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The Bhopal Gas Disaster a Case of WRONG Management and Engineering DECISIONS!!!

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ABSTRACT:

The Indian government, although keen to attract foreign investment through the new initiative of make in INDIA, needed to make a decision on the basic safety requirements for its citizens. During future Multi National Corporations (MNC) projects, designs of installations need to be peer reviewed and more stringent environmental, health and safety considerations should be adopted. During any future plant builds, standards of materials and equipment used should reflect those used in Western countries. MNC need to be aware that reduction in safety standards as a means of improving profit margins is not an option such as the disaster at Bhopal. The Bhopal Gas Disaster, of 2nd-3rd December, 1984, caused by a "run-away chemical reaction" of Methyl IsoCyanate stored in a Stainless Steel Tank, of UCIL (Union Carbide of India Ltd) Factory, is undoubtedly the worst chemical disaster of the world. The sheer magnitude of the industrial catastrophe has aroused the conscience of the world. The physicochemical properties of the deadly methyl isocyanate (MIC) and its biological activity, and probable causes of accident, are discussed.

The role of management and engineering decisions with regard to the dispersion process is also documented. The Mechanical and Human both errors considered in these study. What is good for engineering is not always good for the management. For the people, and for public health, it is good with small income differences, strong working rights legislation, protection of water and ground, manpower-rich companies and the making of strong demands on the company concerning the work environment and the environment as a whole. Computer generation of mathematical models allows predictions concerning the effects of various variables on possible system scenarios. After these observations, qualitative risk analysis

could be performed upon the scenarios to learn how to handle new, similar situations that might occur in the chemical process industry. Recommendations regarding emergency and contingency planning are then provided, and that governments need to be aware of the requirement for segregation of hazardous operations from facilities and adjacent domestic populations. The Bhopal disaster has at least spurred some state pollution control boards taking actions, against the country's blue chip companies of gross environmental negligence and unsafe practices of engineering, managements and profit making.

KEY WORDS:- *MIC, UCC, UCIL, W. Anderson, GAS disaster, Exothermic Reactions & Pesticides.*

I INTRODUCTION

In the 1970's, the crops in India were being destroyed by insects, increasing the hunger and poverty of millions of peasants dependent upon the yield of their crops for both income and personal sustenance. The government of India, seeking to increase the industrial capacity of the country, agreed to license the American company, Union Carbide Corporation (UCC), to manufacture its insecticide Sevin in India. Union Carbide India Limited (UCIL) was incorporated in India in 1934. In 1969, the Bhopal Plant begun operations as a pesticide formulations plant on land leased from the Indian State of Madhya Pradesh. As a formulations plant, UCIL imported the chemical components of pesticide products and mixed the final product, such as the "Sevin" pesticide, in India. At that time, UCC owned 60% of UCIL. In the latter half of the 1970s, the Bhopal Plant was back-integrated into a facility capable of manufacturing the pesticides itself; in connection with this project, UCC's (Union Carbide Company) ownership interest in UCIL was reduced to 50.9%. Union Carbide's coming to Bhopal was welcomed by all, because it meant jobs and money for Bhopal, and savings in foreign exchange for the country, with the rising demand for pesticides after the Green Revolution. Pesticide formulation developed into pesticide manufacture and in 1983, the company's licensed capacity stood at 5,250 tonne (t) of MIC-based pesticides, 200 t of methabenzthiazuran, and 50 t of propoxur, however it never worked to its CAPCITY, and had always some problems.

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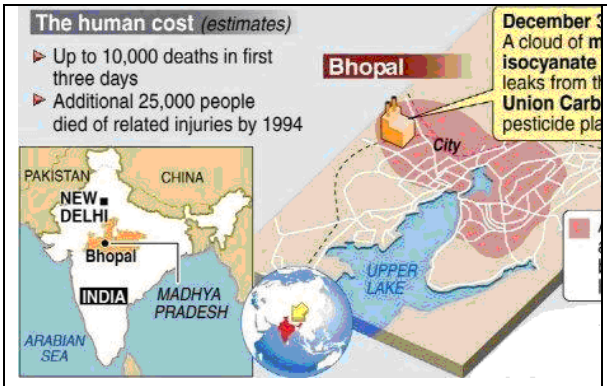


Fig. 1: The GPS location of Bhopal Gas Disaster.

