UNIT 7  INDUSTRIAL AND TECHNOLOGICAL DISASTERS

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7.0 OBJECTIVES

After studying this unit, you should be able to:

• understand the subtle difference between industrial and technological disasters;
• learn about the types of industrial and technological disasters and their special features;
• highlight the case of Bhopal Gas Leak disaster; and
• discuss chemical and biological warfare disasters.

7.1 INTRODUCTION

The industrial and technological hazards do not have a very well defined definition. In general, both these types are the result from accident, failure, mishap or misuse of some kind of technology. The disaster may be brought about by causes like leakage, spills, radiation fallout, explosions and fires, structural failure and transportation mishaps. All the technological innovations have certain amount of risks and very well defined benefits, as the use of the available technologies in appropriate manner make life easier and enjoyable. For example, the transportation sector is serving the mankind in a big way through comfortable and short duration journeys for long distances; at the same time the accidents involved in this sector cannot be ruled out. The major reason behind the large number of accidents is either machine fault or the failure of human beings in one form or the other. The case is almost similar with all disasters involving usage of technology which is getting more and more complex.

However, for the sake of convenience in study, industrial hazards cover the on-side and off-side disasters emanating from large installations or undertakings. All other hazardous events occurring at public places or private premises while using or transporting technical devices or methodology are grouped as technological disasters.
7.2 SPECIAL FEATURES OF INDUSTRIAL AND TECHNOLOGICAL DISASTERS

Industrial and technological disasters are characterised by the following special features:

**Predictability:** Industrial and technological disasters have no predictability as such because of the inherent nature of the causes indicated under introduction above. In case of the machines and equipment, there is a concept of "mean time between failures (MTBF)" but it is not necessary that every mechanical or equipment failure will lead to a disaster. In fact, the technological and industrial systems are designed to shut off partially or totally once there is a sub-system failure. In major industries or technological installations, there are more than one safety systems. But disasters do occur due to a combination of technical circumstances or due to human fatigue or failure. In any case, there is no usable concept of predictability in industrial and technological disasters.

**Contributory Factors:** Most of the industrial and technological disasters are attributable to human error (due to erroneous judgment or operator fatigue or negligence in operation and/or maintenance) or due to system failure (malfunction of equipment or machine or structural failure). The probability of their occurrence is not predictable as explained above. However, there are factors that aggravate the chance of occurrence.

These are:

- Lack of proper maintenance of the installations
- Lack of adequate training of operational and maintenance staff
- Lack of awareness of the serious consequences of negligence
- Lack of safety rehearsals
- Fatigue of overworked staff
- Deactivation of safety systems for repair or maintenance without alternate safety cover
- Sabotage from within or outside

Hence eternal vigilance is the key to reduce the chances of occurrence of industrial and technological disasters.

**Typical Adverse Effects**

Industrial and technological disasters lead to adverse effects that are typically spread over a smaller area as compared to natural disasters but the resultant human misery and economic loss are sometimes more colossal and cruel. The common adverse effects are:

(i) **Physical damage** which may extend to neighbouring areas
(ii) **Large number of casualties** involving deaths and serious injuries requiring urgent medical attention on a large scale
(iii) **Trapped persons** requiring special techniques and equipment for retrieval and treatment
(iv) Environmental degradation of air, water and land which sometimes may take years to be rectified and may therefore, necessitate relocation of the population
(v) **Loss of employment** of not only the involved persons but also of the affected area at large.
Increased Understanding of Disasters - II

Immediate Post-disaster Requirements

Industrial and technological disasters occur without any notice and the disaster management system has to be brought into action as early as practicable. Therefore, the first and foremost requirement is that the incident should be brought to the notice of the local and district authorities (Civil and Police) immediately by the fastest communication methods available. Simultaneously, fire fighting has to commence because most of the industrial and technological disasters result in fire. However, these being different from normal household or building fires, need special equipment and fire-retardant material depending on the causes and nature of the fire. In most cases of fires resulting from industrial and technological disasters, the fire personnel need to wear special protective gear and masks.

