Chemical Industry and Public Health

Bhopal as an Example

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Sammanfattning

Gasolyckan i Bhopal, Indien 1984 är den största kemiska industriolyckan någonsin. 520 000 människor exponerades för gaserna. Mer än 2 000 dog de första veckorna. Minst 100 000 människor har permanenta skador. Industriolyckor är så talrika att att kemiska risker kan betraktas som ett folkhälsoproblem. Företagen bestrider vanligen sitt ansvar för olyckorna och förnekar att de påverkar hälsan negativt.

Det finns fortfarande olika åsikter om orsakerna till katastrofen i Bhopal och ansvarsfrågan. I skadeanalys används begreppet ”olycksfallsprocessen” med skedena före, under och efter olyckan. Många modeller för skadeanalys har utvecklats.

Uppsatsen baseras på en noggrann genomgång av redan publicerat material och på författarens erfarenheter från ett flertal besök i Bhopal. ”Logical Framework Approach” (LFA), en metod för planering och drift av projekt, testas som en metod för analys av olycksfall och skador.

Analysen visar att, oavsett den direkta orsaken till gasläckaget, var det bara två parter som bar ansvaret för katastrofens omfattning: Union Carbide Corporation och regeringarna för Indien och Madhya Pradesh.

LFA visar sig användbar för en så komplex situation som gasolyckan i Bhopal. Trädet liknar dock mer ett ”problemnät”. När författaren ritade ”syfteträdet” fick hon nya idéer beträffande nödvändiga åtgärder för att förebygga en olycka eller lindra effekterna. Matrisen möjliggör att klargöra vilka processer/förändringar hos andra instanser som utgör förutsättningar för att projektet ska lyckas. Att åskådliggöra orsaker och följder i form av träd kan medföra en ny förståelse. När orsaker och följder till denna typ av olycka visas på detta sätt är det uppenbart att ”kedja” eller ”träd” inte är de rätta orden. ”Nät” är mer relevant.

Nyckelord

Bhopal, gasolycka, Indien, MIC, metylisocyanat, industriolycka

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The Bhopal Gas Leak, India 1984 is the largest chemical industrial accident ever. 520,000 persons were exposed to the gases. More than 2,000 died during the first weeks. 100,000 persons or more have got permanent injuries. Industrial disasters are so numerous so that chemical hazards could well be considered as a public health problem. The companies usually dispute their own roll to the accidents, and deny the health effects of the accidents.

There are still different opinions on the cause to the Bhopal disaster and who was responsible. In injury analysis, the conception "the process of the accident", including pre-event, event and post event phases, is used. Many models for injury analysis are developed.

The paper is based on thorough review on already published material and the author's experiences from visiting the city of Bhopal. The Logical Framework Approach (LFA), a tool for project planning and management, is tested as a method for accident and injury analysis.

The analysis shows, that irrespectively of the direct cause to the leakage, only two parties are responsible for the magnitude of the disaster: Union Carbide Corporation and the Governments of India and Madhya Pradesh.

The Logical Framework Approach (LFA) appears useful for a complex situation like the Bhopal gas leak. However, the tree looks more like a "problem net". When drawing the tree of objectives, the author got new ideas on measures necessary to prevent an accident or mitigate the effects of it. The matrix makes it possible to clarify what processes/changes from other instances that are needed if the project should succeed. Visualising causes and consequences in tree models might provide a new understanding of causes and consequences. When visualising causes and consequences to this kind of accident, it is obvious that "chain" or "tree" are not the right words. "Net" is more appropriate.

Key words
Bhopal, gas leak, MIC, methyl-isocyanate, industrial accident, India

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1 ABSTRACT

1.1 INTRODUCTION

The Bhopal Gas Leak, India 1984 is the largest chemical industrial accident ever. 520,000 persons were exposed to the gases, and more than 2,000 died during the first weeks. 100,000 persons or more have got permanent injuries. The catastrophe has become the symbol of negligence to human beings from transnational corporations. It has thus served as an alarm clock. All the same, industrial disasters still happen, in India as well as in the industrialised part of the world. Although they are far from the size of Bhopal, they are so numerous so that chemical hazards could well be considered as a public health problem. The companies usually dispute their own roll to the accidents, and deny the health effects of the accidents. The companies have also been reluctant to compensate the victims economically.

There are still different opinions on the cause to the Bhopal disaster and who was responsible. According to Union Carbide, it was sabotage by a disgruntled worker. In injury analysis, the conception "the process of the accident", including pre-event, event and post event phases, is used. Many models for injury analysis are developed. Usually, they are used for events like traffic accidents and child burns.

1.2 METHODS

The paper is based thorough review on already published material from India and outside India, and the author's experiences from visiting the city of Bhopal. The conceptual models for accident and injury analysis by Haddon and Berger are used to analyse the causes and its consequences. As a complement, the Logical Framework Approach (LFA), a tool for project planning and management is tested on this mega accident.

1.3 RESULTS

The three models provide the same main message: That irrespectively of the direct cause to the leakage, it is only two parties that are responsible for the magnitude of the disaster: Union Carbide Corporation and the Governments of India and Madhya Pradesh. However, the models give somewhat different images of the process of the accident.

The Haddon matrix gives us a good picture of the complexity, and gives us many ideas on actions for prevention and management. The Ten Strategies add information on management of a disaster. The 4 E's tell us about important factors in the society. The Berger model used in this way give us the chance of inventing all different groups of persons involved in the accident. It seems to invite to describe "soft" data, like attitudes and politics.

The Logical Framework Approach (LFA) appears more complete and useful for a complex situation like the Bhopal gas leak. The problem and objectives trees look like a chain of event from where there are branches and roots. Despite of thorough knowledge of the Bhopal gas leak, developing this problem tree gave the author some new views on the connection between causes and effects. However, the tree looks more like a "problem net". Also when drawing the tree of objectives, the author got some new ideas on measures necessary to prevent an accident or mitigate the effects of it. The matrix makes it possible to clarify what processes/changes from other instances that are needed if the project should succeed.

1.4 CONCLUSIONS

Models developed for analysis of injuries can be used for analysing a complicated mega accident like the Bhopal gas leak, although different models might stress different aspects. Visualising causes and consequences in tree models might provide a new understanding of causes and consequences. When visualising causes and consequences to this kind of accident, it is obvious that "chain" or "tree" are not the right words. "Net" is more appropriate.

2 INTRODUCTION

2.1 THE CHEMICAL INDUSTRY AND PUBLIC HEALTH

During the last century, the chemical industry, including the pharmaceutical industry, has grown and developed enormously. It is estimated that several hundred new chemical compounds are being synthesised every day. We know very little about the effects of these compounds on human beings, animals and eco-systems, in either the short or the long term. The trial and error method seems to be the most common method used for risk assessment.

A number of these compounds, as well as many intermediates and waste products, are toxic to nature and to human beings. The health of workers and residents in proximity to mines, transportation routes and plants will be affected, as well as coming generations.

When we talk about "pesticides and developing countries", we should not only consider the use of pesticides, but also their production. Production of pesticides is a part of the chemical industry, which is growing rapidly in developing countries. The history of the chemical industry is lined with chemical accidents and the exposure of workers and people around the plants. The chemical industry is an important factor from a public health point of view.

Pesticides and the chemical industry in developing countries are a public health problem also for those of us who live in high-income countries. Hazardous products and processes exported to the third world are already returning to the developed countries in a "circle of poison". The physical consequences of a chemical accident might spread to other countries through water, wind and food. The political and economic consequences might also spread all over the world.

Cassels (1) points out that the internationalisation of both business and environmental degradation is increasingly teaching the developed world that the provision of aid to poorer countries – in order to better manage the risks and effects of industrial development – may no longer be a matter of charity, but an imperative motivated by self-interest.

The gas leakage from Union Carbide's plant in Bhopal, India, in 1984 is the largest industrial hazard ever experienced in the world. Over 500,000 persons were exposed to the gases, between 3,000 and 10,000 people died within the first weeks, and between 100,000 and 200,000 may have permanent injuries.

Because of its magnitude, this catastrophe has not been forgotten. Hundreds and hundreds of articles have been published as well as several books. Different kinds of research has been done. The process that led to the leakage, the effects of the gases, and the actions of the company, the government and the medical and scientific establishments are documented in hundreds or thousands of articles and several reports and books.

There is no evidence that the processes and actions would have been different with other chemical accidents. On the contrary, the knowledge about Bhopal can be used when we study other accidents or discuss what measures should be taken to prevent exposure to toxic chemical substances.

The Bhopal Gas Leakage has become a symbol of transnational corporate negligence towards human beings. It has thus served as a wake-up call. All the same, industrial disasters still happen, in India as well as in the industrialised part of the world. Although they are far from the size of Bhopal, they are so numerous that chemical accidents could well be considered to be a public health problem. The companies usually dispute their own role in the accidents and

deny the effects of the accidents on health. The companies have also been reluctant to compensate the victims economically.

There are some similarities between the accidents:

- The catastrophes affect countries outside those where the transnational companies are seated. Production is often established in countries where regulations are less stringent.
- Trade unions and occupational health care seem to have been poorly developed, having little influence on the work environment.
- It seems as though the catastrophes could have been predicted and prevented.
- The companies have disputed their own role in the accidents and denied the health effects of the accidents.
- The companies have been reluctant to compensate the victims economically.

2.2 HUMAN RIGHTS

After the Bhopal tragedy, the Permanent Peoples' Tribunal in Bhopal in 1992 concluded that fundamental human rights had been grossly violated in terms of a series of articles in the various international declarations concerned with human rights (2).

National governments have signed those declarations and many try seriously to follow them. Thus it is possible to file a suit with the International Tribunal for Human Rights in the Hague.

However, sometimes transnational companies have more power than national governments. In 1993, the fifteen largest corporations in the world had gross incomes greater than the gross domestic products of over 120 countries (3). So far, these corporations have not signed any declarations on human rights.

One might expect that human rights included the right to life and health as well as the right to a healthy environment.

However, in the *International Bill of Human Rights*, nothing is said directly about human rights to life and health, or human rights to a healthy environment (4).

In the *Universal Declaration of Human Rights*, the following text was found, which to some extent supports the idea of rights to health and a healthy environment:

> "Everyone, as a member of society, has the right to social security and is entitled to realisation, through national effort and international co-operation and in accordance with the organisation and resources of each State, of the economic, social and cultural rights indispensable for his dignity and the free development of his personality" (Article 22).
>
> "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control" (Article 25:1).

The *International Covenant on Civil and Political Rights* in Article 6:1 states that "every human being has the inherent right to life. This right shall be protected by law. No one shall be arbitrarily deprived of his life."

The *International Covenant on Economic, Social and Cultural Rights*, however, is clearer on rights, health and environment. Article 8 talks about the right to form and join trade unions. In

Article 12, the "right of everyone to the enjoyment of the highest attainable standard of physical and mental health" is recognised. It includes child health, improvement of environmental and industrial hygiene, prevention and treatment of occupational diseases, and assurance of medical service and medical attention.

3 OBJECTIVES AND METHODS

3.1 GENERAL OBJECTIVES

The general objectives of this report is to produce a systematic overview of the Gas Leakage in Bhopal in 1984.

3.2 SPECIFIC OBJECTIVES

The specific objectives are to analyse available material to find answers to the following issues:

- If and how the accident could have been prevented;
- What the probable components of the gases were;
- Whether these components could explain the deaths, the permanent injuries and the distribution of symptoms and injuries from grave to light;
- If and how the immediate treatment of the survivors could have been more efficient;
- If and how the long term effects on health could have been mitigated;
- If and how the long term socio-economic effects could have been mitigated;
- If the accident had any influence on the safety policies of the chemical industry in India.

To use the knowledge gained in a discussion on:

- How chemical disasters can be prevented;
- How outbreak epidemiology should be designed;
- The demands to make of authorities, medical establishment and the WHO in the prevention and management of industrial disasters.

3.3 METHODS

The essay is based on material already published in India and other countries, and on the author's experiences from several visits to the city of Bhopal totalling six months.

3.3.1 Studied material

The collected material can be classified as follows.

3.3.1.1 Scientific papers and reports

- By members of IMCB (5, 41, 42, 43, 44, 45, 46, 62, 63, 64)
- By other (medical) authors (23, 30, 50, 56, 57, 58, 59, 60, 61)
- Research on MIC (17, 18, 27, 29, 51)

3.3.1.2 Material from ICMR

- Manuals and the like (47)
- Other reports (16, 25)

3.3.1.3 Material from official Indian authorities

- Government of Madhya Pradesh (68, 69)
- Disaster Management Institute (78, 79)
- Council for Scientific and Industrial Research (20)

3.3.1.4 Material from Union Carbide

- Manuals, published before 1984 (19, 24)
- Pamphlets and video, published after 1984 (6, 14)

3.3.1.5 Material published by NGOs

- BGIA: pamphlets (48, 49, 66, 70, 71, 72, 74)
- Sambhavna: newsletters and annual reports (34), papers (28, 65)
- Other NGOs (2, 73, 80)

3.3.1.6 Books

- *The Uncertain Promise of Law: Lessons from Bhopal* (1) is a thorough examination of the relations between multinational coporations, governments and the people.
- *Bhopal Gas Tragedy* (7). A thorough examination of the causes and the management of the accident, written in 1984 and 1985.
- *Bhopal: The Inside Story* (8, 9, 67). The main section was written by T.R. Chouhan, a former MIC plant operator in the UCIL factory in Bhopal. One appendix has testimonies from 16 plant personnel. Another describes the legal issues.
- *Corporate Killings. Bhopals Will Happen* (12) is a thorough examination of what was known in 1987.
- *Bhopal: Industrial Genocide?* (15, 22, 77) A collection of 30 articles published in different newspapers in 1984.
- *Bhopal Tragedy. Socio-Legal Implications* (35) deals with the economic compensation and the social rehabilitation.

3.3.1.7 Articles from non-scientific papers

(3, 21, 38, 75, 76)

3.3.1.8 Reports

- *The Trade Union Report on Bhopal* (13) is a report by two trade unions.
- *The Toxic Gas Disaster in Bhopal, December 2–3, 1984* (26) is a report for the Swedish National Defence Research Institute. The authors visited Bhopal ten days after the accident.
- *The Bhopal Catastrophe: Consequences of a Liquefied Gas Discharge* (36), also for the Swedish National Defence Research Institute in February 1985, includes dispersion models.

