PART I

POTENTIAL

Report of Working Group 1

An Examination of the Potential for Major Industrial Incidents in Canada

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SUMMARY

This report presents an assessment of the potential for major incidents involving chemicals, natural gas and petroleum in Canada. Bhopal and its aftermath of human suffering has taught the lesson that society must be always on the alert to identify potential hazards and take all practical steps to minimize the probability of their occurrence.

Since it is virtually impossible to prepare an all inclusive list of likely candidate chemicals for a Bhopal-type incident, Working Group 1 directed its efforts to defining hazard criteria for selecting chemicals that could have such a potential. An example list of such chemicals is provided. The Working Group also examined chemicals that have a high probability of release according to historical spill data.

The risk of an accident associated with handling of these commodities, is a function of the hazard and the probability of such an event occurring. Methodologies for assessing such risks exist, are highly technical in nature and require trained expertise to carry them out. The Working Group urges local industry to carry out site specific assessments on chemicals meeting the Bhopal hazard criteria. Steps should then be taken to effectively manage the risk and to communicate such actions to appropriate community officials and involved publics.

As a general conclusion and in response to the question, "Can it happen here?" the Working Group's analysis of the Canadian situation indicates that the possibility for a major industrial incident does exist. However, when the risks are properly evaluated and managed and a backup contingency plan provided for any emergency should it occur, then the probability of a major incident occurring and the impact on the community will be significantly reduced.

1 INTRODUCTION

The potential for Bhopal-type incidents to occur in Canada is examined in this report. Canadians have been made aware of recent major industrial accidents that have taken place around the world, such as in Seveso (Italy), Mexico City and most recently Bhopal. Incidents closer to home such as the Mississauga (Ontario) train derailment and the natural gas blowout at Lodgepole (Alberta) have alerted everyone to the fact that Canada may be not immune to such major disasters.

The Bhopal Aftermath Steering Committee established Working Group 1 in order to determine the potential for major industrial accidents in Canada. This Group was given the following terms of reference:

1) to identify the chemicals and substances which have been or have the potential to be involved in Bhopal-type incident spills and accidents in Canada;
2) to quantify these chemicals and substances according to their shipments/production (i.e., volume supply as well as hazard);
3) to identify major uses, manufacturing and storage sites for these chemicals in Canada; and
4) to determine major modes of transport for these chemicals.

Although all industrial accidents large or small are undesirable, wasteful in many ways and a potential burden on the resources of a community, the primary focus of this report will be on major chemical accidents as defined by the Steering Committee and used by the Working Groups.

A "Bhopal-type" incident is considered here to be a major industrial or transportation incident resulting in acute exposure to a chemical which has the potential to cause death or adverse health effects in the community.

The working group excluded in its investigation:

1) Strategic chemicals used by the Department of National Defense. However, DND is urged to apply the principles presented in this report to conduct risk assessments, to take appropriate preventative measures and to prepare emergency response plans.
2) Radioactive substances in nuclear facilities. The Atomic Energy Control Board regulates and controls the use and disposal of radioactive substances. Other chemicals handled in or associated with nuclear facilities that meet the "hazard criteria", such as hydrogen sulphide, are included.

3) Offshore drilling and producing platforms are regulated by Energy, Mines and Resources (Canadian Oil and Gas Lands Administration); accidents involving chemical releases from these facilities usually would have limited impact on the general public.

4) Sabotage or acts of terrorism.

The types of major chemical accidents that this report addresses are:

a) explosions from a chemical manufacturing plant, oil refinery, on-shore oil or gas wells or storage facility;
b) an inadvertent release of an acutely toxic gas from a manufacturing site, on-shore oil or gas wells or storage facility;
c) misuse of chemicals causing a toxic release (e.g., accidental mixtures); and
d) transportation accidents releasing large volumes of hazardous chemicals.

Working Group 1 is comprised of members of the petroleum and chemical industries and federal departments having direct or indirect involvement with these industry sectors.

The report examines in a qualitative way the potential for major chemical accidents to occur. For releases of industrial chemicals in use, two approaches are taken: the first looks at chemicals already identified as dangerous commodities in Canada, and the second reviews historical chemical spill data in this country.

2 BACKGROUND ON MAJOR INDUSTRIAL SECTORS

The three major industrial sectors that are the primary producers of the chemicals involved in this study are described in this section.