Search and rescue, medical attention including trauma care and evacuation become essential immediately.

Industrial and technological disasters need a thorough clean up mission to retrieve and salvage as much as possible and to arrest the spread of adverse environmental effects.

7.3 THE INDUSTRIAL HAZARDS

The accidents in various types of industries like manufacturing, power production etc. and in storage and transportation of various hazardous materials used in these industries fall under this category. The risk involved under this category is defined as the chances of death or injury per person per number of hours exposed.

The major disaster threats have emerged in the chemical and nuclear industries. The manufacturing, processing, transportation, distribution/storage and the application/use of many products of these two areas are hazardous. The following paragraphs highlight some aspects under these two major groups.

7.3.1 The Chemical Hazards

The chemical industry is massive throughout the globe, manufacturing a huge quantity of chemicals annually. At present four and a half million chemicals are registered with the ‘Chemical Abstracts’, and thousands of new chemicals are created every year. The creation of new chemicals becomes imminent for higher standards of every day life. The advances in this particular industry are due to substantial demand. In our country, the chemical industry is about US$20 billion-a-year industry. The chemical industry faces multiple risks involved with production, transportation, storage, usage and disposing off the effluents containing residual chemicals.

The studies conducted on the chemical disasters show that the incidence of chemical emergencies and disasters are on increase throughout the world. Even the risks involved within these types of industries are higher due to the involvement of larger amounts of materials involved. For example, the tonnage carrying capacity of the sea going petrochemical tankers increased seven times during the period 1960-1980. Similarly, trucks carrying chemicals, even petrochemicals, have increased along with the higher carrying capacity. Thus, the risk involved in the increased capacity is automatically higher.

From the technological hazards points of view, 1984 was the worst year, where three major disasters took place in the world. In these three disasters, about 3,500 people died. These disasters were:
7.3.2 The Nuclear Hazards

The nuclear power industry was developed because initially, it seemed to offer a relatively dependable and inexpensive source of energy. The history of nuclear industrial development is about half a century old. After a few accidents in this industry like Chernobyl (former USSR), the industry is being considered as a major hazardous one. Majority of developing countries including India are using nuclear power increasingly to get rid of continuously increasing need of imported sources of energy. According to the International Atomic Energy Agency (IAEA), developing country’s present share of world’s installed nuclear power plants is about 7.0%. A total of 21 developing countries either have nuclear power plants in operation or have the plants in construction or planning stage. This number will be increasing in future. As per the estimates of IAEA, nuclear energy production is growing at an average of 2.8 to 3.9 percent per year worldwide in the period of 1989-2005.

Besides, the in-plant ‘nuclear plant’ problems, risks are associated with the transportation and disposal of nuclear wastes over long distances including other increasing byproducts of the nuclear plant processes.

7.4 TRANSPORTATION ACCIDENTS

As mentioned in the preceding section, transportation is very much involved in industrial and technological activity. Therefore, transportation accidents constitute a special category of industrial and technological disasters. The accidents in various modes of transport like roadways, airways, railways and seaways fall under this category. The risk involved under this category is defined as the chances of death, or injury per kilometer travelled.

The public transport systems in present times are much safer in comparison to few decades ago. The innovation in the safety systems have reduced the chances of occurrences of disasters considerably. With all available sources, the number of deaths in the transportation sector are on the rise due to increased number of travellers and enhanced travelling distances. The mobility at present is very high due to increased businesses and higher tourist activities throughout the globe. The transport related risk is also high due to higher occupancy of the vehicles used for travelling by air, rail or road ways. Even a majority of passenger vehicles have large capacity to accommodate the large number of passengers. Thus any accident results in more deaths or injuries. One example of this type of disaster is the mid· air collision over Charkhi Dadri near Delhi in November,1996.