3.3.1.9 Submissions (in addition to the material above)

- from survivors to IMCB
- from activists and doctors to IMCB

3.3.1.10 Interviews

- Ms Rashida Bee, the president of Bhopal Gas Affected Women's Stationery Workers' Union (46)

- Ms Champa Devi Shukla, the secretary of Bhopal Gas Affected Women's Stationery Workers' Union (46)
- Mr Abdul Jabbar Khan, the president of the Bhopal Gas Peedit Mahila Udyog Sangathan
- Mr T S Chouhan, a former operator at UCIL plant in Bhopal
- Mr Jayaprakash, the Delhi Science Forum
- Mr Sathyu Sarangi, the president of BGIA and the director of Sambhavna clinic
- Dr Dwivedi, MD, former director of ICMR in Bhopal
- Mr Deena Deenadayalan, the Other Forum

3.3.1.11 Background material

- Human rights (4)
- Night work (10, 11)
- Toxicology and pathology (31, 32, 33, 39, 40)
- Environmental risk management (37)
- Post traumatic stress disorder (52, 53, 54, 55)
- Injuries (81, 82)

3.3.2 General aspects

Many statements and submissions are repeated in different articles and books. For practical reasons, some books and articles are chosen as references. When the statements in other sources are congruent with the references, they will not be indicated in this essay.

In this report, most of the content is not the result of the author's own investigations. However, in chapter 4 to 6, the author has added her own comments to the facts from the studied material.

Except for the Logical Framework Approach (LFA), the conceptual models for accident and injury analysis by Haddon and Berger were also used to analyse the causes of the disaster and its consequences. Because lack of space, only the LFA is described in the essay.

3.3.3 Comments

- The quality of the collected material can be discussed. This is especially true with regard to the submissions from survivors and workers.
- Submissions by survivors may have been biased because of hopes of economic gain.
- Submissions by workers may have been biased due to the intention of avoiding responsibility.
- Even when survivors' home language is Urdu, the interviews are likely to have been held in Hindi.
- Submissions have been translated into English; qualities may have been lost.
- Foreign journalists generally do not know Urdu or Hindi. Many interviews must have gone through an interpreter or were conducted in bad English.
- Many of the original statements or submissions have been repeated in different articles and papers in a way that makes it seem as if they were new.

Some material is missing, because it is not released.

- It is very probable that UC knows much more about the composition of the cloud compared to the information they have released.

- It is likely that there still exists information from governmental institutions which has not been released, for instance, why the Government of India suddenly accepted the sum of compensation offered by UC.
- ICMR's annual reports were kept secret for many years.
- The surveys undertaken by the Tata Institute immediately after the disaster are still not released.

The quality of the epidemiological and clinical research material will be discussed in chapter 6.2.

4 THE PRE-EVENT PHASE

4.1 THE PROCESS THAT LED TO THE LEAKAGE

4.1.1 General aspects

The details of the pre-event phase are described in the extended version of this essay (5).

In the 1960s, the market for pesticides in Europe began to be saturated and, because of new knowledge and protests from environmental activists, was restricted. The multinational corporations then turned to the Third World, which offered cheap labour, low maintenance costs and relative indifference to occupational health. In India, the "Green Revolution" displaced traditional growing methods with high-yielding seed varieties that required large amounts of fertilisers and pesticides.

The Union Carbide plant in Bhopal opened in 1969 to manufacture pesticides. Union Carbide Corporation (UCC) is the parent company and Union Carbide India Limited (UCIL) the Indian subsidiary. 51 % of the stock was held by UCC and 49 % by different governmental departments and organisations.

UCC vindicates that it was not responsible for the maintenance of the safety systems of the UCIL plant in Bhopal. But UCC was allowed majority ownership despite government limitations on foreign investment, because of the technological sophistication of its operations. UCC chose all production processes, supplied all plant designs and designated operational procedures. UCC also conducted safety audits.

In the procedure for manufacturing the pesticides Sevin and Temik, methyl-isocyanate (MIC) was used as an intermediate. In the beginning, MIC was imported, but in 1979 UCIL built an MIC unit. The company was offered a site outside the town, but insisted on using the existing plant area, close to the railway station.

After the leakage, UCC's first line was that the equipment installed in Bhopal was made in USA to US specifications, with safety equipment and standards virtually identical in both Bhopal and Institute, Virginia. Later on, this first reaction proved to be a double-edged sword, as it implied that the killing at Bhopal could recur elsewhere.

The events that led to the leakage were all based on reducing the expenditure of money. Earlier, a cheaper but more dangerous method of manufacturing pesticides was chosen. The plant had a different safety design from corresponding plants in Europe and the US. Huge amounts of MIC were stored. The various safety systems were all underdimensioned. Running them was dependant on manual operations. Safety audits were done every year in US and European plants, but only every two years in other parts of the world.

Accidental leaks from all the units were frequent, and operators and workers were regularly exposed to different toxic substances. The UCIL management advised the workers to develop resistance against toxic substances by drinking six or seven glasses of milk a day and eating a high-protein diet of fish and eggs. The personnel management policy led to the flight of skilled personnel to better and safer jobs. They were replaced by uneducated workers.

There had been several warnings before the leakage 1984. In 1981 a worker was killed in an accident. A 1982 UC audit report from India indicate that worker performance was below American standards. In September 1984, an internal UCC report on the Virginia plant in USA warned that "a runaway reaction could occur in the MIC unit storage tanks, and that the planned response would not be timely or effective enough to prevent catastrophic failure of the tanks". This report was never forwarded to the Bhopal plant, although the main design was the same.

The UCIL factory was running at a loss and it was decided that the factory should be closed down and sold. This was probably the reason why maintenance decreased. In November 1984, the most important safety systems were either closed down or not functioning.

UCC admitted, in their own investigation report, that most of the safety systems were not functioning on the night of the 3rd December 1984 (6). In the report we get the following information:

- Tank temperatures were not logged;
- The vent gas scrubber (VGS) was not in use;
- The cooling system was not in use;
- A slip bind was not used when the pipes were washed;
- The concentration of chloroform in Tank 610 was too high;
- The tank was not pressurised;
- Iron was present because of corrosion;
- The tank high-temperature alarm was out of function;
- Tank 619 (the evacuation tank) was not empty.

In addition, other faults are recorded:

- The meters monitoring tank E610 were showing abnormally low pressure. The reason might be either a faulty meter or an inability of the tank to maintain pressure (7).
- The line connecting the VGS to the flare tower was master carded (7, 8).
- Many valves, vent lines, feed lines etc. were in poor condition (7, 8).

After the leakage, there were findings that give rise to several questions concerning the maintenance of the plant (7, 9):

- Water was discovered by the workers after the accident when they drained the vent lines connecting the tank E610 and the relief valve vent header (RVVH).
- Caustic soda was found in the RVVH when it was opened on December 10th.

Night work has been shown to be a risk factor in accidents (10, 11). This might have contributed to the mistakes made by the staff during the course of the leakage.

4.1.2 Comments

The deficiencies in the Bhopal plant design can be summarised as:

- Choosing a dangerous method of manufacturing pesticides;
- Large-scale storage of MIC prior to selling;
- Location close to a densely populated area;

- Under-dimensioning of the safety features;
- Dependence on manual operations.

Deficiencies in the management of UCIL can be summarised:
- Lack of skilled operators because of the staffing policy;
- Reduction of safety management because of reducing the staff;
- Insufficient maintenance of the plant;
- Lack of emergency response plans.

It was UCC that chose the design. On the UCIL board, UCC was well-represented. Thus UCC can hardly avoid responsibility for the safety status of the plant.

It seems as though the management's views on safety differed from those of the workers. The chief medical officer at Bhopal said, "The safety precautions we took were the best possible. We did everything the Americans advised. In fact we used to think that we were overdoing the safety" (12).

5 THE EVENT PHASE

5.1 THE LEAKAGE

5.1.1 General aspects

The details of the event phase, including the contradictionary statements, are described in the extended version of this essay (5).

The direct cause to the leakage was that big amounts of water entered tank 610. There are at least four theories as to how the water entered the tank: the water washing theory of the workers, the eirect enter theory or sabotage theory of UCC, the economy theory and the warfare Test Theory.

UCC soon took the position that the leakage was caused by deliberate sabotage (13, 14). A water line should have been attached to the tank. First they blamed a Sikh terrorist, then a "disgruntled worker". They still keep on the later theory, although they never gave any evidences on this, neither charged the worker. They did not name the worker, but gave a detailed description so he could identify himself (9).

The opinion of this worker is that if there was a sabotage, it would not have been caused by any worker, because they knew that entering water directly to the MIC tank would be a very dangerous to himself and to people around (9). Also, if the leak was caused by sabotage, the culprit would be the management who was responsible for overseeing the safety of the MIC plant.

The opinion of operators and workers is another (8, 9, 13). In the evening of 2nd December, at 8.30, some workers were told to clean the pipes with water. There was no instruction to put in slip binds, so that water could not pass into connecting lines. Because of grossly inadequate maintenance, valves would be malfunctioning and thus permit water to pass even through closed valves. As tank 610 was not holding the pressure, it was possible for large amounts of water to enter the tank this way. The vent lines were made of carbon steel and handling corrosive substances, which would contaminate the tank 610, and catalyse the reaction.

When water and contaminants reached the 43 tons of MIC, an exothermic reaction started which caused catalytic trimerisation (a runaway reaction). The temperature and the pressure

increased and steam escaped in at least two places. The leakage continued for three hours, until the tank was empty at about two o'clock in the morning.

Neither the workers nor the management did understand how serious the situation was. The first signs of the leak was noted 11.00 PM. At 12.15 AM, the supervisors considered the leakage as "normal" but ordered a water spray onto the leaking point. The water washing of the lines was stopped only at this time. At 12.50 AM the alarms began inside the factory, and at 1.00 AM the loud siren was stopped. It was not restarted until 2.00 AM, fifteen minutes before the leakage stopped.

Even if the supervisors would have been properly trained and had taken action earlier, they would not have been able to control the leakage, as the different safety systems were either under dimensioned or not working.

5.1.2 Comments

The direct cause of the gas leak was the large amounts of water that entered tank 610. A run-away reaction started, which was speeded up because of contaminants, high temperatures and other factors.

The two main theories as to how the water entered the tank are the sabotage theory and the water washing theory. The arguments seem very good for both. As a layman, it is very difficult to judge whether one is more improbable than the other. UC has also pointed out contradictions in the statements from the witnesses (14).

However, it seems like sabotage would have been improbable if
- maintenance had been good;
- the safety systems had been working;
- the saboteur would have wanted to save his own life and health.

Even if the supervisors had been properly trained and had taken action earlier, they would not have been able to control the leakage, as the different safety systems were either under-dimensioned or not working. The leakage stopped when tank 610 was empty.

A very important factor is the temperature of the tank. It is in the UCC's interest to maintain that the temperature was never over $+200^{o}$ C, which would mean that only very small amounts of hydrogen cyanide were formed. However, it seems very likely that the tank temperature was far above this point.

The leakage, irrespective of the initiating cause, would not have reached this magnitude if
- the MIC had been stored in several small tanks instead of two big ones;
- the proper materials had been chosen for the pipeline system, so it would not have contributed to the contaminants;
- the maintenance had been appropriate so the risk of contaminants would have been minimised;
- the safety systems had all functioned as planned at start of the plant;
- the safety rules had all worked as planned at start of the plant;
- the stated safety precautions had been followed;
- the operators and workers had been properly educated.

5.2 THE CONTENTS OF THE CLOUD AND ITS EFFECTS

5.2.1 Theories

The exact contents of the cloud are still not known – partly because Union Carbide has not released the information they have available.

The doctors' first assumption was that phosgene had leaked. This was later said to be impossible, because phosgene was never stored, and the MIC-plant had been shut down (15). However, in 1981, a worker died from phosgene inhalation, although phosgene ought not to have been present in the lines after the MIC-plant was shut down (12).

In a paper (16) that was probably written by ICMR directly after the leakage, not only MIC is described, but also phosgene, hydrogen cyanide and carbaryl (Sevin).

When cyanide was found in the blood of dead victims, there was a discussion about whether the cyanide came from MIC in the body or from outside the body. UCC, Bayer AG which also produces MIC, and Dr Jaeger of the WHO stated that the cyanide did not come from the MIC. This means that not only did MIC escape from the tank, but also other gases. This is verified by the findings of high concentrations of hydrogen cyanide in air samples close to the tank two to three days after the leakage (12).

On the basis of investigations of post-mortem blood and tank residues (17, 18), ICMR in their 1991 report drew the following conclusions: "MIC trimer was found to be present in preserved autopsy samples of gas tragedy victims along with DMI, dione and several other unidentified compounds in the category of molecular weight of 269, 279 etc. The presence of MIC trimer and other similar peaks of the tank residue in the blood-stream of victims indicate a definite evidence of entry of mixture of gases and particulates into the body system contrary to the statements of the manufacturers of MIC."

Union Carbide has still not released any kind of information on the composition of the cloud. In the manual (19) there is a list of compounds derived from burning MIC. The highest concentration would be nitrogen (N_2), the next carbon dioxide (CO_2) and water. Smaller amounts of carbon monoxide (CO), O_2, H_2, OH-, and NO would also be released.

In the manual (19) a range of different reactions are described. The names and properties of the resulting products are not described. It seems, however, likely that at least some of those products would also be present in the cloud.

In the CSIR report (20) it is assumed that the gaseous products from a MIC-water reaction would be mainly MIC, carbon dioxide (CO_2), methylchloride, methylene dichloride and carbon tetrachloride. Some alkylamines may have been present in very small amounts. Phosgene and methylcarbamyl chloride, present in very small amounts, are readily hydrolysed with water to give hydrogen chloride (HCl).

Subramaniam (21) also discusses the possible components of the gas cloud. In his opinion, nearest the factory, the cloud would have been mainly composed of MIC and trimers of MIC, but would also have contained hydrogen cyanide (HCN), oxides of nitrogen (NO_X), carbon dioxide (CO_2) and carbon monoxide (CO), all of which replaced the air. As phosgene is always present in the MIC tank, it is most likely that phosgene was also released.

Subramaniam is of the opinion that the bulk of the MIC released, once in contact with the moisture in the air, would have been converted in the atmosphere into monomethylamine (MMA) and more carbon dioxide. It is likely that the heaviest (crystals and liquids) and the

lightest (HCN, NO_X, CO_2 and CO) would have been confined to the area adjacent to the plant. Therefore it is highly improbable that cyanide would have been widely dispersed. Stable compounds might have been carried away by the wind, to the lakes and the soil. As most of these compounds are heavier than air, concentrations would have been highest close to the ground.

Estimates are based on the leakage of 30 tonnes of MIC spread over the whole volume of a two kilometre radius up to a height of 30 m and indicate that the air would have had about 0.03 ppm of MIC (22). As MIC is heavier than air, it is likely that its concentration would have been much higher near the land surface.

Singh and Ghosh have provided simulations of exposure concentrations at various distances downwind of the plant. 27 sites were identified with ground level concentrations ranging from 85.6 ppm to 0.12 ppm with a median of 1.8 ppm (23).

5.2.2 Methyl-isocyanate

According to reports seized from the research and development centre of the plant at Bhopal as well as documents traced from other offices of the firm, the corporation had conducted a number of experiments on animals and plants, and was well-aware of the effects of MIC (12). It is likely that they had information not only on short-term effects, but also on medium and long-term effects.

