

*1 Introduction**

1.1 OBJECTIVES AND SCOPE

The project was aimed at evaluating and improving the methodologies available for the assessment and reduction (mitigation) of injury to man and non-human biota and ecosystems, in chemical accidents.

Major industrial chemical accidents are low frequency, but highly significant events in terms of loss of lives, injuries, environmental impact and material damage. These accidents may occur in industrial process, energy-related and transport activities. They are generally associated with either large inventories of flammable, explosive, or very reactive substances or of common toxic chemicals in process industries or smaller quantities of very toxic and persistent chemicals.

The frequency and severity of these accidents seems to have increased during the last few years (Seveso, Mexico, Bhopal, Basle, etc., see Section 1.2). This increased frequency may be related to the rapid development of the chemical and petrochemical industries, the diversification of derived products, the increase in the size of plants, storage and carriers, the progressive industrialization in developing countries, and the proximity of plants to densely populated areas.

Chemical accidents involve a series of events starting with a technical breakdown or human error initiating uncontrollable physico-chemical phenomena, such as runaway chemical reactions, fires and explosions. These events are followed by propagation beyond the plant boundaries of toxic compounds in gaseous or liquid phase or as particulates. Damage may also be caused by the blast of explosions or the heat of fires.

Human beings and non-human targets may suffer injury from acute and/or residual exposure in the form of immediate, acute effects or long-term consequences.

Action should be undertaken to prevent the occurrence of such accidents through the introduction of safer process technologies, the improved performance of safety devices, and by the reduction of human error. Once an accident occurs, engineering systems (scrubbers, flares, venting systems, etc.) should intervene to mitigate its consequences.

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Post-accident management of the consequences to humans must be aimed at minimizing injury to human populations and the environment. This action involves as a prerequisite an accurate estimation of the damage to be expected.

Recently, a number of national and international projects have addressed various aspects of the problem of chemical accidents. The present SGOMSEC project focuses on the methodologies which can be used to assess and reduce injury to human populations and other biota, as well as ecosystems, following a chemical accident. (Accidents involving ionizing radiation alone and oil spills in the marine environment are excluded from consideration as they have been extensively covered in other reports and studies.) These methodologies are reviewed critically and research needs are identified to improve and shorten disaster response time and to improve assessment of the extent and probable spread of toxicants by transport through air, aquatic systems and soils. In addition, an attempt is made to use information from past accidents to improve the above methodologies.

In devising a strategy to manage a chemical accident a multi-phase action plan may be envisaged. Phase 1 would aim primarily at ensuring survival of exposed humans with minimization of both short-term effects and later consequences. This implies also a consideration of behavioural responses of the public. Phase 2 involves a more careful assessment of potential spread, fuller search for the presence of multiple contaminants and identification of the potential scope of ecological injury. Phase 3 would include the development of registers for follow-up purposes and the establishment of ecological zones under threat and surveillance schedules to follow the movement and transfer of chemicals in air, water and soils.

It is anticipated that, although not constituting a manual for chemical accident management, the report will provide a critical information base to help those in public authorities and industry who have to deal with such emergencies. Recommendations for urgent research needs are identified to guide R&D funding agencies in the public and private sectors (see Section 1.3 and Chapters 2 to 5 of the Joint Report).

1.2 CONTEXT

The last 50 years have seen extraordinary advances in chemical technology throughout the world. The production of chemical products has increased exponentially as have their multifarious uses. Technological progress has provided new materials, new processes, and whole new industries. As the ability to engineer for large-scale manufacture has grown, there has been concomitant pressure to lower costs through increased production capacity. Compared to earlier plants, present plants are huge, the capacity of some hydrocarbon processing plants, for example, has increased tenfold in the last 20 years. In addition, we have seen a proliferation of chemicals entering the

market each year, probably between 200 and 1000 in excess of 1 tonne. These add to the 60 000–70 000 chemicals in common use of which some 3000 account for 90% of the total weight.