Mid-air Collision between Saudi-Kazakh Aeroplanes:

On November 12, 1996 around 6.40 P.M. two planes owned by Kazakh Airlines(KZA 1907) and Saudi Airways (SVA 763) collided in the air near Charkhi Dadri, 80 Km north-west of Delhi. The following is the fact sheet of the disaster:
The chronology of the events leading to the disaster can be summarised as follows:

- Saudi Airlines flight took off from the Indira Gandhi International Airport at Delhi at 6:33 P.M. for Dahran and Jeddah, with 312 persons on board. The Air Traffic Controller at Delhi airport tells the pilot to climb to a height of 14000 ft. and standby.

- At the same time, a Kazakh Airlines plane coming to New Delhi with 39 persons on board is cleared to descend to 5,000 ft. by the Air Traffic Controller.

- Both the pilots confirmed the stipulated heights as given by the Air Traffic Controller. Within a minute, the radar in the control room had two blips on screen, indicating two planes approaching each other and merge with each other. The blips disappeared from the screen just after merger.

- A US plane saw the bright glow in the sky and two fire balls falling down to the ground.

- As the debris was spread over five Km radius area, without proper road connection, it took about 2 hours by the local authorities, to reach the debris site.

- The local people started the rescue and search operation immediately after the disaster.

- There was no survivor.

- The cause was faulty equipment in aircraft and pilot error.

Check Your Progress 1

Note:  
i) Use the space given below for your answers.  
ii) Check your answers with those given at the end of the Unit.

1) What do you understand by industrial and technological disasters?
1.2) What are the various types of industrial hazards?

3) Describe any disaster related to transportation sector.

7.5 INDUSTRIAL DISASTERS: A CASE STUDY OF BHOPAL GAS LEAK DISASTER

One of the most disastrous events since the history of chemical industry occurred in Bhopal, the capital city of Madhya Pradesh, on the night of December 02, 1984, in the factory of Union Carbide of India Ltd. (UCIL) due to leakage of Methyl Iso Cynate (MIC) gas. UCIL, a subsidiary of the multi national company Union Carbide Corporation (USA) was in the business of manufacturing agricultural pesticides among other things. MIC was required in these manufacturing activities and was therefore, manufactured and stored at the UCIL plant in Bhopal.

Characteristics of MIC

MIC has very special characteristics which make the chemical very hazardous. Some of the properties of the MIC are:

- It is extremely volatile and vaporises very easily
- It can boil at a temperature of 38 degrees C, so it is very important to be kept cool.
- It is chemically very active and reacts violently with water.
- It is highly toxic, it is about 100 times lethal than cyanide gas.
- It is heavier than atmospheric air, it stays near the ground after release.

The Disaster

During the night of December 2-3, 1984, about 45 tonnes of MIC (Methyl Iso Cynate) gas leaked from the UCIL (Union Carbide of India Ltd.) plant at Bhopal. MIC was stored in the underground tanks, which became contaminated with water. The contamination produced chemical reaction, followed by a rise in gas pressure and a subsequent leak. The chronology of the events leading to one of the most disastrous events in the history of chemical industry is as follows:
Chronology of the Event

- December 2, 1984, was a routine day at the UCIL factory in Bhopal.
- MIC was stored in an underground tank. The pipeline washing started at 9:30 p.m. as a routine maintenance operation.
- Between 10:30 – 11:00 p.m.: workers engaged in pipeline washing became aware of a leak. Little attention was however paid considering it a normal leak. A casual attempt was made to trace the source of leakage, but of no use. The leak continued.
- Around 12:15 – 12:30 a.m.: The pressure in the MIC tank climbed up to 55 pounds per square inch (which was the maximum the gauge could read). The temperature had also shot up to 200 degree C and was increasing. An operator saw that the concrete above the tank was cracking. About 12:30 a.m., the relief valve of the tank gave away and large quantities of MIC gas leaked into the atmosphere.
- The workers at the factory realised the risk of a massive disaster. They tried to activate the safety systems available at the factory at about 12:30 a.m. The three safety systems available within the factory and their condition at that time were as under:
  - Turning on the flare tower to burn off toxic gas. This system was not in working condition as a piece of pipeline leading to the tower had been removed for maintenance.
  - Using the vent gas scrubber, which was considered the main line of defence. It was also not in an operational condition.
  - Transferring the MIC from the tank into a nearby spare tank. The gauge of the spare tank indicated that the tank already contained something. This gauge indicator was found defective, later on.