The properties of methyl isocyanate are described in the manuals from Union Carbide (19, 24) and in the trade union report (13).

MIC is a colourless liquid with an odour like tear-gas, slightly soluble, highly reactive when in contact with water, and lighter than water. The vapour is heavier than air. MIC is reactive, toxic, volatile and flammable. The flash-point of MIC is –18 ^oC, and a concentration of only 6 % in air is explosive. MIC boils at 39.1^oC. Its reactivity is inhibited by phosgene and increased by metals.

The threshold limit value set by the American Conference on Government Industrial Hygienist is 0.02 ppm. MIC is defined a poison by inhalation in DOT regulations.

According to ICMR, MIC has anti-cholesterase activity (25).

At 1 ppm in the atmosphere people's eyes will start to water and, at that stage, there may already be a high enough concentration to cause serious internal damage. When four healthy volunteers were exposed for MIC for brief intervals (up to 15 minutes), they reported some irritation, with resulting tears, at 2 ppm. As the concentration increased, symptoms worsened until they became unbearable at 21 ppm (12).

In the UC manuals from 1976, the effects on health are described (19, 24): "MIC may cause severe or permanent injury in contact with eyes or skin. If inhaled or swallowed in sufficient quantities, death may result. MIC acts like tear-gas, but is (many times) more lethal. "MIC is a poison by inhalation ... and is intensely irritating to breathe. It causes severe bronchospasm and asthma-like breathing. ... It should also be regarded as an oral and contact poison. Skin contact can cause severe burns. The liquid will seriously injure the eyes, even when it is diluted with an non-toxic liquid to a one percent concentration".

A run-away-reaction is described in the UCC manuals:

- "Water reacts exothermically to produce heat and carbon dioxide. As a result, the pressure in the tank will rise rapidly if MIC is contaminated with water. This reaction may begin slowly, especially if there is no agitation, but it will become violent."
- "MIC reacts vigorously with contaminants such as water, acids, alkalis and amines and can polymerise rapidly if in contact with iron, steel, zinc, tin, galvanised iron, copper and its alloys. Stainless steel is safe."

It is calculated that the leakage of one gallon (4,5 litres) of MIC can cause health problems two miles (3 kilometres) away (12).

Exposed to high temperatures, MIC breaks down to hydrogen cyanide (HCN) (26). At 200^{o}C three percent of the gas is hydrogen cyanide. At +400^{o}C the proportion has increased to 20 percent. It has been suggested that alternatives to chronic cyanide poisoning exist, for example modification of the haemoglobin molecule (26). This issue became an important controversy. Chloroform may inhibit the breakdown of MIC to hydrogen cyanide (20).

After the Bhopal leakage, UCC as well as some scientists maintained that MIC cannot penetrate the lung-blood barrier, and that MIC cannot lead to permanent injuries. They said that MIC would neutralise itself immediately in the presence of moisture (27).

MIC is soluble in and reacts with water e.g. in mucous and thus can penetrate tissues in the respiratory tract and stomach and interact with proteins. ICMR (Indian Council of Medical Research) found MIC trimers, hydrogen cyanide and other compounds in autopsy samples and maintains that this is evidence that different substances entered the body's system. A study on methyl carbamylation in post-mortem blood supports this (27).

In a series of experiments, animals were exposed to MIC by inhalation (28). This caused serious injuries to the entire respiratory tract, the viscera and the brain, as well as genotoxicity. Exposure to methylamine and N,N'-dimethyl-urea, hydrolytic derivatives of MIC, did not have the same effects. Rats exposed to MIC by inhalation or by subcutaneous inception suffered serious damage to the lungs and other organs, although the effects were not exactly the same (29). MIC exposure by pregnant rats resulted in increased numbers of dead foetuses, decreased neonatal survival rates and a higher incidence of foetal malformations (30).

5.2.3 Other possible released substances

The information is mainly collected in the textbooks on toxicology by Patty (31) and Clayton & Clayton (32).

Monomethylamine gives the same acute symptoms with burning in the respiratory passages and eyes, but is much less toxic. Methylamines are able to adversely affect foetal development in mice.

Hydrogen cyanide inactivates the enzymes necessary for the transport of oxygen into the cells and can cause immediate respiratory cessation.

Carbon monoxide takes the place of oxygen in the haemoglobin and thus interrupts the normal oxygen supply to the body tissues.

Carbon dioxide in high concentrations can contribute to oxygen deficiency.

Phosgene was used in chemical warfare during first world war. It is a lung irritant and can cause pulmonary oedema, sometimes with a latent effect.

Nitrogen dioxide can give similar symptoms to phosgene. Inhalation of nitrogen oxides can cause bronchiolitis obliterans in the lungs (33).

Chloroform was earlier used as an anaesthetic. High concentrations result in narcosis and anaesthesia because of the depression of the central nervous system. Chloroform may inhibit the breakdown of MIC to hydrogen cyanide (20).

Hydrogen chloride is extremely irritating to the nose and throat. When inhaled in high concentrations, the gas causes necrosis of the tracheal and bronchial epithelium as well as pulmonary oedema, atelectasis, emphysema, and damage to the pulmonary blood vessels.

5.2.4 Hypoxia and Asphyxia

Oxygen-deficient atmospheres can cause sudden unconsciousness and death. When the concentration of oxygen in the atmosphere falls below 10 percent, the patient will experience nausea and vomiting and inability to move freely.

When the anoxia is severe and prolonged, with unconsciousness, irreversible degenerative changes in the nervous system, especially in the cerebral cortex and basal ganglia, may occur. These result in paralyses, amnesia, and other manifestations of permanent injury.

The oxidation of haemoglobin to methaemoglobin makes it incapable of its usual functions of transporting oxygen, and chemical asphyxia may be said to have occurred. When 60 percent or more of the haemoglobin has been transformed, symptoms of hypoxia may follow.

Various nitro compounds can cause methaemoglobin formations. The major manifestation of methaemoglobinemia is cyanosis, a purplish blue colour of the skin.

Carbon monoxide and hydrogen cyanide also lead to chemical asphyxia.

5.2.5 Comments

The sudden deaths without pulmonary oedema can be explained by hydrogen cyanide and/or phosgene in high concentrations, carbon monoxide and oxygen deficiency. The acute deaths with pulmonary oedema could be caused by MIC, hydrogen chloride and nitrous oxides. The less serious symptoms that were experienced at some distance from the plant could be caused by MIC and monomethyl amine.

That children were more hit than adults might depend on higher concentrations of toxic compounds close to the ground, in combination with higher susceptibility.

The somniferous effect could have been caused by chloroform.

The delayed pulmonary symptoms, after 24–48 hours, might be caused by phosgene, nitrogen dioxide and nitriles.

Deaths within days-weeks without delayed pulmonary symptoms might be caused by hydrogen cyanide in low concentrations, MMA in high concentrations, nitrogen oxides, nitriles, middle and low concentrations of phosgene, hydrogen chloride and MIC.

The chronic symptoms from lungs, eyes, intestinal channel and the nervous system as well as the late deaths could be the result of persistent damage caused by MIC, carbon monoxide,

nitrogen dioxide, hydrogen chloride, monomethyl amine, low concentrations of phosgene and hydrogen cyanide, and oxygen deficiency. Liver damage can be explained by hydrogen chloride, anoxia and probably also MIC. Many of those substances are also skin irritants and can cause sensitisation.

It is also possible that the residents reacted more seriously to the gases because of earlier sensitisation to MIC during previous leaks.

5.3 OUTSIDE THE PLANT

5.3.1 General aspects

The details of the events during and immediately after the leakage are described in the extended version of this essay (5).

The residents of Bhopal were generally asleep, on the streets or in the station, in kuccha houses without door or windows, in pucca (permanent) houses with windows and doors, or on the second or third floor in the Old Town. They woke up because they were coughing and suffocating. Then they felt something like “burned chilli”, their eyes started to burn as well as their respiratory passages, they started to vomit. Some stayed in bed under a blanket, but most people went out, scared and angry, and tried to get away from the cloud. They ran, or used vehicles if possible, and moved away from the factory, following the direction of the cloud. As they ran, they inhaled larger amounts of the gases.

Not until around 2.00 AM, the plant siren was heard outside the plant.

Later, they went to the hospitals. The doctors and the staff were completely taken by surprise as thousands and thousands of survivors entered the gates. When they got hold on the doctor of the plant, they were given the message, “It is only like tear gas”. Meanwhile the doctor’s own mother died of the gases. At the hospitals, all kind of medicines were tried to give relief.

The alarm reached the fire corps on the direct telephone line at 1.00 AM (26). When they arrived at the plant gates, the plant staff said that “It was just a gas leak” and there was no need of help from the fire corps, which returned to the station.

The Police Superintendent reached the control room at 1.25 AM and found the staff coughing violently (34). He put some men on to calling the UC factory. Up to 02.10 AM the Police Superintendent got through on telephone to the UC factory three times. Twice he was told “Everything is OK”. The third time, “We don’t know what has happened, Sir,” before the phone was banged down.

Around 6.00 AM, police vans with mounted loudspeakers announced: “Something had gone wrong somewhere. Everything is normal now. Citizens are requested to return to their homes.”

When the morning light came, the extent of the disaster was obvious. In the areas around the factory, every goat, cat, dog, cow and buffalo had died. Outside and inside the houses dead human bodies were lying. Only the birds and rats did not die. In a few days, all the leaves of the trees fell off, and the grass became yellow.

The doctors and the staff were completely taken by surprise as thousands upon thousands of survivors entered the gates. They were half-blinded, gasping for breath, foaming at the mouth and vomiting. Most of the patients had to be treated outside. There was no time to keep any

kind of records. All types of medicines were tried to give relief. When the hospitals got hold of the doctor of the plant, they were given the message, “It is only like tear gas”.

Many dead bodies were taken to hospital for registration and identification. Dead bodies were also carried away from the hospitals before any registration was made.

Doctors, nurses, paramedicos, volunteers and students were attending the gas-affected patients by the evening of 3rd December (35) Medical experts from all parts of the country and abroad rushed to Bhopal to guide and assist in the treatment of the patients.

For several days, or even weeks, gas was trapped in cupboards and closed rooms. The ground, the houses, clothes and the water were covered by a layer of white powder that later turned green. There was no information whatsoever to the residents on how to behave - for example to wash their clothes, or not to eat polluted food.

Two weeks later, the inhabitants once more fled from the town, when tank 610 was emptied of the residue (“Operation Faith”) (5, 20). They did not trust the safety measures that were taken this time.

5.3.2 Information

In the studied material, it has been very difficult to find facts about what information Union Carbide Corporation and Union Carbide Indian Limited provided for workers, authorities, health care services and residents. Instead, complaints of a lack of information or misinformation are legion.

Not even the medical doctor of the Bhopal plant had proper information about the properties of the gases. He continued to insist that MIC was only an irritant and not life-threatening (13). In reply to telegrams sent to both UCC’s US headquarters, doctors in Bhopal were told that the gas was “harmless” (1).

An Indian government spokesperson was of the opinion that “Carbide are more interested in getting information from us than in helping our relief work” (12). Although doctors from UCC headquarters in Danbury turned up in Bhopal, they did not give any information.

Up to today, UCC has not released information about the possible composition of the cloud.

Also conserning information to the residents, the issues are lack of information or misinformation. On the radio, the tragedy was mentioned only in passing in the regular news bulletin (7). Eight hours after the leak, the atmosphere in Bhopal was declared free of the gas, though people were warned they should be careful about what they ate for another seventy-two hours (12).

Chauhan maintains that the public was advised to wash all vegetables and food articles with water and clean floors, walls and surfaces with water (35). The residents, however, do not remember having heard this advice.

Other authors describe that within a few days of the accident, presumably on the basis of preliminary investigations, formal statements were issued that air, water, vegetation and foodstuffs were safe everywhere in the city. At the same time, television features informed people that poultry was unaffected, but warned people not to consume fish, etc. Confusion was rampant and people were asking whether it was safe to consume eggs, vegetables, etc. (7).

It was an open secret that consignments of fresh vegetables and fruit were arriving regularly from the government farm at Pachmari, a hill resort near Bhopal, for ministers and senior bureaucrats (12).

5.3.3 Comments

Because of the different properties of the compounds of the cloud, it is likely that people living at various distances from the plant were exposed to different compounds in different concentrations.

This may well explain the concentration of deaths to the area close to the factory, the statements of the witnesses, and the findings made by IMCB, that those who lived closer to the plant had more symptoms and more pathological test results than those who lived further away.

The gases were heavier than air. It is thus likely that children were exposed to higher concentrations of the toxic gases as well as to lower concentrations of oxygen. This would have resulted in higher concentrations per kilogram weight than for the adults, and thus led to the higher death-rate among children (35).

5.4 ACUTE HEALTH EFFECTS AND TREATMENTS

5.4.1 How many were affected?

36 wards were marked as being "gas affected", with an estimated population in 1984 of 520,000. Of these 520,000 exposed people, 200,000 were below 15 years of age and 3,000 were pregnant women.

On the basis of the mortality figures, which became available immediately after the gas leakage, these areas were classified as being severely (two wards with 32,000 inhabitants), moderately (five wards with 72,000 inhabitants) and mildly affected (29 wards with 416,000 inhabitants).

However, there are many doubts concerning the accuracy of these figures. The area covered by the cloud was probably much larger than first estimated. In 1989, when decisions about interim relief were taken, all 56 wards in Bhopal were considered to be affected: two severely, five highly and 47 generally affected.

5.4.2 How many died?

The first official death toll figure was 1,408. Later it rose to 2,259, including 541 children and 318 women (36). In 1991, 3,928 deaths had been certified. Kulling and Lorin make this estimate (26): 500 persons died before they got any medical treatment. Of the 6,000 who got treatment for serious symptoms, 2,000 died within the first week. According to Pandey (37), those who died within hours of the tragedy numbered 2,500, and within months 3,100 more persons died.

Even this is probably an underestimate:

- Registration at the hospitals was cut off when an upper limit or top number was reached.
- As soon as a patient was declared dead, it was common for his/her relatives to vanish with the body, before registration was possible. At Hamidia Hospital, it was estimated that 500 to 1,000 bodies were taken away without registration (12).

- Bodies collected on the streets by the police were dumped in the Narmada River without being registered.
- Shrouds for Hindu and Muslim death services were distributed.
- Those who fled Bhopal and died in other places were not registered.
- In March 1985, there were still thousands of people registered as missing (13).

Other estimations vary between 10,000 and 20,000 (12). Sambhavna estimates 8,000 deaths during the first weeks, and another 8,000 since then (34).

During the first 48 hours, the death rate in some of the worst affected areas has been estimated to 20/1,000 (35). During December 1984, it was 24/1,000, compared to the national average of 1/1,000. The worst affected age-group was children below 5 years age, with a death rate of 33/1,000.

Around 800 buffaloes and 3,000–4,000 other larger domestic animals died or had to be put to death (26).