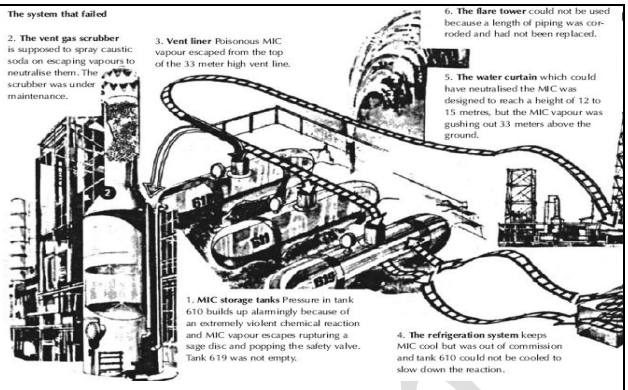
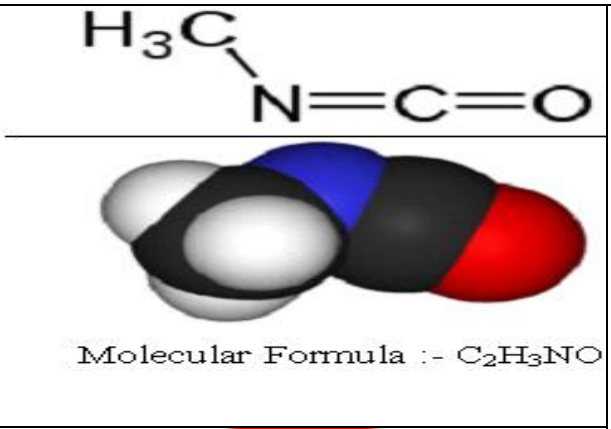
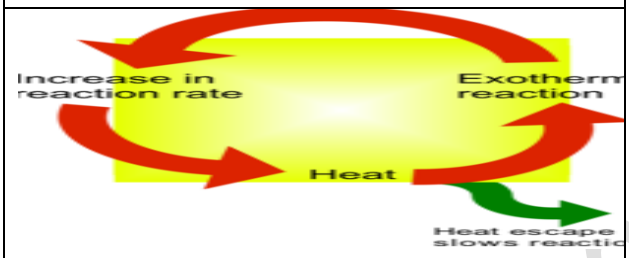


Fig. 2: Engineering System which was failed.

The Bhopal gas tragedy is one of the worst industrial air pollution disasters that has ever occurred in the world. The countdown for the disaster started around 00:30 IST (Indian Standard Time) when untreated vapors of methyl isocyanate (MIC) were seen escaping through a nozzle of 33 m high atmospheric vent-line, from the Union Carbide (UC) plant located at Bhopal (India), in the early hours of Monday~ 3 December 1984. During the night Dec 2-3, 1984, large amounts of water entered a tank containing 43 tonnes of Methyl isocyanate (MIC) in Union Carbide's plant in Bhopal, India. A strong chemical reaction started and a big cloud of toxic gases spread over the sleeping town. 500,000 people were exposed to the gases. 8,000 died within the first week, and 8,000 since. 100,000 have permanent injuries[1]. Today, Dow Chemical has taken over Union Carbide Corporation. The survivors fight for their right to full economic compensation and medical care. Together with other residents, they fight for Dow and the Government of India to clean up the polluted area and the ground water. Fig. (1) Shows the Global Positioning of the Bhopal City with the details of the disaster and Fig. (2) Shows basic locations of all the production, storage and distribution unit operations. The cloud of gas dispersed across the plant grounds and, by morning the toxic fog enveloped most of the area in and around Bhopal. **Methyl isocyanate** (**MIC**) is an organic compound with the molecular formula CH_3NCO. Synonyms are isocyanatomethane, methyl carbylamine, and MIC. Methyl isocyanate, as shown in Fig. (3), is an intermediate chemical in the production of carbamatepesticides pesticides (such as carbaryl, carbofuran, methomyl, and aldicarb). It has also been used in the production of

rubbers and adhesives. As a highly toxic and irritating material, it is extremely hazardous to human health.