2.1 Oil and Gas Production Sector

Over 65 major companies active in the oil and gas production sector are represented by the Canadian Petroleum Association. In addition, many other companies carry out independent exploration and drilling. In 1984, in Alberta alone, there were almost 6000 drilling completions with additional activity in British Columbia, Saskatchewan and Manitoba.

The major concern in this sector is the drilling operation, where the unknowns are considerable compared with those in pipelines and gas plants. Pipelines and gas plants may still present a potential risk but preventive measures can be better engineered and implemented than for drilling operations. Tracers can be used on pipelines to detect leaks and gas plants are really a chemical process industry which can be designed and operated using the techniques described in Part II.

In drilling a sour gas well, the unexpected release of hydrogen sulphide (H_2S) poses the major chemical hazard. Wells where the concentration of hydrogen sulphide in the gas exceeds 5% and the gas contains high volumes of condensate are considered "critical sour wells"; therefore, special precautions must be taken. These precautions include, amongst other things, a more comprehensive monitoring and inspection plan, and an accident contingency plan. As will be discussed in Parts II and III, procedures now call for ignition of the well once it is considered "wild".

The scientific debate continues as to the safe exposure limits for hydrogen sulphide. The summary and recommendations report for the Lodgepole Blowout states:

> "The protection plan was designed to ensure that if an H_2S concentration of 15 parts per million (ppm) was reached in any area where people were residing, then they would leave the area. Additional standards were identified for persons described as "sensitive", which generally was taken to mean persons with respiratory problems, very young children, the elderly, and pregnant women. However, for various reasons, these additional standards, while acknowledged, were not actually applied.
>
> The monitoring data gathered during the event shows that the dispersion of the gas cloud from the well was actually quite rapid, notwithstanding the large volumes of H_2S gas being emitted. For

> example, no concentrations in excess of 10 ppm were found at any residences located farther than 20 km from the well, and there were only a few instances inside that 20 km radius. The highest concentration recorded at Cynthia was 14 ppm, at Lodgepole 14.5 ppm, and 5 ppm at Drayton Valley, some 45 km from the well. The highest reading in Edmonton was 0.5 ppm.
>
> Throughout the 26-day period that the well was not on fire, H_2S concentrations were generally low. For example, at Lodgepole, the concentrations were less than 1 ppm for 87 percent of the recorded hours, while at Cynthia and Drayton Valley they were less than 1 ppm for about 95 and 96 percent of the time, respectively. In Edmonton, though the odour was detected, the H_2S concentrations were actually less than 0.1 ppm for 93 percent of the time." (Lodgepole Blowout Report, 1985).

Health effects were evident as stated in the "ERCB Lodgepole Blowout Report - Causes, Effects, Actions":

> "Local area residents, and a group of Edmonton respiratory patients, described how the blowout had affected their health. The effects included headache, eye irritation, sore throat, nose bleeds, some breathing problems, nausea and diarrhea. While scientific data was not available to link these health problems to the blowout, the Panel is satisfied that emissions from the well did lead to short-term health effects for a substantial number of people. The evidence also suggests that some people are especially susceptible to H_2S emissions."

Another potential concern was sulphur dioxide. "During the 41 days that the well was on fire, and the sulphur was being emitted as sulphur dioxide, the concentrations were substantially less than the evacuation limit." (Lodgepole Blowout Report, 1985).

Since Lodgepole, many steps have been taken including establishing exposure limits, improving monitoring techniques and conducting drilling operations in the critical zone in a more cautious manner. The potential for chemical releases does exist from well drilling, pipelines and gas plants and adequate precautions to minimize the risks must be implemented.

2.2 Petroleum Refining Sector

The Canadian petroleum refining industry processed 225 800 m^3 of crude per day in 1984. Fifty-five percent of this production was located in Ontario and Quebec, Alberta accounted for some 12% and the remaining 33% was distributed between British Columbia, Saskatchewan and the Maritimes (Oilweek, 1985).

In the past five years there has been a considerable decrease in refined oil product demand due largely to energy conservation measures. This has resulted in the closure of some 10 refineries so that today there are only 28 operating. These refineries are distributed across Canada from Nova Scotia to Vancouver and several are located in urban areas close to residential communities.