5.4.3 Short-term impact on health

The acute symptoms were burning in the respiratory tract and eyes, breathlessness, stomach pains and vomiting. Those living close to the factory had very severe acute as well as long-term symptoms. Several kilometres away, in the New Town, the residents only felt a passing mild irritation in the respiratory passages and eyes. Those who worked with patients or dead bodies suffered from delayed symptoms, even if they had not been exposed to the leakage as such.

The acute clinical picture was transient irritation and redness of the skin, intense irritation from the eyes including blepharospasm, profuse eyelid oedema and superficial corneal ulcerations (26). A soothing and somniferous effect is also reported (37). From the respiratory tract physical findings were rhinitis, pharyngitis, coughing, respiratory distress including bronchoconstriction, shortness of breath and choking. Many patients died from choking or reflexogenic circulatory collapse. Pulmonary oedema developed in many patients in the acute stage. In others, pulmonary oedema developed later, after a free interval. All types of complications from the respiratory tract were seen, such as pneumothorax, subcutaneous and mediastinal emphysema, bronchopleural fistulas, secondary infections etc.

The worst hit were children below 2 years, old people and persons with previous pulmonary diseases, like chronic bronchitis and emphysema (26).

The findings during autopsies on victims revealed changes in many organs, but the most pronounced findings were related to the lungs. The lungs were enlarged and oedematous, showed congestion, haemorrhage and consolidation, with microscopic findings such as bronchiolitis and pulmonary oedema. There were focal haemorrhages in the other organs. In addition, the consistency of the brain was softened through cerebral oedema. The kidneys showed congestion and tubular necrosis. In a large number, the liver showed fatty degeneration. In the gastro-intestinal tract, necrotising enteritis was found.

At Hamidia hospital, nine cases of partial paralysis were found.

Women's reproductive health was affected. Immediately after the gas leak, the stillbirth rate increased by up to 300 % and the perinatal and neonatal mortality rate by 200 %. The spontaneous abortion rate increased three to four times and stayed raised for several years. The rate of congenital malformations increased.

A study prepared by ICMR found that the spontaneous abortion rate following the gas leak was 24.2 per cent, about three times the national average. The stillbirth rate was 26.1 per 1,000 deliveries, compared with a national figure of 7.9 per 1,000. A year after the disaster the infant mortality rate in Bhopal was 110 per 1,000 births, compared with a national average of 65.2 per thousand (1).

5.4.4 Treatment

No official line of treatment was forthcoming because of the lack of information. On December 5, a telegram from UCC recommended amyl nitrites for cyanide poisoning, and if needed also sodium thiosulphate. Later this was withdrawn.

A telex message on December 11, 1984, from the Disease Control Centre at Atlanta gave the following information (17):

- No antidote is known for MIC exposure.
- Give cortisone and oxygen.
- If cyanide poisoning is suspected, it should be treated suitably.

In the acute phase, eyes were treated through irrigation, homatropin, and local antibiotics and in some cases corticosteroids (26). Symptoms from airways and lungs were treated with oxygen, bronchodilatators, diuretics and corticosteroids. When steroid treatment was stopped after 2–3 days, pulmonary oedema returned in about 40% of the patients, and was resolved when steroid therapy was reinstituted. Stomach problems were treated with antacids. Antibiotics and corticosteroids were not available in sufficient quantities (7).

5.4.5 The Detoxification Question

The detoxification issue is described by Kulling and Lorin (26), Sathyamala (38), Jones (12) and in the Trade Union Report (13).

The question of detoxification is one example of the confusion of the scientific and medical establishments that characterised the first year after the leak.

The day after the gas leak, there was a telegram from UC in Virginia, saying “use sodium thiosulphate if needed”. Later this was withdrawn. To admit that NaTs could give symptomatic relief would be to admit that the toxic gases had crossed the blood-lung barrier.

In December 1984, a small double blind clinical trial on intravenous administration of NaTs was carried out by ICMR. A highly increased excretion of urinary thiocyanate and marked symptomatic relief followed.

Based on the experiences from the trial, NaTs was recommended as the drug of choice, and guidelines were drawn up. Three days after the press statement by ICMR, there was another press statement from Gandhi Medical College, with argues that there was no evidence in medical literature about any form of chronic cyanide poisoning. On the bases of this statement, the MP Government decided not to support NaTs therapy.

In April ICMR released some more information, and the MP Government officially sanctioned the use of NaTs. During the period June 1985 to middle of 1987, NaTs treatment was given at JSK (Peoples Health Centre), a NGO clinic.

5.4.6 Comments

5.4.6.1 Mechanisms

It is obvious that most of the organs of the body were affected by the gases and/or hypoxia. Four different mechanisms may be responsible for the damage to the body:

- Direct damage to the mucous membranes of the respiratory tract, the stomach and the eyes;
- Damage to the brain caused by lack of oxygen;
- Toxic effects on cells after penetration of the blood stream, including chromosomal aberrations;
- Post-traumatic stress disorder (PTSD).

5.4.6.2 Disaster management

Exposure to the gases would have been reduced if the inhabitants had

- been warned by the alarm earlier;
- covered their faces with a wet cloth;
- stayed inside if they lived in good houses;
- walked instead of run;
- moved at right angles to the wind instead of moving in the same direction as the wind.

It is likely that exposure to different toxic compounds would have been reduced if the inhabitants had been reached by the information of the necessity to wash their clothes and homes and not to eat or drink contaminated food or water, and if clean food and water had been distributed.

5.4.6.3 Medical treatment

Subsequent research has shown that the treatment that is indicated for toxic pulmonary oedema is symptomatic treatment with oxygen, beta-2-stimulators, and when needed, continuous positive airway pressure (CPAP) or positive end-expiratory pressure (PEEP). There are different views on the relevance of treatment with corticosteroids (39, 40). It is obvious that the doctors in Bhopal gave the best treatment, using the resources they had. Because of having no training in disaster medicine, they might, however, have used the respirators on patients who were doomed to death already from start of treatment.

The indicators that cyanide was present in the gases are strong. It is obvious that sodium thiosulphate, which is a very non-toxic substance, should have been tried as an antidote on a large scale, as soon as possible. There was no real reason not to try it at a later stage. It is very possible that impairment would have been mitigated for a large group of survivors if they had been treated with sodium thiosulphate as soon as it was available in Bhopal.

The question of detoxification is one example of the confusion within the scientific and medical establishments that characterised the first year after the leak.

To admit that sodium thiosulphate could give symptomatic relief would be to admit that toxic gases had crossed the blood-lung barrier. This is probably the explanation of why UCC withdrew their recommendation on treatment.

6 THE POST-EVENT PHASE

6.1 LONG-TERM EFFECTS ON HEALTH

6.1.1 General aspects

For several years, there were different opinions about the long-term effects. UCC consistently maintained that MIC could not cause permanent impairment. Parts of the scientific and the official establishments were of the same opinion. The victims' organisations, activists and NGOs, however, have fought to have their opinion acknowledged, namely, that thousands of people have been permanently disabled by the gases.

In 1986, Dr CR Krishna Murti, who was the president of the commission that investigated the accident, visited Stockholm (26). He stated that 30,000–40,000 persons had persistent disabilities. He recognised the following categories:

- Those who were so seriously disabled that they cannot work. They often experienced difficulties in walking or cycling because of bad co-ordination.
- Those who had some persistent dysfunction in the airways and suffered from chronic pulmonary insufficiency, but still manage to work.
- Those who seem well, but who have a strongly decreased resistance to infections, especially in the lungs and airways.

The experiences of witnesses at different distances from the plant differed: Those living close to the factory suffered from very severe acute as well as long-term symptoms. For some, the symptoms became aggravated with time. Those who lived a little further away, or who spent the night on the second or third storey, recovered better, with only a slight degree of breathlessness remaining. Those who lived on the slopes of the southern part of the Old Town have no remaining symptoms, but they live with the memories and are worried about the effects on future generations.

In their annual reports from 1990 and 1992, the ICMR reports on the long-term studies, in which many long-term health effects were found. The long term symptoms 10–15 years after exposure are investigated by IMCB (41, 42, 43, 44, 45), Eckerman (46) and Sambhavna (34). Earlier findings were verified.

In the most affected bastis, Jaiprakash (JP) Nagar, at least one person in every family is acutely ill, and at least two people in every family are under constant medication. There is a tendency of accumulated deaths in certain families.

The survivors complain about breathlessness, coughing, chest pains, fatigue, body aches, abdominal pain, numbness and tingling in the limbs, weak sight and runny eyes, anxiety attacks, bad memory, concentration difficulties, irritability, headache and mental illnesses.

An unusually large number of women have menstrual irregularities and excessive vaginal secretions. Mothers complain of retarded physical and mental growth in children exposed at infancy or born after the disaster.

Symptoms of fever, burning sensations in the body, loss of appetite, numbness and tingling in the limbs, backache, giddiness and *ghabravat* (panic attacks) seem to have manifested 3–4 years after the disaster and are getting worse.

A reasonable estimate is that 200,000 people are permanently impaired.

The ICMR centre in Bhopal closed down in December 1994, after ten years work. The Centre for Rehabilitation Studies (CRS) at the MP government has now taken over responsibility for the long-term research.

6.1.2 Investigated and reported long-term effects

Many of the epidemiological and clinical studies have methodological shortcomings, which are discussed in chapter 6.2.

The eyes show chronic conjunctivitis, deficiency of tear secretion or eye watering, persistent corneal opacities and the early onset of cataract (23).

Findings concerning the respiratory tract include abnormal lung function with obstructive and/or restrictive disease, aggravation of old diseases like tuberculosis and chronic bronchitis, and pulmonary fibrosis (23).

Some studies show impaired cell-mediated immunity in rats. The human studies, however, have limitations that make it difficult to arrive at definitive conclusions regarding the influence of the gases on the immune system.

Neurobehavioural tests show impairment of memory, attention response speed and vigilance (23) as well as finer motor skills (44). There are also neuromuscular symptoms such as tingling, numbness and muscular aches (23).

The psychological problems are post-traumatic stress disorders, pathological grief reactions, emotional reactions to physical problems and exacerbation of pre-existing psychiatric problems (23).

There is also reported menstrual cycle disruption, leucorrhea and dysmenorrhea. No long-term studies on women's reproductive health have been done.

In 1989, the still-birth rate, the crude birth rate, the perinatal death rate, the neonatal death rate and the infant mortality rate were all high in severely affected areas, compared to rates in less affected or control areas (7).

The affected children have the same symptoms as the adults. A higher incidence of psychiatric illnesses, febrile illnesses, acute respiratory infections, gastrointestinal infections and other superficial infections of the skin, eyes and ears was reported, compared to control groups (47). There are also reports on intellectual impairment and epilepsy (48). Failure-to-grow, delay in gross motor and language sector development was found in children born a considerable time after their mothers' exposure to the gases (49).

Chromosomal aberrations were found to occur in exposed persons (50, 51). A population-based cancer registry has been established in Bhopal, but it is not expected that the onset of gas leak related cancers would occur before the 30 to 40 year lag period (23).

According to an article in the *National Mail*, 30/11/1994, the doctors working in the areas affected by the gases agree that there has been a marked increase in the number of tuberculosis cases in Bhopal. No specific study has been conducted though and there is no central TB-register for Bhopal.

At Sambhavna, symptoms, findings and treatments are documented for every person at every visit (34). Most patients over the age of 40 suffer from chronic obstructive airway diseases. Sixty patients were diagnosed with TB. Many patients have hypertension. Corneal opacities are found and refractive errors in young gas victims are common problems. This is the

impression also at the BHT clinics, although there is no documentation. Menstrual abnormalities and vaginal discharge are also common symptoms. Twelve women who were in their twenties at exposure have secondary amenorrea.

6.1.3 Bronchiolitis obliterans and Cor pulmonale

Breathlessness is the most pre-dominant symptom among the survivors. The commonly used diagnosis is bronchiolitis obliterans (BO). BO is a pulmonary disease connected with many conditions, among which are toxic damages like inhalation of nitrous or chloride gases (33). It is mainly a histological diagnosis, with thickening of membranous bronchiole including collagenous storage and fibrosis. If lumina are constricted, the patient will be seriously and irreversibly obstructive.

The symptoms are coughing and increasing dyspnoea and obstructivity. At auscultation a rattling sound is heard, but seldom the rhonci. X-ray and laboratory examination is usually normal. Spirometria shows strongly reduced FEV_1 (forced expiratory volume per second) with normal or even increased diffusion capacity.

There is no cure for BO. Corticosteroids initially may reduce the inflammation. Broncho-dilators seldom have good effects on the obstructivity. The long-term prognosis for BO is bad.

When the damage to the lungs is serious, the flow of blood through the lungs is restricted. The heart must use more power, which leads to an increase in the size of the heart, so called cor pulmonale. Too little oxygen-rich blood from the lungs reaches the body, and the patient becomes still more handicapped through restricted physical activity.

6.1.4 Post traumatic stress disorder

Post traumatic stress disorder (PTSD) was first used to describe Norwegian civilian sailors, who had been threatened by the German navy during the second world war. Decades after the war had stopped, they were still being hit by their experiences.

Common problems are lack of control of impulses and problems with aggressiveness, susceptibility to noise, tendency to isolation, sleeping problems and tiredness (52). Addiction problems occur to a larger extent in patients with chronic PTSD. The experience of pains is a common sign of somatisation.

Re-experiencing the trauma is a necessary criterion for the diagnosis of PTSD. This may happen when the patient is reminded about the trauma, or has nightmares.

Post-traumatic stress disorder (PTSD), if not treated properly, can lead to persistent somatic symptoms (52, 53, 54, 55).

6.1.5 Comments

The impression gained is that the information from UC as well from the Indian Government and ICMR was meant to give a picture of mild injuries only. The long-term effects were not illustrated in the court. There seem to be several reasons for this fact:

- UC wanted to reduce their liability.
- Many of the leading doctors of ICMR were closely related to UCIL.
- Would careless handling of cyanide be regarded as murder in the US?
- Multinationals did not want mother companies to be responsible for daughter companies. If this were the case, it would affect the global market.

- The Government of India desired not to alienate multinational capital.
- There was pressure on the Government of India from the local chemical industry, which wanted no restrictions.
- The Government of India had invited chemical industries to establish themselves in India.
- The Government of India did not want to spend much money on health care.

Not one of these reasons is related to caring about the victims.

6.2 EPIDEMIOLOGICAL AND CLINICAL RESEARCH

6.2.1 TATA-institute

A TISS-survey on socio-economic factors dealing with about 25,000 families was undertaken immediately after the disaster by the TATA Institute of Social Science in Bombay. The data is still not released.

Children born after the leakage were not included in the survey (10).

6.2.2 Indian Council of Medical Research

After the leakage, the Ministry of Gas Relief decided to set up a research institute in Bhopal for ten years. During this period, the Indian Council of Medical Research (ICMR) conducted a long row of studies. The institute was closed in January 1995. Up to that point, the authors were not allowed to publish their results. The author of this account was the first outside person ever to receive a report through official channels, in 1995. On the first page of the 1990 and 1991 annual reports is printed: "The contents of this report should not be reproduced, reviewed, abstracted or quoted without the written permission of the Director."