This progress in industry and trade has increased significantly the number of people, whether employees or members of the public, at real or potential risk of exposure. In addition, the rate of technical advance means that there are more opportunities for disasters to occur. Throughout the world industrialization exacts its toll on the working population with both the steady accretion of mortality and morbidity and dramatic major accidents. It is the latter which has aroused great public concern in recent years. The most notorious events have been: Flixborough, UK, when a cyclohexane explosion killed 28 (1974); Seveso, Italy, releasing 2,3,7,8-tetrachlorodibenzo-*p*-dioxin with extensive animal deaths (1976); Mississauga, Canada, where a train derailment led to chlorine release which required the evacuation of 216 000 people (1979); a liquid petroleum gas explosion in Mexico City with 500 deaths and 5000 injured (1984); and finally, the worst man-made accident in history in Bhopal, where leaking methyl isocyanate killed 2500 people (1984). Although not a chemical accident, the nuclear reactor explosion at Chernobyl (1986) has exacerbated worldwide public concern on industrial accidents. This concern, in turn, has led to a number of international initiatives for evaluation and containment of these accidents. The fire in Basle (1986) caused a major ecological accident by releasing large quantities of pesticides and related chemicals into the River Rhine.

Major industrial chemical accidents may be considered as those which cause extensive damage to human health and the environment both without and within the site of the manufacture, formulation, or processing of chemicals. It should also cover the transportation of dangerous substances and their loading and discharge at installations. As already mentioned, it is not intended to include in this context nuclear accidents or oil spills.

The initial stage in hazard control is to establish criteria by which the most hazardous installations can be recognized (The World Bank, 1985a, b; Silano, 1985). The following types of material could be involved: toxic gases and solids, flammable liquids or gases, unstable or highly reactive materials. The most comprehensive list of potentially dangerous substances together with their threshold amounts is the subject of the European Communities Directive (85/501/EEC), commonly known as the 'Seveso Directive'. This list has recently been used by the US Occupational Safety and Health Administration in its post-Bhopal inspection of plants producing chemicals likely to be most hazardous to workers or surrounding communities. The value of these Directives was underlined at the ILO Tripartite Meeting on Prevention of Major Hazards in Industry (1985).

After identification of major hazards assessment and analysis, management of prevention systems, and emergency operations follow in logical sequence as the elements of a control programme (PAHO, 1984).

For identification of hazardous chemicals there are a number of international inventories and guides in addition to the 'Seveso Directive'. There is, for example, the European Community Inventory of Existing Commercial Chemical Substances (EINECS) which includes about 100 000 compounds, and ECDIN, a data bank on environmental chemicals with extensive data on over 20 000 chemicals. There is also an International Register of Potentially Toxic Chemicals (IRPTC) of UNEP which now has data profiles on some 450 chemicals of major international significance. The profiles contain information on physico-chemical properties, production and use, environmental transformation, toxicity, spills, waste management, poisoning, and national and international recommendations. The UN *Orange Book* provides information on transported chemicals in terms of immediate response to accidents. Canada follows this approach with its own guide (Transport Canada, 1982). ILO has established a Hazard Alert System for a limited number of hazardous chemicals.

Assessment of risks of chemical accidents can be carried out retrospectively or prospectively (Environment Canada, 1986). The former has been invaluable in showing the types of accidents most likely to occur but new dangers arise, as at Bhopal, and the human element remains unpredictable. The prospective analysis can provide a statistical probability of an accident occurring so that the reduction in risk can be weighed against the economic consequences. The UK study of Canvey Island, where there was a high concentration of flammable and dangerous chemicals, showed that the hazards to the inhabitants were, at most, not appreciably greater than the normal hazards to the general population (HSE, 1978, 1981). Unfortunately the importance of human factors in accidents, although widely acknowledged, is not well understood.