The potential for major accidents associated with petroleum refineries and the downstream product distribution system is generally in the form of fire or explosions. Not as likely, but still a possibility under certain local conditions, is a toxic release of hydrogen sulphide gas from refineries.

Historically the Canadian refining industry has a good safety record with only isolated major accidents reported. The last major Canadian incident took place in 1957 at a Montreal East refinery where an explosion and fire was initiated by butane release from a storage sphere (Journal of Hazardous Materials, Vol. 3, 1979). More recently, refineries at Clarkson, Ontario (1975), and Dartmouth, Nova Scotia (1985), were involved in incidents resulting in releases to the surrounding communities of hydrofluoric acid in one case and hydrogen sulphide in the other.

In the United States such events are comparatively more frequent with the latest incident reported on November 5, 1985, when an explosion and fire occurred at a petroleum refinery and storage facility near Houston, Texas. Two workers were killed and over 1 700 people in the nearby community had to be evacuated.

2.3 Chemical Industry Sector

The Canadian Chemical Industry is generally organized along product lines. Chemical companies therefore group together in different associations such as: the Canadian Agricultural Chemical Association, the Canadian Fertilizer Institute, the Canadian Manufacturers of Chemical Specialties Association, Society of Plastics Industry, and the Canadian Paint and Coatings Association to represent their specific interests. The majority of chemical manufacturers is represented by the Canadian Chemical Producers' Associations (CCPA) which is made up of 65 member companies that produce a broad range of petrochemicals, inorganic chemicals and other specialty chemicals.

The chemical industry is the fifth largest industry in terms of value of product output. As is the case with the petroleum refining sector, chemical manufacturing plants are located throughout Canada. Most of the chemicals supplied are manufactured in Ontario, principally in Sarnia's "Chemical Valley", and in Alberta in the Fort Saskatchewan area.

The chemical industry supplies a network of secondary industries such as: textiles, manufacturers of plastic goods, automotive supply, pulp and paper and mining.

This is significant because major chemical users could also be involved in major chemical accidents.

As discussed in Part II, the chemical industry has a good record of accident prevention when compared to all industries. In addition members of CCPA have adopted a policy of "Responsible Care" which addresses product stewardship throughout the chemical lifecycle, from development, introduction, manufacture, transportation, storage, handling and ultimate disposal in order to minimize the possibility of adverse effects on human health, well-being and the environment (Petrochemical Industry Task Force Report to the Federal Minister of Regional Industrial Expansion, 1984).

Similarities exist between petroleum refinery and chemical plant operations except that chemical plants generally tend to be smaller in size and certain chemicals produced present a higher toxicity hazard. Section 3 of this report describes the criteria necessary to evaluate the degree of hazard of these chemicals.

3 ASSESSMENT OF RISK

In order to deal with the vast array of chemicals in Canadian commerce and determine those chemicals that would logically fall into a Bhopal-type incident grouping, the process shown in Figure 1 was used. The Transportation of Dangerous Goods Act (TDGA) criteria for listing dangerous chemicals provides what could be termed a prospective approach and permits the identification of hazardous chemicals before an accident. An analysis of historical data would be a retrospective approach and facilitates priority setting to deal with the most accident prone chemicals. Together they provide an overview of the potential dangerous chemicals in Canada.

3.1 Prospective Approach

In any analysis of chemical accidents, we must consider the element of risk. Risk, in engineering terminology, is defined as the product of hazard and the probability of its occurrence (Krewski et al., 1984). The hazard is a function of the physical, chemical and toxicological properties of substances. The probability in turn is a function of the likelihood of occurrence of an event or sequence of events that gives rise to the release of a chemical and the mechanism by which the population is exposed. It should be noted that these definitions vary from one scientific discipline to another (e.g., engineering and biology) (Royal Society, 1983).

3.1.1 Hazard Criteria. In attempting to identify the chemicals that have a potential for a Bhopal-type incident, it is necessary to define the selection criteria on a scientific basis. Once the criteria are set, it is then possible to screen any chemical in use in Canada for its potential to cause a major public disaster.

In establishing these criteria, a review of criteria used by other jurisdictions such as the United Kingdom, the United States and those already in existence in Canadian legislation, (i.e., the Transportation of Dangerous Good Act) was undertaken (Canada Gazette, 1985). As the TDG Regulations were put into effect in July, 1985 and prior to that had undergone a thorough scientific review by industry and government at various levels, Working Group 1 decided that this was the most logical starting point for this review.