Research personnel were employed on a temporary basis and several projects suffered due to the transfer of the principal investigators employed by the state government (34).

ICMR initiated 24 research projects on different areas. However, many areas like fertility and immune deficiency were not covered, although scientists suggested them. Some studies, for example on children exposed in-utero, were terminated after six years, before definite results could be gained.

The last two projects were terminated in December 1994. There was no review of data prior to termination of the studies to determine whether some of them needed to be continued or whether any fresh studies were required to be commissioned. Members of IMCB had put forward 18 project proposals that were not taken into consideration.

Long-term effects of MIC are measured through cohort studies. From the estimated exposed population of 521,262 persons, 20.3 % or 80,021 persons were chosen. The cohort has been stratified in relation to the estimated degree of exhibition, that is, in which of the areas classified as "exposed" they live. Critics consider the cohort as being rather unevenly distributed in the settlements (10). The control group lives in an area classified as "not exposed". The method of measuring is through surveys considering symptoms. Those who move outside the areas are not followed up.

There is bias in the cohort:
- The control group is probably also exposed, although to a lesser degree.
- Those who were very seriously affected by the gases, and those who have hopes of economic compensation, are more likely to remember – or even exaggerate – their symptoms (recall bias).

- Those who lived close to the factory were not only exposed to MIC, but also to many other toxic substances as well as hypoxia.
- In the group that moved out, young women who get married predominate. This leads to underestimatation of symptoms related to women's reproductive health, including malformations of babies.
- No one below 18 years was allowed to register in 1984.

There are also confounding factors:
To live at a longer distance from the factory also means

- The composition of the gases changed;
- The risk of damage caused by hypoxia changed;
- Further away from the plant, the share of wealthy people increases, which in its turn means
    - less exposure because of better housing;
    - being less affected by the gases because of better health;
    - less exposure to other hazardous factors after the gas leak, such as air pollution and infections;
    - better possibilities of taking care of their own health.

Most of the clinical studies, e.g. of children and of psychological effects, were uncontrolled observations on small populations, which led to serious methodological shortcomings. Mehta et al (30) stresses that on a strictly scientific level, these studies do not conclude causality. However, many of the conclusions are supported by experimental studies.

I have been told that when a foreign scientist visited ICMR, the members suggested that he should also look at the neurological sequelae. However, this was "forgotten" by the management.

There are also other fields where the research is rudimentary or missing. Very little has been done on female reproduction including chromosomal aberrations.

Nothing on PTSD (post-traumatic stress disorder) was done by IMCB. This syndrome might at the time have been relatively unknown in a country like India, but should have been recognised by western expertise.

Children born after the disaster are not included in the ICMR research (10).

6.2.3 Centre for Rehabilitation Studies

The research task, including the cohort, was in 1995 given to the Government of Madhya Pradesh, the Centre for Rehabilitation Studies (CRS). A fund of Rs 5 crore was made available by the Ministry of Chemicals and Fertilisers, and 50 persons have been employed on a contract basis.

A study on morbidity and mortality has been carried out. According to this, deaths due to heart problems, gastro-intestinal problems and maternal deaths are half or less among the exposed population as compared to an unexposed population (34). It is questionable whether the data has actually been collected in the field.

Four long-term studies were planned, but it is unclear whether they ever started. There is no system for monitoring and supervision of the centre's research activities.

6.2.4 Bhopal Cancer Registry

The Bhopal Cancer Registry was established by ICMR under the National Cancer Registry Programme in 1986 to ascertain the magnitude of cancer problems in the central part of India and also to study the carcinogenic effects, if any, of toxic gas exposure at Bhopal (56). The main objectives of the Bhopal Registry are registration of all cancer cases of residents of Bhopal, and to generate a database to evaluate risk factors and to follow up the gas exposed population.

The Government of MP has not permitted the Cancer Registry to use the cohort. In a study on cancers of the lungs, oropharynx and oral cavity, the distance to the plant at the time of the leakage was not dealt with as a confounding factor (56).

There are plans to start a cervix cancer-screening program, but so far, the SRS has not provided economic resources.

6.2.5 The Tuberculosis Hospital

As far as known, no research is done at the Tuberculosis Hospital.

6.2.6 Non-governmental organisations

Several small studies were done by NGOs or private persons (46, 57, 58, 59, 60, 61). However, some of these studies suffer from unscientific design, bias, small sample sizes and inadequate ascertainment of exposure.

6.2.7 IMCB

The International Medical Commission on Bhopal (IMCB) spent three weeks in New Delhi and Bhopal in January 1994. The following subjects were studied:

- Morbidity of survivors (41, 43, 42)
- Socio-economic conditions and children's health (44)
- Compensation issues (62)
- Health infrastructure (63)
- Pharmaceutical use among survivors (64)

In the survey on morbidity, it is still unclear why the population from the "control area" had so many symptoms. Neurological examination was not performed for about a third of the chosen population, and the results of the physical examinations are not discussed in the article.

The study of socio-economic conditions and children's health took a qualitative form. The interviews were facilitated by a group of interpreters of varying quality. It gave the interviews a superficial character. The submissions might also have been biased because the women hoped to gain some kind of reward.

The compensation issue is very complicated, and the time and the experiences of the group did not allow for a high quality study.

The studies on health infrastructure and pharmaceuticals do not need comments.

6.2.8 Sambhavna

At Sambhavna, the patient records are computerised. This is used for finding data about for example age, sex and symptoms (34). Some small and well-designed studies on treatments have been conducted, for example on yoga treatment (34, 65).

Surveys on the status of health and health-care are done during home visits in the most affected areas. One study on distribution of medicines in the gas-affected area is completed.

For assessment of the probable cause of death of persons in the affected area, a method called Verbal Autopsy is used, with the help of three external doctors and in co-operation with London School of Hygiene and Tropical Medicine.

6.2.9 Comments

Although the quality of the clinical research varies, the different reports support each other. The findings are also supported by animal experiments.

We are still waiting for the final report from ICMR. We are also waiting for ICMR to release the names, addresses etc. of the cohort, so the Centre for Rehabilitation Studies and the Bhopal Cancer Registry can continue following the cohort.

The official set-up for monitoring exposure-related deaths was disbanded in December 1992 (34, 66). This means that late cases caused by respiratory and/or cardiac insufficiency, cancer and TB will never be highlighted.

In the procedure involved in getting their final compensation, the survivors must hand over their papers. In the future, it may be very difficult to do "sound epidemiology" on exposure and disease.

A programme for "outbreak disaster epidemiology" should be drawn up. The WHO could be responsible.

The recommendations could include the following parameters:

- Find all the important parameters for registration.
- Register the entire population, including children and the non-affected.
- Choose a cohort, of all ages, for long time studies. Every person must be followed up, even if they move.
- Choose certain groups like children, or fertile women, out of the cohort for more detailed studies.

To improve studies of the disaster that led to exposure to chemical and/or radioactive compounds:

Include monitoring for cancer, reproductive health, hormone systems and neurological systems. Always include monitoring for psychological symptoms (post-traumatic stress disorder – PTSD). If several organisations are collecting data, this should be co-ordinated, and it should be possible to combine the different databases.

6.3 SOCIAL AND ECONOMIC COMPENSATION

6.3.1 Economic compensation

The process of claims is described by Jaising (67), Jones (12), Jaskowski et al (62), Cassels (1), BGIA (10), Pandey (37), Morehouse (3) and in the Sambhavna report 1998 (34).

In March 1985, the government of India passed the Bhopal Gas Leak Disaster Act. It gave the government the statutory right to represent all victims in or outside India. The government constituted itself as the sole representative of the victims, with full authority to litigate on their behalf and to settle their claims. The Act empowered the government to frame a scheme for registering and scrutinising the claims of the victims.

In 1985, Union Carbide made an offer of US$ 350 millions, the insurance sum. The government of India refused to accept the offer most emphatically and claimed US$ 3.3 billions. In February 1989, the proceedings were still going on in the Supreme Court of India. There were few signs of progress, Union Carbide denied all liability. After lunch on February 14, it was announced that a settlement had been arrived at. Union Carbide agreed to pay US$ 470 million in full and final settlement of its civil and criminal liability. This sum corresponds to the insurance sum of US$ 350 million plus the interest. There is no explanation why the government of India so suddenly agreed to this sum.

No one under 18 years of age was allowed to register as a victim. To start with, the claimants were expected to prove "beyond reasonable doubt" that death or injury in each case was attributable to exposure. Interim relief started to be paid out only in 1990, and since 1993 the final compensation is paid out. It is not clear how many victims do not have the documents needed to get compensation. The average compensation sum is 25,000 rupees (US$ 830).

6.3.2 Occupational rehabilitation

The Special Training and Employment Programme for the Urban Poor was an ongoing scheme that was used for the gas victims (35). The strategy included the upgrading of skills in appropriate trades, like sewing, stitching and production of stationery items, combined with the grant of a loan of up to Rs 12,000 for self-employment. Fifty worksheds were to be constructed, and 2,500 persons were to be trained.

Only 33 of the worksheds were ever started. 2,300 women were employed. The worksheds ran at a yearly profit of Rs 1 crore (34). The worksheds were also a meeting place for the women. All except the Women's Stationery Workshop (46) were closed by 1992.

In 1986, the MP government invested 8 million rupees (US$ 2.3 million) in the Special Industrial Area Bhopal (66, 68). Here 170–200 worksheds and common facilities like a tool room, postal services, a dispensary and a communication centre were planned. Employment was meant to be provided for 10,000 persons. Vocational training for 3,600 candidates per year was planned. Only 152 worksheds were built. After some years, parts were rented to private enterprises that promised to employ gas victims. Other parts of the buildings are used by the home guard. As far as is known, no gas victims have been provided with jobs in this area.

In 1992, 200 gas-affected women were selected for a 3-month training period in the production of jute handicrafts.

The MP government has announced plans to start colleges of Medicine and Engineering for the rehabilitation of gas victims. It is not know how many of the young gas victims have the necessary education to be allowed to enter these colleges.

Union Carbide runs a rehabilitation programme for their employees, which gives jobs to six to ten people. They are put in different workplaces, so that they cannot communicate with each other.

It is estimated that 50,000 persons need alternate jobs, and that less than 100 gas victims have found regular employment under the government's scheme (34).

6.3.3 Habitation rehabilitation

For gas widows and their families, two- and four storey houses with 3,000 very small one room flats have been constructed outside the town. The widows do not pay any rent.

The height of the houses is a problem to those supposed to live there, as many have difficulties in walking up one set of stairs because of respiratory dysfunction. The water from the water tower does not reach the third and fourth floors; it has to be carried up. It is not possible for the families to keep cattle. There is still infrastructure missing, like buses, schools, banks, workplaces and health centres.

In 1991, during the rainy season, 756 houses in a mildly exposed area, all but four of which belonged to Muslims, were demolished with bulldozers under the close supervision of an armed police force (10). The families were taken out of town to form new settlements, provided with a small amount of money, some building materials, no roads but a few water taps.

Today, the houses opposite the UCIL plant are "puccha" houses, compared to the "kuccha" houses of 1984. The standard of living has risen since 1984 (46). There is evidence that the economic compensation combined with permanent employment has made this possible.

6.3.4 Environmental rehabilitation

The Government of Madhya Pradesh has compiled a list of rehabilitation measures (69) that includes pumps and tree planting. But money meant for improving the living conditions of the survivors was spent on routine municipal activities like resurfacing of roads, planting of trees and construction of drains, in areas that were not or only slightly affected by the gases (70). Many of the pumps are said to be dysfunctional after roadwork, and the water is said to be contaminated from the sewage drains.

The area around the plant was used as a dumping area for hazardous chemicals in the "solar evaporation ponds". Water in over 200 wells around the Carbide factory has been declared unfit for human consumption by the municipal authorities (34). Analysis undertaken in 1990 shows the presence of toxic chemicals in the surroundings of the plant (5). In 1994, a collaborative investigation was done with a UCC paid company and an Indian government agent. The study recommends a fuller investigation for better assessment of the environmental contamination (34).

In 1996, the company management dug up the bottom soil from the solar evaporation ponds and buried the sludge under three metres of farm soil (34).

6.3.5 Comments

With the Bhopal Gas Leak Disaster Act, the government of India became the "lawyer" of the victims, as well as part owner of the company. Today the victims are fighting their "lawyer" to get their rights.

The survivors, who after the leakage had become still poorer than they were before, must find money for bribes and fees to get their economic compensation.

A dependable system for economic interim relief ought to have been developed much earlier. Directly after the leakage, every person, also children and the deceased, should have been registered in a reliable way. This register should have become the base for compensation and rehabilitation.

A system of life-long pensions for those who cannot support themselves should have been developed, to assist groups like widows, orphans, the chronically ill and disabled survivors.

Survivors are exposed to increasing concentrations of air pollution from fires from cooking, diesel vehicles, two-stroke engines, burning of waste, all of which may further injure their lungs.

6.4 MEDICAL TREATMENT AND REHABILITATION

6.4.1 Health care infrastructure

6.4.1.1 Governmental health care

In the immediate aftermath of the Bhopal gas disaster, the health care system became tremendously over-loaded.

Within weeks, the State Government established a number of hospitals, clinics and mobile units in the gas-affected areas. Towards the end of 1986, 18 medical institutions were working in the gas-affected areas: twelve under the Chief Medical and Health Officer (Gas Relief), five under the Indian Red Cross Society, and one eye hospital under the Royal Commonwealth Society. The hospitals were upgraded with more beds and better equipment.

No infrastructure for alternative abortion or ultrasonography was established (12).

The government of India has focused primarily on increasing the hospital-based services for gas-victims. In addition to the already existing hospitals with a total of 275 beds, five additional hospitals with a total of 42 beds have been built. The Pulmonary Medicine Centre was completed in 1994, but in 1998, still had no permanent staff (34). The Indira Gandhi Hospital for women and children was completed in 1994, but still did not function in 1998 (34). In spite of this, it was inaugurated in September, probably to release the funds for the second action plan (5). The construction of the 540-bed Kamla Nehru Hospital is going on since 1987 and the expenditure is nearly three times the budgeted amount (34). It has been transferred from the Department of Gas Relief to the Department of Medical Education. In the interim, the survivors are being offered the 80 year old 300-bed Sultania Zenana Hospital (66).

In 1994, there were approximately 1.25 hospital beds per 1,000 in Bhopal, which compares favourably to the recommendation made by the World Bank of 1.0 beds per 1,000 in developing countries (63). Around 4,000 persons per day visit government hospitals.

The hospitals received new equipment after the leak. However, there is a lack of people who know how to use it. Much of the equipment is dysfunctional, or accessories are missing (34, 66). In the Pulmonary Medicine Centre alone there is equipment worth Rs 1.25 crores that is lying unutilised since the time it was purchased.