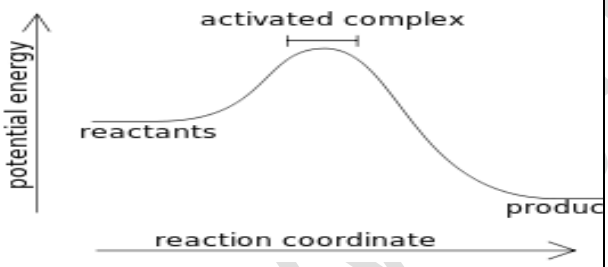


Fig. : [3]:-Exothermic reaction of Methyl Isocynate

And the Energy profils.

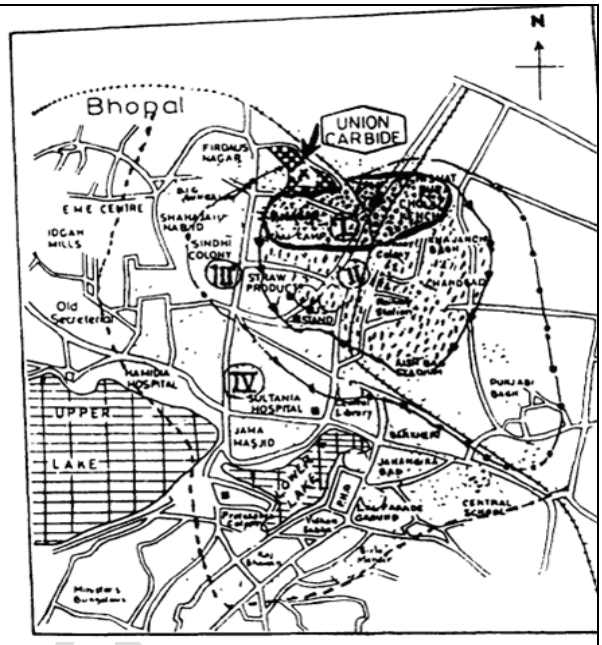


Fig. [4]: The gas affected areas determined on the basis of mortahty state stacs are indicated by dots and the concentration of dots approximately represents the extent of the effect. Contours in & cate the parts per million isopleths are classified as follows: Zone I, 50 ppm; Zone II, 15 ppm, Zone III, 1.5 ppm and Zone IV, < 1 0 ppm.

It was the principal toxicant involved in the Bhopal disaster, which killed nearly 8,000 people initially and approximately 20,000 to 30,000 people in total. Methyl isocyanate (MIC) is extremely toxic as represented in Fig. (4). The threshold limit value set by the American Conference on Government Industrial Hygienists is 0.02 ppm[2]. MIC is toxic by inhalation, ingestion and contact in quantities as low as 0.4 ppm. Exposure symptoms includes coughing,

chest pain, dyspnea, asthma, irritation of the eyes, nose and throat, as well as skin damage. Higher levels of exposure, over 21 ppm, can result in pulmonary or lung edema, emphysema and hemorrhages, bronchialpneumonia and death. Although the odor of methyl isocyanate cannot be detected at 5 ppm by most people, its potentlachrymal properties provide an excellent warning of its presence (at a concentration of 2–4 parts per million (ppm) subject's eyes are irritated, while at 21 ppm, subjects could not tolerate the presence of methyl isocyanate in air), all are represented in the Figure [4].