After failure in all the three safety systems, the workers attempted to douse the leaking gas with water spray. The water spray reached a height of 100 ft. from the ground, while the leak was at 120 ft. above the ground. At 1.00 a.m., realising that nothing could be done to stop the leak, the workers at the plant fled.

- At about 1.00 a.m. thousands of people living around the plant were awakened by the suffocating, burning effects of the gas. As on three sides, the UCIL plant was surrounded by slums and other poor settlements, the people living in these colonies were the worst sufferers.
- There was no warning or guidance to the general public around this time. There were two types of alarms in the factory, one mild siren for workers and one loud public siren. The public siren was started only at about 2:30 a.m.
- About 2.00 a.m., a large number of people were rushing out of the town through the highways leaving Bhopal. The mad rush on the main roads of the city resulted in stampedes. About two lakh people had fled the city by 3:30 a.m. The gas clouds dissipated around 3:30 a.m.
- By 4:00 a.m. hospitals were crowded with suffering people.

In the wake of the tragic disaster, a large number of people lost their lives and received injuries, many to their lungs and eyes. According to the Government reports, 1754 persons had died and 200,000 were injured.

Removal of dead bodies of livestock

The real problem was the removal of dead bodies of livestock, which was still littered on the streets and houses of the affected areas. About 20 dumpers and six
Emergency Response and Relief Operations

The preparation for coping with a major accident of unprecedented dimensions affecting the surrounding communities like this one was minimal. After the event the immediate response was chaotic and inadequate. Information regarding the gas release was late and incomplete. The police and medical services were unaware initially that there had been a release of MIC gas. No one knew about the adverse effects of the gas release and the treatment methods of the affected persons.

For the relief purposes of the affected persons a relief commission was created directly under the Chief Minister. Two additional collectors were made in charge of relief and rehabilitation respectively. The main duties of the additional collectors included the proper field work coordination and to ensure the implementation of administrative directives. Various gas affected localities were divided into seven administrative zones. Each zone was under the administrative control of a deputy collector.

The next of kin of the dead persons were paid immediate ex-gratia compensation of Rs. 10,000. The poor families in the gas affected wards were paid an ex-gratia of Rs. 1500. Wheat and rice were distributed free in the affected localities. The local administration faced problems in the absence of reliable socio-economic surveys which made the identification of poor families very difficult.

The gas relief commission and the state department of industry launched schemes to provide alternative employment for the affected people.

Check Your Progress 2

Note: i) Use the space given below for your answers.
    ii) Check your answers with those given at the end of the Unit.

1) Write a note on Methyl Iso cyanate.

2) Explain in detail the Bhopal gas leak disaster.
3. Explain the various relief measures taken up by the administration after the Bhopal gas leak disaster.

7.6 CHEMICAL AND BIOLOGICAL WARFARE DISASTERS

The threat of chemical and biological warfare has been talked about frequently in the past years but the likelihood of such occurrence has assumed serious concern in the emerging terrorism dominated environment. Such tactics have been rightly given the name of Weapons of Mass Destruction (WMD).