The primary health care system is not very well developed. In 1994, the government ran two clinics and eight dispensaries. In the Action Plan submitted by the state government for the granting of funds by the centre, allocations for community health services make up only 2 percent of the total budget (34, 66). The dispensaries are going to be handed over to the Bhopal Hospital Trust.

There is one tuberculosis hospital in Bhopal, in addition to the District Tuberculosis Centres. The National Tuberculosis Control Programme should be followed here. It includes free treatment for at least six months for everyone who is sputum positive. A follow-up by Sambhavna community workers shows that it is common that the patient has to buy at least one of the medicines and many are denied medicines. As the hospital is open only a few hours every morning, it is very difficult for working people to reach it. It requires considerable effort for a gas victim to get treatment for TB (34).

Three projects under the Integrated Child Development Scheme (ICDS) were sanctioned in the affected areas to look after infants and children in the age group of six months to six years as well as nursing and expectant mothers. Under the auspices of these projects, 633 Aanganwadi Centres were established for the care of infants, children, nursing mothers and expectant mothers. The beneficiaries receive a daily supply of nutritious bread, medical and health check-ups and immunisation. These centres also provide non-formal pre-school education (35).

6.4.1.2 Bhopal Hospital Trust

Union Carbide was directed by the Supreme Court to finance a 500-bed hospital for the medical care of the survivors. This was meant to include a 30-bed cardio-thoracic surgery unit and a research unit (34). A large sum of money has been set aside for the Bhopal Hospital Trust (BHT). To save its resources for those patients who need it, it should only see patients who are referred from outpatient clinics. The hospital, which is situated 8 km away from the gas-affected area, was inaugurated in September 1998. Because of the lack of personnel and equipment, there is still none or only rudimentary activity at the hospital in 1999.

In 1998, two out-patient clinics had been opened in the gas-affected area, and eight more were planned. In the clinics 4–5 doctors are working. 100–200 patients visit each clinic per day. Each patient is registered and for the use of the clinic, registration data is computerised. Patient records are not used. All data on symptoms, examinations and treatments are written in the health booklet that is given to every patient. Medicines are provided free, except uncommon medicines that are not stored in the clinics. In one of the clinics, rational prescription is the guideline.

The laboratories are well-equipped and provide routine biopathology, including blood- and urine microscopy, electrolytes, calcium, liver tests and cultivation. Eye-microscopy, refraction examination of eyes, spirometry and routine x-rays are also available at the clinics. However, doctors working at the clinics admitted that the resources at the clinics are sparsely used for the visiting patients.

6.4.1.3 Private doctors

Since the leakage, a very large number of private practitioners have opened clinics in Bhopal. Of the private doctors in the severely affected areas, nearly 70 percent are not professionally qualified (34).

6.4.1.4 Non-governmental organisations

Radical health groups, such as the Drug Action Forum and the Medico-Friend Circle, provided medical staff for the JSK (the People's Health Centre) set up by the combined opposition in June 1985. It was a free outpatient clinic working with education and public health. Because of overloading and trouble with the authorities, it was closed down after a few years.

Mother Theresa's Missionaries of Charity were reported to be operating a treatment camp at the Bhopal railway station for UCIL (12).

In 1985, the Indian Red Cross Society was given 5 million dollars by UCC. Four community clinics were set up in the gas affected area (34). Four years later, UCC had the Indian Red Cross hand over all its remaining funds, and the clinics were closed down, the last one around 1995. They are now prepared for transfer to the Bhopal Hospital Trust.

The Sambhavna Trust was registered in June 1995 as a charitable trust with objectives concerning the welfare of the survivors of the Bhopal gas disaster through medical care, research, health education and information dissemination (34). It is directed by six national trustees, with an international advisory group of five person attached to it. International and national volunteers give support, and it is co-operating with survivors' organisations as well as national and international non-governmental organisations. The funds are built up from money collected from individuals in the UK, USA, Australia, India and other countries, after advertising campaigns.

In 1996, the Sambhavna Clinic was opened. It is a small clinic, with two doctors of modern (allopathic) medicine, one of Ayurvedic medicine, two Yoga teachers, two massage therapists and three community workers. Basic laboratory facilities for the examination of blood, urine, sputum and smears are available. The dispensary provides modern as well as Ayurvedic medicines free of charge. The work is thoroughly described in the 1998 report (34). Between 20 and 100 patients come here every day. Yoga and health camps have been held as well as seminars for doctors.

6.4.2 Treatment

The ICMR working manuals of 1986 (70) and 1989 (47) gave advice on management of treatment.

For respiratory symptoms, bronchodilators are recommended for those patients who show evidence of reversible airway obstruction. Corticosteroids may be used "as bronchodilators" for long-term treatment if a significant benefit is likely. Long-term side effects are described. Antibiotics are recommended for 6–8 day courses as soon as the sputum becomes purulent, and as prophylactics during acute viral chest infections in-patients with badly damaged lungs. Other drugs recommended are anti-anaemic drugs, analgesics, vitamins, cough suppressants and expectorants.

Recommendations for children include bronchodilators, steroids for acute episodes and for long-term treatment, sodium chromoglycate, antibiotics, expectorants, mucolytics and high doses of vitamin C.

A TB treatment programme is included in the manuals. It gives different alternatives for treatment lasting at least 6 months.

For psychiatric problems, anxiolytic drugs and antidepressants are recommended for both children and adults. There is no warning about the side-effects of long-term use of diazepam.

Non-pharmaceutical treatments are also recommended in the manuals:

- Respiratory exercises, physiotherapy and postural drainage for respiratory problems;
- Psychotherapy for psychiatric problems;
- Balanced diet;
- Physical exercises and yoga;
- Health education ("The patient must stop smoking for life");
- Social, economic and occupational rehabilitation.

However, there do not seem to be any resources provided for either physiotherapy or yoga, nor for psychotherapy and health education. The available social, economic and occupational rehabilitation is described in chapter 6.3.

In 1990 a study on 13 patients at two government hospitals for gas victims found that patients were being prescribed irrational or unnecessary medicines as well as medicines known to be hazardous, having been banned in other countries (34).

In the study by IMCB in 1994 (64) it was found that the therapies prescribed seemed to be aimed at giving temporary symptomatic relief rather than long-term amelioration of a chronic disease process. The patients reported the best effect on respiratory symptoms from bronchodilators and corticosteroids, but only a minority of patients with symptoms in the lungs received bronchodilators. In the government hospital sample, complaints of breathlessness, cough, chest pains and colds were all treated primarily with antibiotics, analgesics and anti-histamines. Vitamins were routinely prescribed as well as tonics and enzymes.

Drugs with a significant potential toxicity were prescribed in preference to less toxic alternatives. Analgin and hydroxyquinolin have been banned in many countries. Oral corticosteroids were used for rashes and also as primary therapy for pulmonary symptoms. Often fixed dosage combination medicines were given; some in combinations that have the potential for inducing serious toxicity. Several drugs prescribed for the gas victims have the potential for inducing significant iatrogenic disease (64).

Drugs used commonly are analgesics, bronchodilators, steroids, antacids and H_2-receptor antagonists (Ranitidine). Chloromycetin ointments and sulphacetamide eyedrops have been liberally used (34). The private doctors prescribe steroids, intravenous drips and antibiotic injections indiscriminately (34).

In the 1996 Sambhavna study of 50 chemist shops, it was found that the quality of the prescriptions was low (34). The three most sold drugs were anti-infectives, enzymes/tonics and cough syrups. The following groups had an "unknown composition": Ayurvedic drugs, analgesics, steroids and anti-ulcer drugs. Useless, hazardous and combinations of irrational drugs were mostly given for ill-defined symptoms, and appropriate drugs were more used for well-defined symptoms or conditions.

Drugs are supposed to be provided free of charge at the government hospitals, the TB-hospital and the BHT clinics. However, in 1998, 30–40 percent of the medicines were out of stock in two hospitals (34). This verifies what the patients say, that they have to buy medicines outside the hospitals (44).

There is no information on the efficacy of the treatments at government and private hospitals or clinics, as no evaluation is made. At Sambhavna, it is documented that a substantial number of persons have not found relief through the treatments, and many report a relapse of symptoms (34).

In 1997, at Jawaharlal Nehru Hospital close to the most affected area, 80 percent of the medicines meant for delivery free of charge were out of stock (66).

6.4.3 Documentation

During the first days after the leakage, it was impossible for the medical staff to organise any kind of documentation. Nor was it done later. In December 1985, it was reported that proper medical records only existed for less than 10,000 victims (12).

In 1999, these conditions have not changed much. In the government hospitals, the patients gather in the emergency departments, and are treated as if they only have acute complaints. If a record is written, it is placed on the top of the day's records and later put in some storeroom. In the government hospitals and clinics, it is not possible to follow the development of the health of an individual patient. Sometimes the patient is given the records.

Private doctors often give the records and results to the patient.

In Sambhavna, everything is documented in two ways: in a health booklet for the patient, and visit cards for the clinic. The latter are all collected in an individual envelope, with a unique code, for each patient. Administrative as well as medical data is entered in a computer program (EpiInfo).

In the BHT clinics, all medical documentation is entered in a booklet that the patient in the beginning carried him/herself. Now the clinics keep the books, maybe because Sambhavna made a small study on the content of the books. Administrative data is entered in a computer program.

6.4.4 Survivors' views

Many survivors express a common dissatisfaction with the health care facilities (44, 63, 71, 72). They pay a lot of money, but they are not cured. Often they have to pay for medicines that should be dispensed free of charge. Other reasons for dissatisfaction with hospital services were overcrowding and long waiting times, lack of proper attention, distance and behaviour of doctor/staff not being professional. The complaints are similar to those expressed by other slum dwellers (9).

Those who can afford it, prefer private doctors to the government hospitals, as they consider that they are listened to better there (44, 46). In surveys it is found that 77 percent of the persons undergoing medical treatment visit private clinics (34).

Survivors' organisations have long been demanding the setting up of a community based health infrastructure in which medical care and monitoring services are available to persons within the community itself and the hospitals are used as referral centres (34).

In letters, the survivors' organisations have opposed the building of the Bhopal Trust Hospital, and said that "in the absence of any information based treatment protocol being offered, the Trust's hospital will be just one more building, good to look at, but ineffective in care" (34). They are calling for the setting up of a competent local body with survivors' participation that would take control of the funds and administer appropriate health care among the gas affected population.

6.4.5 Recommendations from IMCB

The International Medical Commission on Bhopal (IMCB) has made recommendations on medical, social and environmental rehabilitation. It proposed a four-tier health infrastructure with community health units as the base in place of the current hospital centred system (63).

IMCB also expressed serious reservations regarding the relevance of the special facilities in the Bhopal Trust Hospital.

IMCB recommended that the Government establish an independent National Medical Commission in Bhopal, and convene an International Conference on Urban Community Health Centres.

6.4.6 Comments

Health care in Bhopal has many shortcomings that would not be too difficult to improve:

- There is no formal infrastructure at community level, and there are no concrete plans for improving the community based health care system;
- The working manuals of ICMR were poorly distributed to the doctors;
- Neither government nor private doctors use rational prescription of drugs;
- A systematic further education programme for graduated and not graduated doctors is missing;
- Alternative and non-pharmacological treatments are not evaluated properly;
- There is no systematic documentation of symptoms, investigations and treatments.

In rich countries, patient records usually belong to the hospital or clinic, and there are laws regulating responsibilities and storage. In Bhopal, it seems safer to give the documentation to the patient than to keep it at the hospital. But this will inhibit clinical research. To get the final compensation, the victims had to deliver their medical records. If copies were not made, the patient will have lost the information about him/herself.

Survivors and activists are very sceptical of the BHT hospital, as they believe it will be used by Bhopal's upper class. The future will show whether they are right.

6.5 PSYCHO-SOCIO-ECONOMIC EFFECTS ON SURVIVORS

6.5.1 Who was affected?

6.5.1.1 Demography

In 1984, Bhopal had around 800,000 inhabitants. In 1981, 38% of the population were in the age group 0–14 years (6). The 36 wards that were classified as affected had around 520,000 inhabitants (7). This means that around 200,000 children between 0–14 years were affected by the gases.

In 1985, of the total affected, 80% earned below Rs 145 per month (around US$ 5). 1,2% earned more than Rs 465 per month. 47% lived in a kuccha (non-permanent) house. 50% were Hindus and 49% Muslims (7). Muslims are generally considered to be poorer than Hindus are and it is less common for Muslim women to work outside the home.

The total population of Bhopal in 1994 was 1,062,800. The number of houseless households was 5,331. With a mean household size of 5 people, it means around 29,000 people do not have a house (8).

The per capita expenditure on family welfare services by the government of Madhya Pradesh was Rs 7.08 during 1985–1986 (9).

The inflation rate has been high. In 1994, 1 rupee was worth one-third (or 30 paysa) of the 1984 rate. Bhopal is said to have become one of the most expensive towns in India since the interim relief began to be paid out.

6.5.1.2 Those affected

One study found that 74 percent of those in affected areas fled on foot, 6 percent by vehicle (motorised or bicycle) and 21 percent remained. None of those who went by a vehicle died. A study done by the Centre for Social Medicine, Jawaharlal Nehru University, New Delhi, found that "those who died are the poorest. More than half the affected people belong to an income group – about 150 rupees per head per month – which cannot afford two full meals a day around the year. Those who died were even more disadvantaged than the overall affected population."

Henry Falk of the US Centre For Disease Control noted that people who were lucky enough to live in well-sealed homes managed to avoid the choking gas while some escaped by climbing to a higher level (12).

Small children were more severely hit than adults were. If the total immediate death toll was 2,500, the figure for children would be at least 1,000. If we instead estimate the death toll to be 8,000, this would imply that 3,000 children died within the first weeks. Severely affected children would be 13,000, moderately affected 29,000 and mildly affected children 166,000.

Some sources maintain that nearly half of those who died immediately were children (12). That would mean that 2,000 to 4,000 children died directly.

6.5.2 Long-term economic effects

The economic situation of the most affected part of the population can be categorised as follows:

- Dependence on physical and casual work for income;
- Dependence on cattle for income;
- Dependence on sons for support in old age.

A door-to-door survey in the last week of December 1984 found that 75 percent of the workforce was incapable of work, mainly because of breathlessness (13). Many families lost their cattle. Many parents and widows lost their sons and will thus have no support at all in old age.

An analysis of the socio-economic survey conducted between January 1985 and December 1985 revealed that about 25,000 families reported a total or substantial loss of income (35).

With a mean of 5 members per family, around 125,000 persons suffered from a reduced family income.

Young girls had difficulty in getting married, because of doubts whether they will have healthy children (58). When the interim relief began to be paid out, they again became interesting objects for marriage (46).