II METHODOLOGY

An introduction to a process to support decision making for engineering design problems, the Systems Engineering and Management Process (SEMP)[8]. The SEMP has a four phase process that begins with an understanding of the current situation and ends with the implementation of an engineering design to meet the desired end state. The phases are Problem Definition, Design and Analysis, Decision Making, and Implementation. Within each of these phases, there are a number of tasks as depicted in Figure [5]. The process is iterative and involves assessment and feedback. Six environmental factors (cultural, historical, technological, historical, political, and moral/ethical) were included in the SEMP to emphasize that systems engineering must explicitly consider the future environment of the system. McCarthy selected the colors to have a clear problem solving meaning: red for stop until you fully define the problem, yellow for caution to not take the first feasible solution you find, green for the green light you hope to receive from the decision maker, and blue for the blue skies and smooth sailing you hope to have in implementation. . The new process could be named as the Systems Decision Process, Figure [6] to emphasize the problem solving focus of the department and avoid confusion with the system life cycle. Focusing on the decision maker and stakeholder value. Stakeholders and decision makers identify important functions, objectives, requirements, constraints, and screening criteria that are essential for systems decision making. Explicitly considering the environment (historical, legal, social, cultural, technological, environmental, and economic) that systems will operate within and the political, organizational, moral/ethical, and emotional issues that arise with stakeholder and decision makers in the environment. Between 1980 and 1984, the plants workforce was reduced by half with no clear investment in technology to warrant this

reduction. The basic operation of the plant was further compromised by management decisions to operate the plant either outside its designed operating parameters or to implement revised processes to ensure continued production while essential components of system had known defects which had potential to impact on safety integrity of the plant[3].

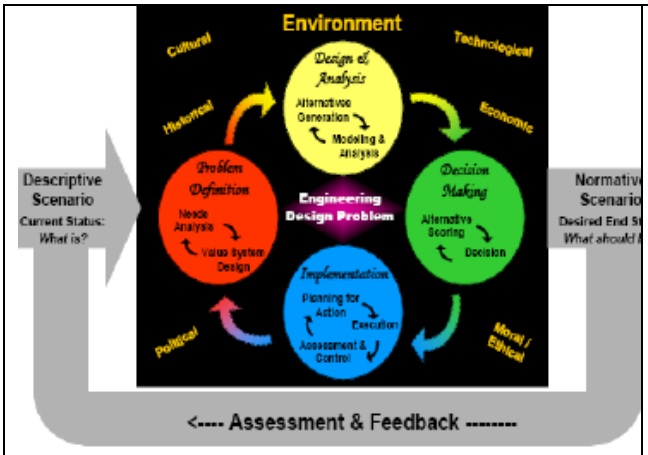


Fig. [5]:- Systems Engg. & Management Process.

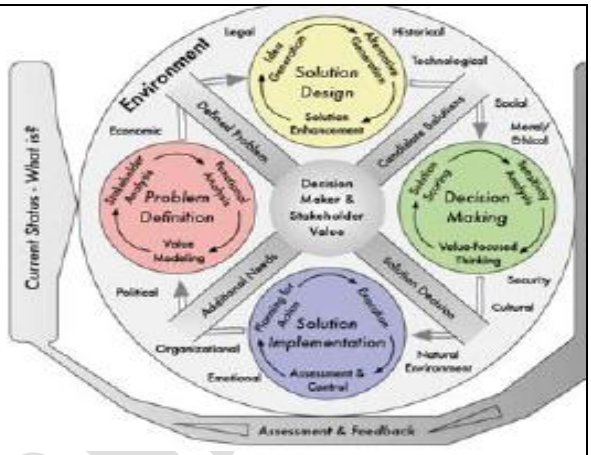


Figure [6] :-Systems Decision Process.