As discussed in detail in the following chapters of this Joint Report, the management of major accident prevention systems requires inherently safe design and the use of high-reliability plants. After due consideration to siting policy – whose inadequacies were apparent in Mexico City and Bhopal, although it must be recognized that, in some cases, population has concentrated around the plants after they were established – the key elements are plant integrity, appropriate operating procedures, and safeguards against process deviations.

Emergency planning follows as the support to the above evaluation and preventive measures. The prior allocation of responsibility for different services is essential as is the establishment of emergency control centres; contingency planning at the local, regional and international level has been the subject of a WHO report (1981). Little information may be available on the toxic components released after a major accident so that medical treatment can be severely hampered. Toxicological data for aiding the suffering may be obtained from poison control centres (Health and Welfare Canada, 1982). (See Appendix in Part A of this volume). Biological monitoring through blood and

urine samples can be invaluable in determining human exposure for subsequent epidemiological investigation.

Because of the extensive source material in the contributed papers, the Joint Report has limited references; thus, individual contributed papers are cited as sources of additional information. These contributed papers, of course, also contain extensive references. In addition, the Appendix contains a list of additional reference sources for supplementary information.

1.3 MAJOR CONCLUSIONS AND RECOMMENDATIONS

The following chapters of the Joint Report are based on the content of the individual papers and of the discussions held during the Workshop. The main conclusions and recommendations which are presented in various parts of the Joint Report are summarized here:

1. Studies of the type of HAZAN (Hazard Analysis) and HAZOP (Hazard in Operation) should be an integral part of plant design and safety audits should be regularly undertaken. Plant modifications must be subjected to the same stringent requirements.
2. Information exchange on accidents and dangerous occurrences should be organized by industry or professional associations on an international basis.
3. National governments should implement regulations incorporating a requirement for a safety case, taking account of the models provided by UK CIMA Regulations and the European Community Seveso Directive.
4. Continued operation of potentially unsafe and outdated plants should be subject to regular review and governments should consider appropriate legislation.
5. Emergency plans for on- and off-site contingencies should be revised and updated regularly with the implementation of practice drills.
6. A disaster plan for provision of emergency medical and essential public services needs to be prepared at each organizational level. The plan should be readily accessible and ready for implementation at the time of the accident. The plan should be self-sufficient, describing in detail all aspects needed for implementation, as described in Section 3.3.1.
7. A toxic substances control centre, modelled after poison control centres should be established at regional or national levels to assure ready access to complete and up-to-date toxicologic information at the time of an accident including protocols for treatment.
8. To ensure a sound population database for long-term evaluation and to identify questions for research in epidemiology, health effects, medical treatments, etc., an interdisciplinary team should be identified and established with specific responsibility to record the events of an accident, to assure registration of the exposed population, and to provide guidance in long-term follow-up and investigations.

9. As far as protection of the environment and of non-human targets is concerned, pre-siting studies should include investigation of the ecosystems involved in order to determine their vulnerability and their ecological value. Post-accident measures should include recording of gross effects, and possibly soil decontamination. Autopsies of affected animals may also be useful in providing indications for treatment of humans.

The Workshop was concerned mainly with the use of scientific methods for assessing and reducing injury from chemical accidents and, to a lesser extent, with associated sociological and psychological issues. However, any consideration of this topic cannot be completely divorced from the obvious political dimension, and this entered the deliberations of the Workshop in the review of systems for the regulatory control of major hazards activities. Such systems, to be wholly effective, need to address the difficult political/economic questions of:

- whether older plants, operating with outdated technologies, should be permitted to continue in production, and
- whether plants, irrespective of age, that are so located in relation to vulnerable population groups as to present an irreconcilable conflict between risk and the cost of improvements, should be relocated.

In the former case, there is an acute scientific/technological problem of assessing the hazards and quantifying the risks, especially where the plant has been modified over time with inadequate documentation of the changes from the original design. In both cases, the ultimate resolution of the questions is likely to be encouraged by financial inducements by government.

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