6.5.3 Long-term effects on family life

The survivors not only lost their economic standard. Their whole existence changed. "Who will care for us when we grow old? Our life has been destroyed." This sentence, from a man who lost both his sons, is repeated in many ways by hundreds of witnesses. Testimonies by survivors are well documented (34, 44, 70, 71, 72, 73, 74, 75, 76).

The loss of income not only meant a lower standard of living, but also involved worries about the future. Parents did not have sons to support them in old age any longer. Young girls did not get married and would remain dependent on their parents for a living.

The loss of health leads to restrictions in activities compared to previously, but also involves spending time at hospitals and clinics. The expenses for medicines can sometimes exceed expenses for food (44). Adults worried about their own health as well as their children's, and pregnancies were avoided for many years (44, 46).

The conditions in the family changed. In many cases some or even most family members were not there any more. Others might be ill, having not only somatic symptoms but also suffering from irritability, depression and mourning. Daughters, old enough to be married, were still around. Relatives who had lost their families moved in. - There is a mean of one ill person per family (34), but with a tendency to concentration to certain families (46).

The social life outside the family changed. Relatives, neighbours, or fellow workers were lost.

Fear led to preparedness to leave the town immediately when threats of new leaks were experienced (see 6.6.1).

The victimisation and disempowerment of the survivors is discussed in the extended version of this essay (5).

6.5.4 Comments

How seriously a person was affected was largely dependent on socio-economic factors:

- Age;
- Living area;
- Type of house;
- Access to a vehicle.

The psycho-socio-economic long-term effects might have been mitigated through investments of a different kind:

- Involving the survivors in the decision-making process;
- A community based health care system of good quality;
- Economic support immediately after the leak;
- Permanent worksheds for those who cannot find suitable work on the open market;
- Pension and boarding for those who cannot provide for themselves and have no family to provide support.

- A programme for systematic debriefing work, including psychological support;
- An environmental rehabilitation programme for the most affected areas.

6.6 EFFECTS ON SOCIETY

6.6.1 Effects on the "spirit" of the town

It is natural that the leakage occupied the minds of people for some time afterwards. Bidwai writes one week after the event, "there is a total collapse of all individual identities into a general identity – victim of Union Carbide, direct or indirect, a participant in the collective trauma, the sufferer in an unending purgatory" (77). However, the "victimisation" seems to have become permanent (44, 46).

The change was also physically noticeable. Before the leakage, all the boys would be out on the streets playing cricket. After the leakage, the streets were silent. No boys played cricket – they did not have the breath.

The day after the leakage, several thousand Bhopal residents tried to storm the factory. Plant officials and police guarding the plant only succeeded in turning the crowd away by telling them that another poisonous gas leak was in progress (12).

One day shortly after the leak, there was a rumour that there had been another gas leak in the Union Carbide factory (35). This led to people leaving Bhopal for neighbouring districts. "Operation Faith" was the second exodus out of Bhopal. A third exodus took part in March 1985.

The migration out of Bhopal was affected by the fear of another leak, anxiety over soil and water contamination, and difficulties in earning one's living. Many of the migrants may have stayed away for a long time. There was also a return migration of people originally coming from other places. They left Bhopal to go "home" where they felt safer. There are no official figures of how many migrated, but it may be tens of thousands.

The residents, UCC workers and activists in Bhopal, protested at an early stage against the behaviour of the government. In 1985, state repression towards the opposition was very strong, which resulted in mass arrests and police violence. Since then, rallies and protest meetings have become a regular part of life. Every Saturday, the BGPMUS *(Bhopal Gas Peedit Mahila Udyog Sangathan)* arranges a meeting. Foreigners are often seen taking part in the anniversary rally.

6.6.2 Effects on the infrastructure

The effects on the infrastructure and economic life are described by Chauhan (35), Cassels (1) and others.

Over half of the population of Bhopal was exposed to the gases. Those who were most affected were those who did the labouring work: road repairs, building, transport, industrial work, household work, small businesses. Many others migrated from Bhopal, for economic reasons or because of fear. When all these people did not go to their jobs, the whole town was affected.

Communications came to a stop. Key-persons for train and public transports were missing. For example, 72 railway employees were killed and about 400 admitted to hospitals. For days, truck owners and drivers were afraid of making even a single trip to Bhopal.

The State Government ordered the closure of all schools, colleges, offices and shops until further notice. The closure of the fish and meat markets did not hit only the salesmen at the markets, but also butchers and fishermen outside Bhopal. The closure of the shops involved economic losses for the shop owners as well as for the contractors. Many shops never opened again.

At least 2,000 commercial animals were killed and crops were destroyed. With shops and markets closed, the prices of food went up.

When trade, commerce, building, and industrial activity came to a halt, it led to large-scale unemployment. Not only were daily-wage labourers left without work. Around 850 workers were employed at the UCIL plant in Bhopal. Only two of them died, but all lost their jobs. There was complete collapse of administrative machinery as well.

Many migrated from Bhopal, but others came instead: lawyers, volunteers, experts, media, doctors etc.

6.6.3 The effects of the distribution of relief

In January 1985, large protests to the withdrawal of free distribution of rations were organised (12). This resulted in police violence and arrests. After this, the rations were restored.

A doctor from Bhopal describes the situation immediately after the leak (12). Food, blankets, clothing, medicines were distributed to people who lived in the area, irrespective of whether they had suffered or not. Men stopped working, got a certificate from a local doctor and joined the handout queues. People outside the affected area resented the growing level of prosperity in the affected area. This brought about a split in the society. On several occasions other residents stoned lorries carrying supplies to the affected areas.

Mr Ram Shankar Tiwari, professor of economics at the Academy of Administration, has done a survey of 21,000 survivors both before and after the disbursement of interim relief. The report was submitted to the government in 1991. In an interview in *The Chronicle*, 28/11/1994, he said that the wholesale price index as well as the consumer price index of Bhopal had gone up substantially since the distribution of relief was started. Even the cost of labour has increased.

The distribution of relief has not had much of a direct impact on the middle classes and left the rich almost untouched. In the two poorest categories (very poor and lower middle class), there was a definite increase in the number of children going to school after the relief began to be handed out. Some money has also been spent on remodelling and reconstructing the houses. There was no definite improvement in the peoples' standard of living.

In the interview, Mr Tiwari stressed the findings that money also was "frittered away on things like the consumption of liquor and gambling". He said that the money has certainly not helped to bring about a better quality of life for the citizens. Now, when the final compensation is about to be paid out, "Bhopal's economy is set to suffer total disruption and chaos. This huge amount of money will make life miserable. Except for human beings, everything else will become costly here."

Other studies have shown that living standards have increased since the gas leak, more in families where women had employment than in families where the women lost their jobs (46). Children usually go to school and many are immunised. Much of the relief is used for medicines (44).

6.6.4 Effects on the political society

The Congress (I) Party got involved in the state repression of the opposition in Bhopal (12). During the June 1985 repression, members of the party distributed posters alleging that the Morcha had CIA links. During the rally they infiltrated the crowd and threw stones at the police.

Political decisions on relief were made to gain positive publicity or even votes.

The capitalist opposition parties did not really respond to the catastrophe and its aftermath (12).

Jones (12) notes the effects on the political society in Madhya Pradesh. The Minister for Labour in the MP government resigned after accepting moral responsibility for the disaster. Two labour ministry officials were suspended and two others sent on leave. The Chief Minister dismissed the chief inspector of factories, who "went on renewing the licence of the UC factory every year without taking into cognisance the safety lapses in the factory".

6.6.5 Comments

I have not found any attempt to calculate the total costs for the leakage. They must, however, be considerable, if the economic impact on society is included.

Concerning the suggested negative impact of more money on Bhopal, no comparison has been made with inflation and increased costs in other Indian towns during the same period. Inflation has resulted in a decreasing value of the determined relief sum.

6.7 PREVENTING "NEW BHOPALS"

6.7.1 India

6.7.1.1 Laws

After the Bhopal Gas Leakage, many new acts and rules were created. The following acts and rules lay down requirement for emergency preparedness and litigation (1, 35, 78):

Acts:
- The Factories Act, 1948, as amended in 1976 and 1987;
- The Environment (Protection) Act, 1986;
- The Public Liability Insurance Act, 1991 as amended in 1992.

Rules:
- The Model Rules under the amended Factories Act;
- The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989;
- The Public Liability Insurance Rules, 1991 as amended in 1992.

The new statutory amendment to the Factories Act creates a general duty for occupiers of hazardous installations to ensure the health and safety of workers, adequate safety systems, equipment arrangements and maintenance, training and information, safe practices and processes.

The Environment Protection Act provides for better zoning of industrial locations, a more intensive system of inspections, and the development of prevention guidelines and emergency response systems.

An Emergency Preparedness Plan (EPP) has to be prepared both by the occupiers and the district authorities.

The District Industrial Health and Safety committee, under the District Collector, is supposed to supervise the safety aspect in hazardous industries and the implementation of precautionary measures. A Crack Committee is supposed to supervise the most hazardous industries.

6.7.1.2 The Disaster Management Institute

The Disaster Management Institute in Bhopal (DMI) was established in 1987, after the Bhopal Gas Disaster, by the Government of Madhya Pradesh (79). It is the only institute of its kind in India. The aims are to provide training in Disaster Management, to carry out research-oriented studies concerning causes and effects of disasters, their prevention and mitigation by management, to collect information concerning hazards and disasters, and to offer consultant services to industries and others.

A State Crisis Group has been set up, and action plans for flood disaster preparedness and earthquake disaster management have been prepared. A project on reducing the risks of environmental deterioration due to pollution from chemical industries was started in 1994 in co-operation with NORAD (Norwegian Aid and Development Agency).

6.7.1.3 Non-governmental organisations

NGOs in India have found it necessary to co-operate in networks that together cover a large area with broad competence. The Other Media and the Delhi Science Forum together with the survivors' organisations are responsible for keeping the criminal cases alive. The Bhopal Group for Information and Action (BGIA) supports local survivors' organisations and keeps in touch with an international network. The Sambhavna Trust not only provides health care, but also different kinds of support to survivors and other documentation.

6.7.2 The international society

6.7.2.1 International labour organisations

The International Labour Organisation (ILO) has developed a series of conventions:

- The Code of Safety, Health and Working Conditions in the Transfer of Technology to Developing Countries emphasises the continuing responsibility of all parties in hazard management, specifying detailed procedures for the design, operation and alteration of hazardous technologies.
- Convention No. 170 of 1990 deals with the safe use of chemicals at work.
- Convention No. 174 of 1993 deals with major industrial accidents.
- The Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy, stipulates that a national or multinational enterprise with more than one establishment should provide safety measures without discrimination to the workers in all its establishments, regardless of the place or country in which they are situated.

An ILO-aided project has identified nearly 600 major hazardous installations that will be included in a developing control and inspection plan (1).

The International Confederation of Free Trade Unions (ICFTU) is represented by the United Nations Commission on Sustainable Development (CSD), which is the UN body meant to co-ordinate Agenda 21 efforts. For the 1998 session, a declaration was prepared by the ICFTU and the Trade Union Advisory Committee to the OECD (TUAC) (37).

Trade unions also participated in the preparatory work for the Third European Ministerial Conference on Environment and Health, London 1999. The declaration includes a paragraph on health, environment and safety management.

Local trade unions are involved in environmental issues. In India, the West Bengal Cha Mazdoor Sabha is pressing for amendments to the Plantations Labour Act to bring protection and training to team workers exposed to agri-chemical hazards (37).

6.7.2.2 Inter-state organisations

Inter-state organisations have also drawn up declarations and conventions (1):

- The "Bhopal Resolution" of the European Parliament calls upon European firms to maintain levels of safety abroad that are comparable to those in place in their home operations.
- In the OECD Guidelines on Multinational Enterprises, the member states agree to regulate their multinationals doing business abroad, to ensure that their operations "are in harmony with national policies of the countries in which they operate".
- The OECD Code on Accidents Involving Hazardous Substances emphasises the imperative of providing citizens with full information and enhancing their role in the decision-making process.
- The proposed UN International Code of Conduct on the Transfer of Technology articulates the responsibilities of the contracting parties.

6.7.2.3 The international non-governmental society

After the Bhopal Gas Leak, several national NGOs, who also co-operated in networks, adopted the issue. These networks are still functioning, although the work may have turned to toxic chemicals in general, with Bhopal as an example. However, these networks have been engaged in collecting money for the Sambhavna Trust.

The international non-governmental society has its own declaration (80). The Permanent Peoples' Tribunal has developed a charter on Industrial Hazards and Human Rights, following a row of international conventions and guided by other declarations. Some points are:

- Right to organise;
- Right to appropriate health care;
- Right to living environment free from hazards;
- Right to environmental information;
- Right to enforcement of environmental laws;
- Right to relief and compensation.

6.7.3 Comments

We do not yet know whether these laws, regulations, conventions and declarations will be enough to prevent another Bhopal disaster. One type of convention is still missing: the multinational corporations' code of ethics.

The ILO conventions are not an assurance that the labour organisations will co-operate in order to reduce pollution. The catastrophe in 1997 at the Halland hill in Sweden, where toxic chemicals used for tightening a tunnel leaked out into the ground water, would not have been possible if the French trade union had informed the Swedish trade union of the nature of the compound.

There is often a conflict between the workers' need of employment and a society's need to reduce pollution. This conflict seems to have found a solution when trade unions start to co-operate with employers and governments to make the plants more environmentally friendly.

However, the NGOs inside India will keep an eye on how the Government of India fulfils its plans. The international networks of NGOs will go on lobbying, demonstrating, writing articles etc. to influence the development of the world in an environmentally friendly direction.

7 ANALYSIS & CONCLUSIONS

7.1 ANALYSIS OF CAUSES AND CONSEQUENCES

7.1.1 Injury analysis methods

Many models for analysing the extent of injuries have been developed (81). Usually they are used for events like traffic accidents and children's burns.

The most known model is the Haddon model, whcih has three components: the causal chain of events, the Haddon matrix, the Ten technological strategies and the Four E's. The conception pre-event, event and post-event phases is used. LR Berger pointed out the limitations of the Haddon matrix: prevention is not emphasised, the social environment is hidden, and it is too complicated (personal communication). He has suggested a new model for prevention. The Logical Framework Approach (82) is a tool for project planning and management.

The author has tested the three different models on this complex mega-accident. Because of lack of space, only the LFA will be described here.

In the analysis, it is considered proved that the reason that water entered tank 610 was the washing of pipelines.

7.1.2 The Logical Framework Approach

The Logical Framework Approach (LFA) (82) is an analytical tool for objectives oriented project planning and management. The key words are *objectives oriented*, *target group oriented* and *participatory*.

The LFA consists of the following parts:

1 *Participation analysis.* A comprehensive picture of the interest groups, the individuals and the institutions involved is developed.