III DIRECT CAUSES OF THE ACCIDENT

The gas cloud, The gases were blown in southeastern direction over Bhopal. As of 2008, UCC had not released information about the possible composition of the cloud. Apart from MIC, the gas cloud may have contained phosgene, hydrogen cyanide, carbon monoxide, hydrogen chloride, oxides of nitrogen, mono-methyl amine (MMA) and carbon dioxide, either produced in the storage tank or in the atmosphere. As the gas cloud was composed mainly of materials denser than surrounding air, it stayed close to ground and spread outwards through surrounding community. **Thermal runaway** by definition the enthalpy change has a negative value: $\Delta H < 0$ in an exothermic reaction, gives a negative value for ΔH, since a larger value (the energy released in the reaction) is subtracted from a smaller value (the energy used for the reaction). For example, when hydrogen burns: $2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g)$, $\Delta H = -483.6$ kJ/mol of O_2. An **exothermic reaction** is a chemical reaction that

releases energy in the form of light or heat. It is the opposite of an endothermic reaction. Expressed in a chemical equation: reactants → products + energy.

Sodium methoxide, triethyl phosphine, ferric chloride and certain other metal compounds catalyze the formation of the MIC-trimer, while the high-molecular-weight polymer formation is catalyzed by certain trialkylamines. Since the formation of the MIC trimer is exothermic (298 calories per gram of MIC), the reaction can lead to violent boiling of the MIC. The high-molecular-weight polymer hydrolyzes in hot water to form the trimethyl isocyanurate. Since catalytic metal salts can be formed from impurities in commercial grade MIC and steel, this product must not be stored in steel drums or tanks[7]. The MIC must be stored at temperatures below 40°C (104°F) and preferably at 4^0 (39^0F). The toxic effect of the compound was apparent in the Bhopal disaster, when around 42,000 kilograms (93,000 lb) of methyl isocyanate and other gases were released from the underground reservoirs of Union Carbide India Limited (UCIL) factory, detailed chemicals was present at time of disaster is listed in Table [1].

Table (1) :- Chemicals dumped by Union Carbide management in and around the factory from 1969 to 1984.

S.No.	Chemicals	Amount	Use in	Pollution
1.	Methylene Chloride	100 MT	Solvent	Air
2.	Methanol	50 MT	Solvent	Air
3.	Ortho-idichlorobenzene	500 MT	Solvent	Air, Water, Soil
4.	Carbon tetrachloride	500 MT	Solvent	Air
5.	Chloroform	300 MT	Solvent	Air
6.	Tri methylamine	50 MT	Catalyst	Air
7.	Chloro benzyl chloride	10 MT	Ingredient	Air, Water, Soil
8.	Mono chloro toluene	10 MT	Ingredient	Air, Water, Soil
9.	Toluene	20 MT	Ingredient	Air, Water, Soil
10.	Aldicarb	2 MT	Product	Air, Water, Soil
11.	Carbaryl	50 MT	Product	Air, Water, Soil
12	Benzene Hexachloride	5 MT	Ingredient	Air, Water, Soil

13	Mercury	1 MT		Water, Soil
14	Mono methyl amine	25 MT	Ingredient	Air
15	Chlorine	20 MT	Ingredient	Air
16	Phosgene	5 MT	Ingredient	Air
17	Hydro chloric acid	50 MT	Ingredient	Air, Soil
18	Chloro sulphonic acid	50 MT	Ingredient	Air, Soil
19	Alpha Naphthol *	50 MT	Ingredient	Air, Soil
20	Napthalin	50 MT	Ingredient	Air
21	Chemical waste Tar	50 MT	Waste	Water, Soil
22	Methyl Isocyanate	5 MT	Ingredient	Air, Water, Soil

IV DISCUSSION

UCIL had allowed safety standards and maintenance at the plant to deteriorate to cataclysmic levels even though the potential for such an incident had been highlighted two years prior in a UC internal report. Clearly UCIL had dropped the operating and safety standards of the Bhopal facility well below those maintained in the near identical facility in West Virginia. The fact that UCIL was able to do this was due in part to lacking safety and environmental laws and regulations which were not enforced by the Indian government. Immediately after the disaster in India, UC, while maintaining no knowledge of the cause of the accident in India, shut down the MIC plant in West Virginia to allow five million dollars worth of changes to its safety devices to be accomplished.