It should be noted that the approach taken by U.S. EPA differed in that they started with a long list of chemicals which could cause acute toxic effects. In Canada this was already done under the TDG Regulations.

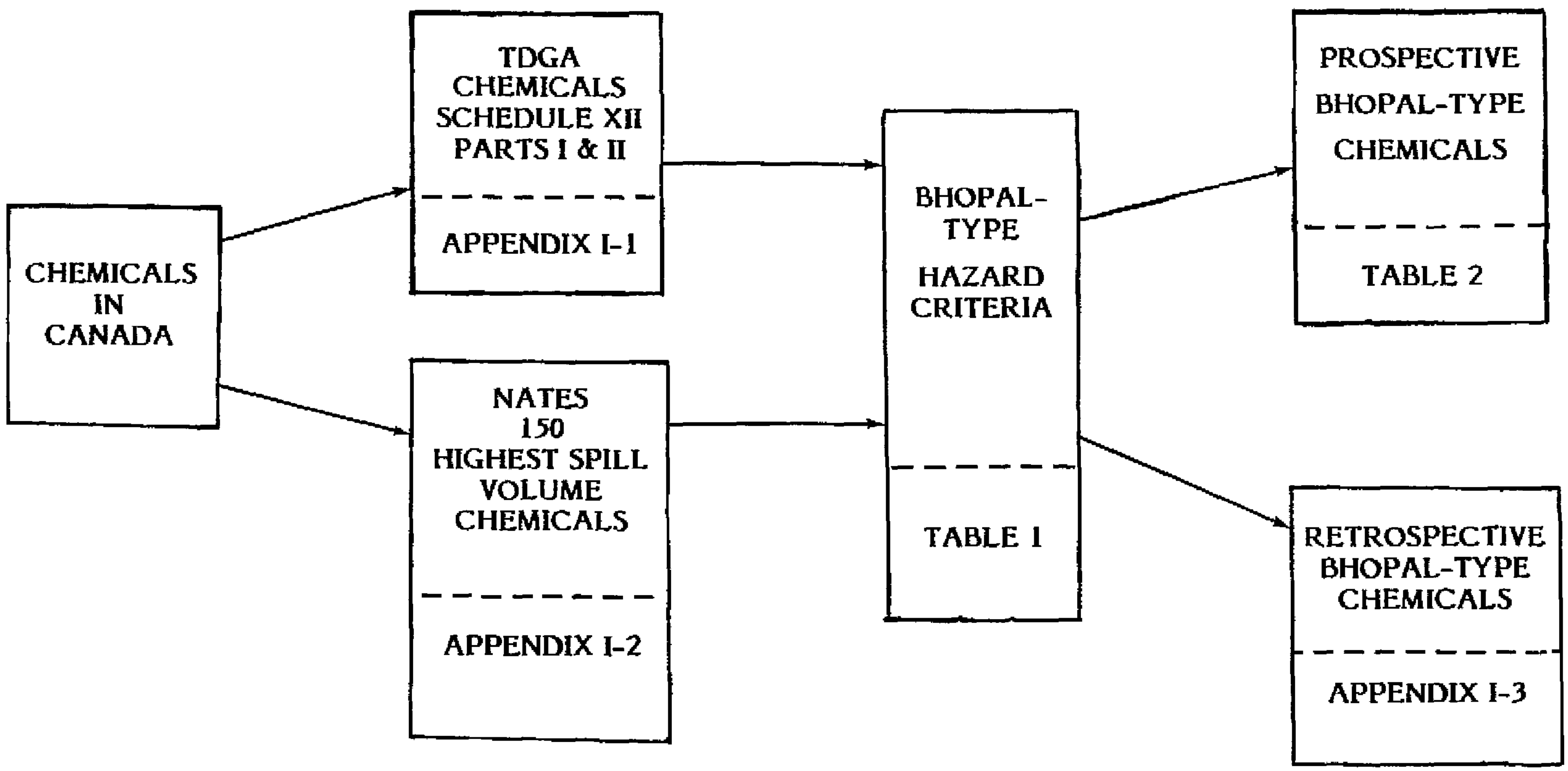

FIGURE 1 PROCESS FOR IDENTIFYING BHOPAL-TYPE CHEMICALS

The TDG Regulations list some 2400 dangerous goods. Schedule XII - Parts I and II of these regulations further refines the list of hazardous chemicals to those with a potential risk to human health or the environment during a spill situation or an explosion. The toxic chemicals that could migrate well beyond the borders of the transportation corridor's right-of-way fall into this classification. Using this criterion, the Schedule XII - Parts I and II listing is reduced to some three hundred chemicals for which spill response plans are required. This gives a list of three hundred dangerous chemicals used in Canadian commerce (see Appendix I-1). Chemicals on this list can be further examined to identify those that could possibly give rise to a Bhopal-type incident, i.e., the physical, chemical and biological characteristics of a substance that could produce such effects must be identified. Properties that could lead to a major industrial incident are:

1) a poisonous gas or aerosol that has good dispersive properties or is contained in a pressured system;
2) a highly flammable gas or liquid with an explosive potential;
3) a highly reactive material that combines violently and generates toxic products; and
4) a chemical that generates a toxic gas when it burns.

In this study, only chemicals that produce lethal or adverse health effects upon exposure are considered. Substances that may lead to only chronic effects (i.e., long-term health effects) are not within the scope of this study. The hazard criteria for potential Bhopal-type incidents chemicals are listed in Table 1.

3.1.2 Probability. The risk of a particular chemical producing a Bhopal-type incident is also a function of the probability of a chain of events or conditions occurring so as to allow the chemical to come in contact with the population at large.

An assessment of probability is made on a site or situation specific basis. Whereas potential <u>hazard</u> identification using established criteria is objective (i.e., based on measurable scientific data), the <u>probability</u> is often complex, requiring subjective judgement. As an example, the following factors must be considered in arriving at the probability estimate:

1) volume of chemical present at any one time (there is a minimum quantity below which the risk is too low to produce a Bhopal-type incident; by rule of thumb for railways this is considered a car-load quantity);
2) conditions of confinement (temperature, pressure, etc.);
3) conditions of storage;