7.6.1 Chemical Warfare/Terrorist threat

i) Poisons

Chemicals, in the form of poisons, have been used as agents of harm since times immemorial. These assume disastrous proportions when used for large scale or mass killings. Such situations can arise either inadvertently, or through ignorance or in a criminally planned manner. Inadvertent use of poisonous substances – by children in many cases or mixing of toxic chemicals or poisons in country liquor, are well known examples. In times of strife, there are threats of poisoning the water supply of entire town or city and hence special vigilance is to be maintained around water works and water tanks in case of actual or perceived threats of this type.

ii) Toxic Gases

Quick acting, toxic gases have been envisaged as the means of immobilizing or killing large segments of population and are reported to have been manufactured and stored by many countries during wars or war like situations although it is not very clear if these were used as Weapons of Mass Destruction (WMD) so far. The chemicals, in the form of gases, that have been usually talked about in this context are the following:

(a) Nerve Gases are basically highly toxic insecticides and act by inhibiting important enzyme activity in human body. These are generally the compounds of fluorophosphoric acids with alcohol and known as esters. In a well reported case, the Aum Shinri Kyo cult in Japan released Sarin nerve gas in Tokyo subway in 1995. It resulted in the death of 12 persons and many more had to receive medical treatment for extended periods.

(b) Phosgene is the name given to carbonyl chloride and is a poisonous gas used in certain chemical and dyestuff manufacturing processes. It acts on human body by damaging the lungs quickly.

(c) Hydrogen Cyanide interferes with the transfer of oxygen from the blood to the human tissue. This was the killer agent in the Bhopal gas tragedy of 1984 when the Methyl Iso Cyanate gas in contact with the moisture in human eyes, nose and lungs generated hydrogen cyanide which blocked the supply of...
oxygen to these organs and blinded and killed thousands. That was a chemical accident but a similar scenario of a chemical disaster can be created by a terrorist or enemy agent.

(d) Mustard gas is also called yperite and is chemically identified as dichlorodiethyl sulphide. It has a faint odour of garlic. It causes conjunctivitis in the eyes leading to blindness and creates very painful blisters on the skin.

Release of a poisonous gas at single point or even a multipoint ground based release may affect only the people in the vicinity or the down wind communities. However, aerial spray from low flying vehicles such as helicopters or crop spraying light aircraft is a more dangerous proposition.

If people can get away quickly or otherwise limit exposure to the poisonous gas and can receive prompt medical attention, chances of survival with manageable injuries will be quite high. But this will depend upon the ability of the medical personnel to correctly identify the toxic gas from the first symptoms on the victims and the availability of antidote medicine in the required quantity.

The All India Institute of Medical Sciences in New Delhi has established the National Poisons Information Centre in its premises to collect and disseminate information about different poisonous substances.

7.6.2 Biological Warfare / Terrorist threat

In the context of biological disasters, mention is often made of botulism, smallpox, Venezuelan Equine Encephalitis (VEE) and anthrax; the last one being the one that has recently come into great prominence because determined efforts appear to have been made to use it as a weapon of harming targeted individuals and terrorizing the general public although there has been no evidence of its use as a weapon of mass destruction.

(a) Botulism is perhaps the most lethal biological agent. It is made by a bacterium and spreads through contaminated air, food or water. Death occurs within 24 hours due to paralysis of breathing muscles. Antibiotic treatment, to be effective, must start before symptoms appear.

(b) Small Pox: Even though smallpox as a disease has been eradicated from the world, the virus has been preserved in a few reputed laboratories and is kept under high security. The fear is that if it comes in the hands of a terrorist organization, it may be released through aerosol spray. The problem is that there is no effective drug treatment and vaccination programmes have long been stopped.

(c) Venezuelan Equine Encephalitis (VEE) is fatal among humans and there is no known cure so far. It kills through inflammation of brain tissues.

(d) Anthrax is caused by the spore forming the bacterium Bacillus Anthracis and is really a disease associated with herbivorous animals. The disease occurs naturally in areas where people raise livestock. Humans contract the disease through cuts in the skin or by breathing in anthrax spores or by eating anthrax-infected meat. If anthrax spores are collected in a concentrated form and spread in the atmosphere on a large scale quietly, as a colourless odourless and invisible spray, it can certainly turn into a biological disaster because it spreads rapidly when it is inhaled into the lungs. At that stage, it is difficult to control although antibiotic treatment of anthrax is available. The problem here also is that the antibiotic treatment must start before the development of symptoms of fever and cough, otherwise the mortality rate is almost 90%.
7.6.3 Nuclear Warfare/Terrorist Threat