GOVERNMENT / MANAGEMENT DECISIONS:

- The Government of India passed Bhopal Gas Leak Disaster ACT that gave the government rights to represent all victims in or outside India.
- UCC offered US $350 million the insurance sum. The Government of India claimed US$3.3 billion from UCC.
- In, 1989, a settlement was reached under which UCC agreed to pay US$470million (the Insurance sum plus interest) in full and final settlement of its CIVIL & CRIMINAL liability. Both US & INDIAN Government said nothing on law suite.

- As the UCC CEO, Anderson was charged with manslaughter by Indian authorities.
- The chief judicial magistrate of Bhopal, Prakash Mohan Tiwari, issued an arrest warrant for Anderson on July 31, 2009.
- The Congress Government sent safely Mr. Warren Anderson the CEO of UCIL at the time of massacre in 1984, to US who passed away on 29th September, 2014, at his home town Berkeley, US, just close date of 30th. ANNUSSARY of disaster.
- Mr. Anderson ruled over an empire with 700 plants in more than three dozen countries. Lack of evidence held up Anderson extradition: MEA Anderson died on September 29, 2014. He was 92, there never was any intention of any Indian government to get him back to India to stand trial and prosecute him for his crime, he did not commit.[4]
- Indian Government closed plant to outsiders and failed in making the DATA public.
- The Council of Scientific and Industrial Research (CSIR) were forbidden to publish their data on health effects until after 1994.
- The Indian Government and UCC deny permanent injuries were caused by MIC.
- When UCC wanted to sell its SHARES in UCIL, it was directed by SUPREME COURT to finance a 500 bed hospital for the medical care of the survivors.
- Bhopal Memorial Hospital and Research Centre (BMHRC) was inaugurated in 1998. It was obliged to give free care for survivors for eight years.
- US Court rejected the LAW suit blaming UCC for causing soil and water pollution around the site of the plant and ruled that responsibility for remedial measures or related claims rested with STATE Government and not with UCC.
- Civil and Criminal cases are still pending in United States District Court, Manhattan, and the District Court of Bhopal, India. Involving UCC, UCIL, employees and Mr. Warren Anderson.
- In August 2009, a UCC spokesperson said Union Carbide had no role in operating the plant at the time as the factory was owned, managed and operated by employees of Union Carbide India Limited. Eight former senior employees of the subsidiary were found guilty on June 7, 2010. After these convictions, a UCC spokesperson said, "All the appropriate people from UCIL officers and those who actually ran the plant on a daily basis – have appeared to face charges.

- UCC has tried every gimmick to pass on the buck. It has blamed its local subsidiary, the Bhopal plant's workers, and has even tried to suggest sabotage. However, when asked by a US Congressional panel, chairperson Warren Anderson, admitted in past that he had "no evidence whatsoever that sabotage was behind" the Bhopal disaster of 1984., and so on[6]……

TECHNICAL / ENGINEERING

- The steam boiler intended to clean the pipes was out of action for unknown reasons.
- Carbon Steel valves were used at the factory, even though they corrode when exposed to acids.
- According to the operation the MIC tank pressure gauge had been malfunctioning for roughly a week.
- UCC admitted in their own investigation report that most of the SAFETY Systems were not functioning on the night of December 2, 1984.
- UCIL didn't maintained SAFETY rules contributed to negligence as;
- The MIC tank alarms system did not worked for last four years before the incident.
- The FLARE tower and the VENT gas scrubber had been out of service for five months before disaster.
- To reduce energy costs, the refrigeration system was idle.
- The MIC was kept at 20 degrees Celsius not the 4.5 degrees advised by the OERATION manuals.
- It resulted in EXOTHERMIC reaction and finally to a explosion.