TABLE 1 HAZARD CRITERIA FOR BHOPAL-TYPE INCIDENT CHEMICALS

Group	Hazard	Criteria
I	Toxic substances (Class 2, Divisions 3 and 4 TDGR)	Toxic gases and/or Toxic liquids under pressure that will easily evaporate or form aerosols and that meet LC_{50} < 5 000 mL/m^3 provided they possess good dispersive properties.
II	(A) Flammable gases (Class 2, Division 1 TDGR)	a) Flammable gases Gases which at normal pressure when mixed with air are flammable, i.e., (i) ignitable at normal atmospheric pressure when in a mixture of 13 percent or less (ii) have a flammability range of at least 12
	(B) Flammable liquids (Class 3, Divisions 1, 2 and 3 TDGR)	b) Flammable liquids Substances having a flash point < 37.8°C
III	Explosive substances (Class 1, Divisions 1 and 5 TDGR)	Substances which can explode under fire or shock situations.
IV	Reactive substances producing toxic, dispersible materials or fires or explosions (Class 4, 5, 6 or 9 TDGR)	Substances which, on burning or reacting in a violent manner, produce a product of reaction listed under Group 1 (Toxic Substances) or produce a serious fire or explosion. - flammable solids - substances liable to spontaneous combustion - substances that on contact with water emit flammable gases - oxidizing substances and organic peroxides - poisonous dust or mist emissions with LC_{50} < 500 mg/m^3 at normal atmospheric pressure

4) equipment and system engineering design criteria;
5) manufacturing process or method of use (including an analysis of intermediates and potential mixtures);
6) routine safety precautions taken;
7) reliability engineering principles and techniques in use at the location;
8) secondary containment employed;
9) possibility of process upsets (particularly start-up and shutdown procedures);
10) maintenance practices;
11) probable atmospheric conditions at location (wind speed, inversions, etc.); and
12) population density at the location.

The analysis of factors becomes more difficult for those involved in transportation as roads, rail and even canals and harbours can either pass through or near dense population areas in Canada.

The above probability factors are presented only by way of example, since each situation is unique and must undergo an individual risk assessment by specialists in the field. Such an approach is termed prospective, since it attempts to forecast risk on a predictive basis using local parameters. Table 2 gives examples of some of the substances that under the appropriate conditions, and in sufficient quantity, could result in a Bhopal-type incident. **This table should not be considered a comprehensive or a priority listing.**

3.2 Retrospective Approach

Another approach, called retrospective, is based on historical records. By examining accident statistics, it is sometimes possible to assign probability and therefore estimate risk.