Even though many countries possess nuclear arsenal, yet on a realistic assessment it is sensible to think that these may never be used as has been seem for over a half century that such lethal weapons have been in existence. But the possibility always remains of some terrorist organizations making a crude device. Noting the complexities of design and manufacture and the need for a long distance delivery system, the use of a nuclear device by terrorists would perhaps be a remote possibility. Even if it takes place, the incident would not pose problems more complex than those associated with a technological accident in a nuclear power plant, which we have discussed earlier.

7.6.4 Institutional Arrangements

A Nuclear Biological and Chemical (NBC) Warfare Directorate has been set up by the Defence Services. An inter-services coordination committee monitors the activities.

The Defence Research and Development Establishment (DRDE) of the Defence Research and Development Organization (DRDO) is the premier establishment for studies in toxicology and biochemical pharmacology and development of antibodies against bacterial and viral agents.

7.7 LET US SUM UP

This Unit brings out the fact that industrial and technological disasters result from accident, failures, mishap or misuse of some kind of technology. The disaster may be brought out by the agents like technical spills, radiations fallout, explosions and fires, structural failure and transportation mishaps. Special features of industrial and technological disasters have been discussed in some detail. A case of Bhopal Gas leak disaster has been presented. Finally, chemical and biological warfare disasters have been discussed.

7.8 KEY WORDS

- **Bacterium**: Microscopic or even smaller single-called organisms occurring in enormous numbers every where in nature in air, water, land, sea, plants and animals. They can start chemical changes including disease and decay.

- **Hazardous Industry**: An industry using raw materials which by themselves, produce such products which could lead to massive disasters and heavy loss.

- **Spores**: Minute reproductive bodies produced by plants or animal cells.

- **Herbivorous**: Animals that feed on plants and vegetation.

- **Toxic Leak**: Uncontrolled leakage and eventual spread of a hazardous gas, e.g., Ammonia, Chlorine, and other more toxic gases which can be fatal and can cause asphyxiation, i.e., difficulty is normal breathing. Some of the gases – like the Methyl Iso Cyanate in Bhopal Gas Tragedy can leave far reaching disabilities among survivors.

- **Trauma**: Sudden shock either physical or mental or both.
REFERENCES AND FURTHER READINGS


7.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) Your answer should include the following points:
   - There is only a subtle difference between industrial and technological disasters.
   - While almost all industrial disasters are also technological disasters, all technological disasters are not industrial, e.g., transportation accidents.
   - Industrial disasters have on-site and off-site aspects.

2) Your answer should include the following points:
   - Chemical hazards
   - Nuclear hazards

3) Your answer should include the following points:
   - A major transportation disaster occurred near Delhi in November 1996 when two aircrafts collided in mid air about 80 km from airport.
   - One aircraft was ascending while the other was descending.
   - There was no survivor and all the 351 persons on board the two aircraft perished.
   - The cause was faulty equipment in aircraft and pilot error.

Check Your Progress 2

1) Your answer should include the following points:
   - MIC is very volatile
   - It boils at 30°C and has to be kept cool
   - It reacts with water violently
   - It is highly toxic—much more lethal than cyanide
   - It is heavier than air and spreads near ground surface.

2) Your answer should include the following points:
   - It occurred on the night of December 2, 1984
   - All three safety systems were either inoperative or did not work
   - Gas leaked and spread around
   - There were populated areas on three sides of the factory
   - Nobody seemed to know the defensive methods against the gas
   - 1754 persons dead and 2,00,000 were injured.
3) Your answer should include the following points:
   - Affected persons were treated in hospitals
   - Next of kin of dead were paid Rs. 10,000/-
   - Poor families were paid Rs. 1500/- per family for immediate expenditure
   - Dead bodies of cattle were buried to avoid epidemics
   - Employment schemes were launched for surviving persons.