LOCAL AUTHORITY of BHOPAL / MANAGEMENT

The DATA sheets or LOG sheets, which need to be signed by OPERATOR & ENGINEER each shift, which indicates the pipeshop foreman has his men part the piping at the indicated locations. During each shift operator must inspect and report any repairs or renewals needed immediately.[10] Importantly, process operations such as steaming and washing are need to be completed and signed, with continuous inspection with record aids inspections scheduling. Generally, the scheduling board keeps track records of all the employees.

1. Use of a more dangerous pesticide manufacturing method for decreasing generation cost.
2. Plant location close to a DENSELY POPULATED area of Bhopal City (Capital of Madhya Pradesh).
3. Lack of SKILLED and trained Operators.
4. Reduction or no SAFETY management.
5. Insufficient or no maintenance.
6. Inadequate or no emergency action plan.

AFTER DISASTER NO EMERGENCY MANAGEMENT

- Medical staffs were un-prepared for the thousands of casualties.
- Doctors and Hospitals were not informed of proper treatment methods for MIC gas inhalations. They were told to simply give cough medicine and eye drops to the patients.
- The gases immediately caused visible damage to the trees, within a few days all the leaves fell off.
- Over 2,000 bloated animal carcasses had to be disposed of from and near the plant's compound.
- Operation FAITH, on December 16, the tanks 611 and 619 were emptied of the remaining MIC. This led to a second mass evacuation from Bhopal.
- UCC was also guilty of prolonging the agronomic engineer, who was with UCC entrusted responsibility of US & INDIAN technology, just can't go wrong, we just can't have such leaks.
- MANAGERS either took no DECISIONS or took the WRONG DECISION.

V CONCLUSIONS

The MIC in the storage tank therefore was warmer than allowed by the plant's operating manual. "The refrigeration unit had been down over five months," With the refrigeration unit out, it was crucial that instruments designed to measure the temperature and pressure of the gas in the storage tank be in good operating order. But the Temperature Indicator Alarm had been giving faulty readings for years. The Pressure Indicator Control was similarly faulty.

The plant also had an emergency scrubber system to neutralize gas in the event of a leak. But the scrubber system had been out of use for six weeks. The leak was apparently triggered when an untrained worker attempted to wash a pipe that was not sealed. It was the mixture of water and gas that triggered the chemical reaction and caused the gas leak. "Everything that could possibly go wrong had gone wrong," said Bruce Agnew, editor of *Safety and Risk Management*, the magazine of the British Safety Council. "Machinery failed; workers panicked; managers either took no decisions or took the wrong decisions[5]."

The economic, engineering and managemental errors attributated to the root causes of the Bhopal disaster of the 2nd and 3rd of December 1984. In particular, the technical causes of the failure from a design and operational perspective are described above in methodologies. Lessons we learned form Bhopal Tragedy; (1) Reduce inventory of hazardous material (MIC), (2) Keep all the safety related equipment in order (3) Keep residential areas away from the plant, (4) Proper Management. The Logical Framework Approach (LFA) seems more complete and useful for a complex situation like the Bhopal gas leak. The problem and objectives trees look like a chain of events from where there are branches, roots, mainly bad management practices and wrong engineering decisions. The Bhopal gas leak clearly illustrates the threat to public health posed by the chemical industry: (a) A hazardous work environment. (b) The risk of exposure for the host population. (c) Direct damage to the environment during the production process, which creates hazards to human health. (d) Production of substances, in this case pesticides, that are toxic to human beings when used, and are the cause of many deaths in large parts of the world. (e) Production of substances that have long-term toxic effects on the environment, and which may lead to contaminated food and water as well as to decreased food production in long run[9]. The newer system would limit human error not by eliminating the human component from the system, but by designing the system to be user friendly and user active. Participants in the human component would be less in number but greater in knowledge, ability, and activity.

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