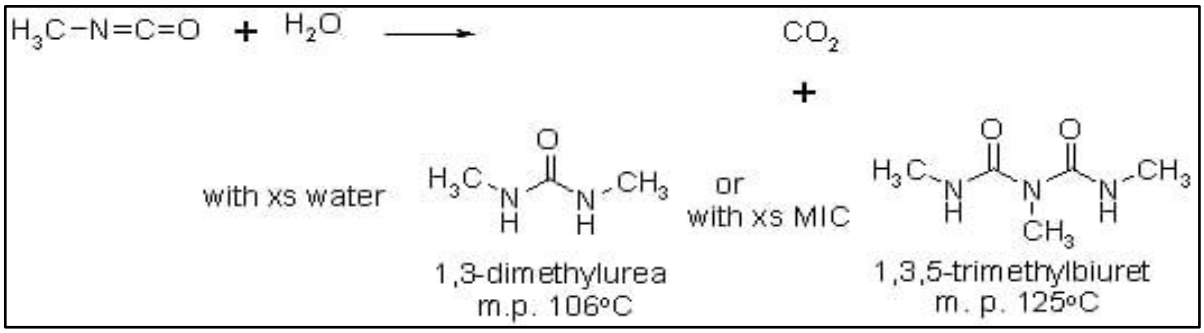

Fig. 5: Reaction that took place inside the reactor.

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Conflict of Interest
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