2 *Problem analysis.* On the basis of available information, the existing situation is analysed. The major problems are identified and the main causal relationships between these are visualised as a problem tree.
3 *Objectives analysis.* The problem tree is transformed into a tree of objectives (future solutions to the problems) and analysed.
4 *Alternatives analysis.* Identifying possible alternative options, assessing the feasibility of these and agreeing upon **one** project strategy.
5 *Develop the LFA matrix (matrices).* The main project elements are derived from the objective tree and transferred into goals, purpose, outputs, activities and inputs. Assumptions describe conditions that must exist, but which are outside the control of the project management. Indicators provide a basis for monitoring and evaluation and should specify target groups, quantity, quality, time and locations.

7.1.2.1 Identification of parties involved

Governmental organisations
Government of India
Government of Madhya Pradesh
Government of USA
International governments
WHO, United Nations

Commercial community
UCC management
UCIL management
International trade organisations

Trade unions
Trade unions at UCIL
Trade unions in India
Trade unions in West Virginia
ILO

Civic community
Residents in Old Town
Residents in New Town
Workers and operators at plant
Survivors' organisations
NGOs inside India
NGOs outside India

Medical community
Doctors at hospitals in Bhopal
Other medical staff
ICMR
Private doctors in Bhopal
Medico Friend Circle
Indian Medical Association
IMCB
Scientists internationally

7.1.2.2 Problem tree

See Fig. 1.

7.1.2.3 Tree of objectives

See Fig. 2.

7.1.2.4 Alternatives analysis

Not appropriate here.

7.1.2.5 Matrix according to LFA

See Table 1.

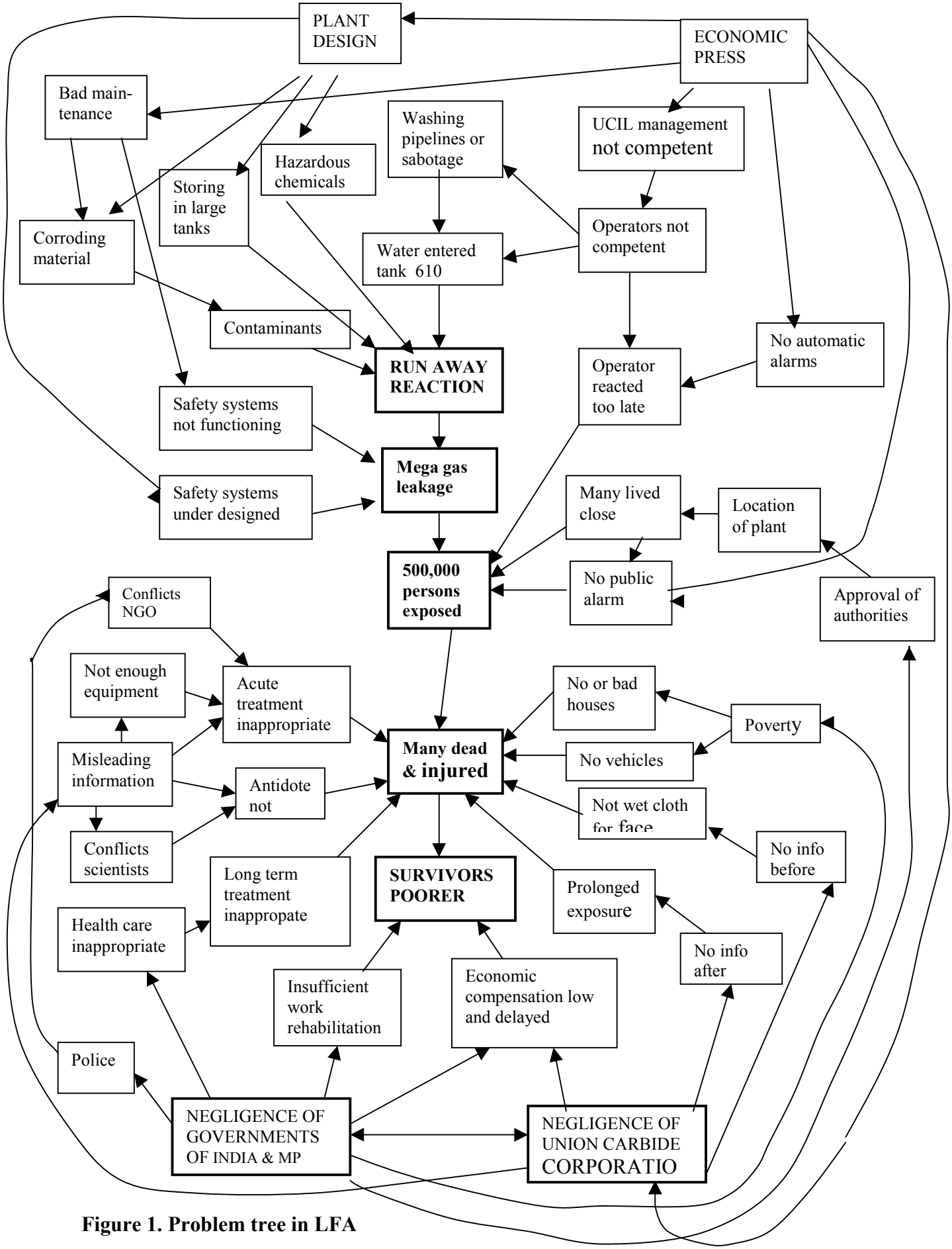

Figure 1. Problem tree in LFA

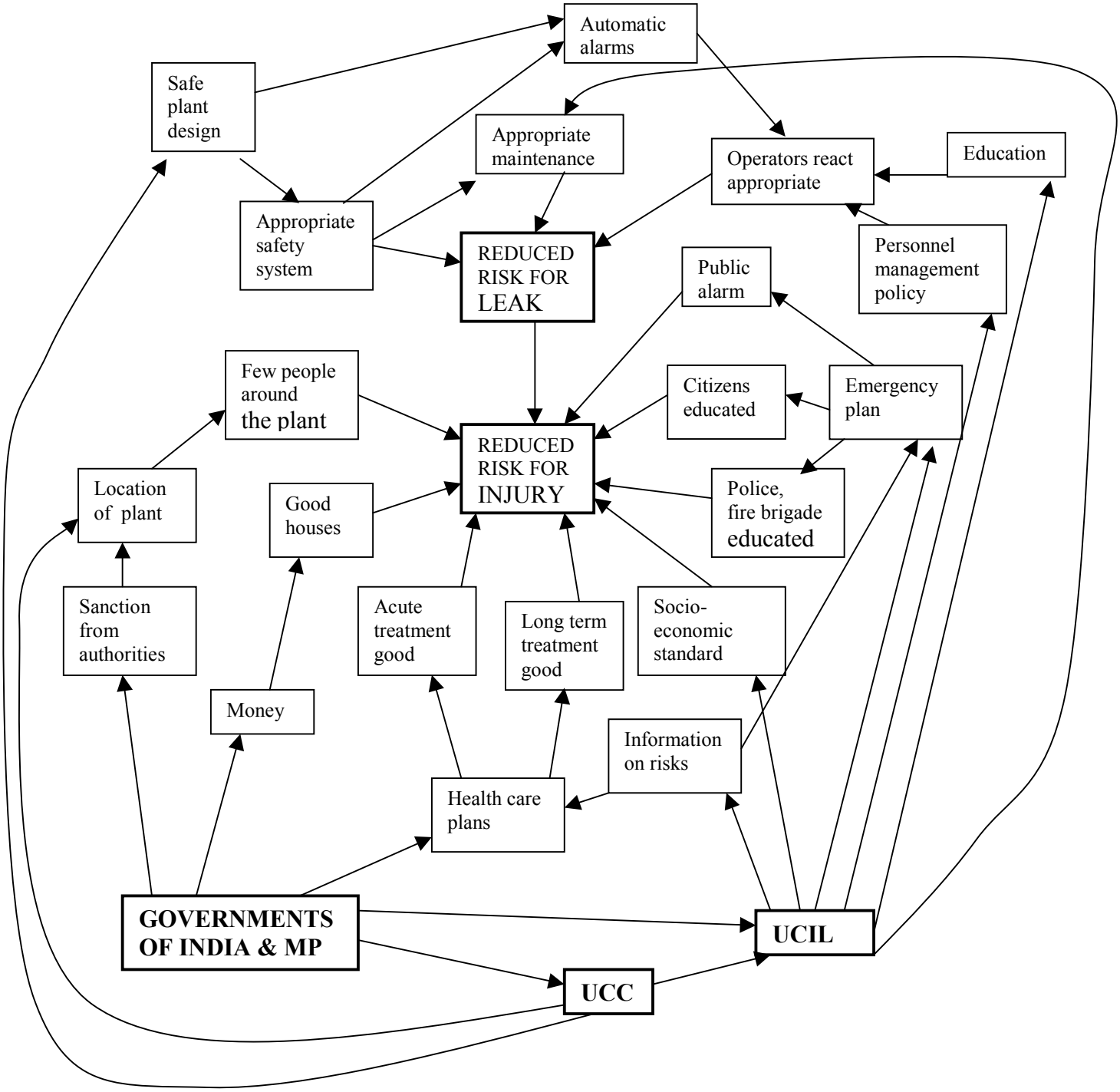

Figure 2. Tree of objectives.

Table 1. Matrix according to LFA.

Goal Reduce the risk of the inhabitants being injured by toxic gases from plant	*Indicators* No personal injuries from toxic gases from plant	*Assumptions* Appropriate laws Appropriate funds Interest from management Interest from government Residents interested
Purpose Reduced risk for leakage Reduced risk for being injured during leakage Appropriate treatment if leakage occurs	*Indicators* Fewer narrow escapes and small incidents Residents have knowledge No people living without houses or with bad houses close to plant Health staff have knowledge and equipment Employees, police, fire corps have knowledge about first aid	*Assumptions* Interest from UCC Support from Government
Outputs Managers, operators and workers have adequate knowledge The plant in good shape at check-ups All safety systems and rules always functional Health staff have emergency plans Police, fire corps, authorities have emergency plans	*Indicators* Tests Protocol. Investigation teams Protocol. Investigation teams Documented plans Practical exercises Documented plans Practical exercises	*Assumptions* Change of attitude of management Redirection of investments
Activities Move factory? Choose another method? Change from storing in single large tanks to storing in several small tanks Rules for safety controls Education programme for employees Education programme for inhabitants Repairing all safety systems Rules for maintaining Education programme for health staff, police, fire corps, authorities	*Inputs* Money from UCC ” ” Time enough, knowledge Teachers, money Teachers, money Technicians, money Skilled workers Teachers, money	*Assumptions* UCC interested Other methods exist and are cheap enough

7.2 CONCLUSIONS

7.2.1 Analysis of methods

It is possible to use all three models to analyse a complicated mega-accident like the Bhopal gas leak. However, the pictures that are created with the various tools give very different impressions.

The Haddon matrix gives us a good picture of the complexity, and gives us many ideas about the actions to be taken for prevention and management. The Ten Strategies add information on the management of a disaster. The 4 E's tell us about important factors in society.

Using the Berger model in this way gives us the chance of compiling lists of the many different groups of persons involved in the accident. It seems to invite descriptions of "soft" data, like attitudes and politics.

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 and roots. The matrix makes it possible to clarify what processes/changes from other instances are needed if the project is to succeed. As this is an analysis of an accident that has already happened, the matrix deals with both prevention and management. When planning a project, it may be clearer to create one matrix for prevention and another one or several others for management.

Despite her thorough knowledge of the Bhopal gas leak, developing this problem tree gave the author some new insights on the connection between causes and effects. However, the tree looks more like a "problem net". When drawing the tree of objectives, the author also acquired some new ideas on the measures necessary to prevent an accident or to mitigate its effects.

When visualising causes and consequences of this kind of accident, it is obvious that "chain" or "tree" are not the right words. "Net" is more appropriate.

7.2.2 Results of analyses

Analysis according to the LFA Problem Tree demonstrates that to create the mega-gas leak, it was not enough that water entered the tank. The most important factors were the plant design and the economic pressures.

The same analysis shows that the most important factor for the outcome of the leakage is the negligence of the Union Carbide Corporation and the Governments of India and Madhya Pradesh.

- The direct cause of the leakage is still unknown. The water washing theory seems the most plausible, but the sabotage theory cannot be dismissed.
- The direct cause of the leakage is less interesting, as the magnitude of the disaster was dependent on other factors.
- The parties responsible for the magnitude of the disaster are the two owners, Union Carbide Corporation and the Government of India, and to some extent the Government of Madhya Pradesh.
- The leakage could have been prevented, even if the direct cause was sabotage.

- If the personnel management policy had been better, no “disgruntled worker” would have existed.
- The impact on health could have been reduced if the residents had been given information on how to behave in case of a leakage, and if they had been warned by the siren early in the leakage.
- It is probable that closest to the factory, where the most serious health effects occurred, hydrogen cyanide was present in considerable concentrations.
- Therefore, early treatment with sodium thiosulphate would have mitigated the effects on the health of those living close to the factory.
- The effects on health caused by the leakage could have been mitigated if the medical, social, and economic rehabilitation had been adequate.

7.3 DISCUSSION

The Bhopal gas leak clearly illustrates the threat to public health posed by the chemical industry:

- A hazardous work environment.
- The risk of exposure for the host population.
- Direct damage to the environment during the production process, which creates hazards to human health.
- 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.
- 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 the long run.

The Bhopal Gas Leak shows us the complexity of the chemical society we live in today. The fact is, that we do not know which compounds we might be exposed to from chemical plants, and we do not know in what way and to which degree these compounds are harmful to us, in the short-term and in the long-term.

It also illustrates the roles of transnational companies and how they succeed in influencing decisions at governmental and local levels. The same mechanisms are found everywhere, also in “rich” countries.

It is obvious, that there are two antipodes concerning industrial hazards to public health: the industries on one side, and the trade unions and non-governmental organisations working for human rights and the environment on the other side.

The NGOs and trade unions usually fight for what is best for human beings. But we must realise that this is not the primary goal of a company. What is good for a company is not always good for the people.

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.

For the companies it is good to have few employees, ease in exchanging the labourers, an unsafe labour market which leads to the employed working hard and keeping silent, and low demands on the work environment and environment.

It is the task of the government to strike a balance between these two needs. For both the people and the companies, it is of course important that the company does well. The politicians should, nevertheless, put the interests of the people, both those now living and coming generations, in the first place.

The NGOs and trade unions could provide good support for the governments when trying to find out what is realistic and what is not concerning designs and safety measures. In Sweden, the taxes are quite high, but some of the taxes are paid to NGOs. For example, the Swedish Society for Nature Conservation gets economic support from the state, which gives it the opportunity to employ different kinds of experts as well as to inform the Swedes. The organisation is one of the instances for reviewing submissions on environmental questions for the government, and its influence is not negligible. The trade unions have had a very large impact on work safety and environment.

Taking care of our earth needs everyone's participation. Is there any hope that companies will participate? On the other hand, maybe they do not have any choice? To reduce the continuing degradation of our earth, there will be new rules of the game on the market. Will environmentally unfriendly companies survive in the long run?

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