The Environmental Protection Service of Environment Canada has developed a data base of spill statistics over the past fifteen years known as the National Analysis of Trends in Emergencies System (NATES) (Figure 2). This data base now contains twenty-three thousand spill events involving petroleum products and chemicals.

These statistics indicate that a hundred and fifty chemicals make up 97 percent of the spill volume. As shown in Figure 2, spill volume also correlates well with the supply volume (sum of production and importation of chemicals).

The relationship of spill or supply volume and number of chemicals can be usefully applied by screening the list of 150 most spilled chemicals through the Bhopal-type hazard criteria (Appendix I-2). In this way, it is possible to identify those chemicals that historically have a high probability for involvement in a Bhopal-type incident

TABLE 2 EXAMPLES OF BHOPAL-TYPE INCIDENT CHEMICALS IN CANADA

Substances	Transport Class	Product Identification Number
Group 1 - Toxic Substances		
Ammonia	(2.4 and 9.2)	1005
Arsine	(2.3 and 2.1)	2188
Chlorine	(2.4 and 9.2)	1017
Hydrogen Chloride	(2.4 and 9.2)	1050
Hydrogen Fluoride	(2.4, 6.1, 9.2)	1052
Sulphur Dioxide	(2.3)	1079
Group 2 - Flammable Substances		
(a) Flammable Gases		
Natural Gas	(2.1)	1971
Propane	(2.1)	1978
Ethylene Oxide	(2.1 and 6.1)	1040
Hydrogen Sulphide*	(2.1, 6.1, 9.2)	1051
Methane	(2.1)	1971, 1972
Butane	(2.1)	1011
Ethylene	(2.1)	1962, 1038
Hydrogen	(2.1)	1049, 1966
Propylene	(2.1)	1077
Vinyl Chloride	(2.1)	1086, 1060
(b) Flammable Liquids		
Hydrazine	(3.3 and 6.1)	2029
Propylene Oxide	(3.1 and 9.2)	1280
Carbon Disulphide	(3.1, 6.1 and 9.2)	1131
Group 3 - Explosive Substances		
Ammonium Nitrate	(1.1)	0222
Group 4 - Substances with Toxic Products of Reaction (Classes 4,5,6,8 and 9)		
Phosphorous	(4.2 and 9.2)	2344
Sodium Cyanide	(6.1 and 9.2)	1689

* H_2S is also a toxic substance

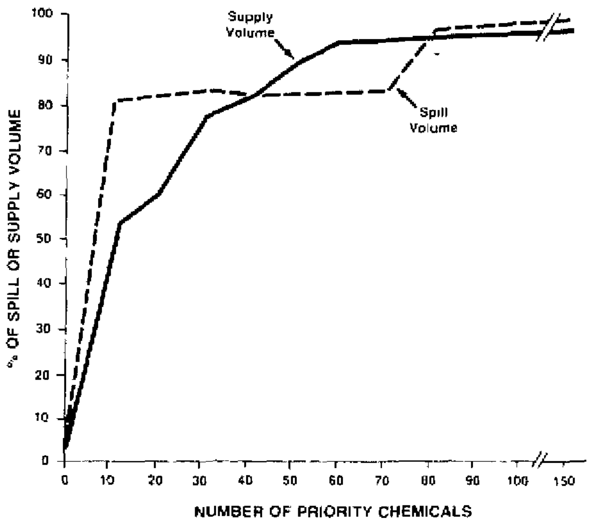

FIGURE 2 "NATES" CHEMICALS RELATED TO SPILL OR SUPPLY VOLUME

(Appendix I-3). The production, uses, transport and hazard associated with some of these chemicals are presented in Appendix I-4.

It cannot be overstressed that these lists are not intended to be all inclusive and should be used with caution. For one thing, the list of accidents included in NATES is far from complete. It was recently reported that fire departments in Ontario responded to over 4 600 spills in 1984. (Office of the Fire Marshall, Ontario). This exceeds the number of spills recorded in NATES for all of Canada by a factor of 3 to 4.

There is an obvious need to improve the spill reporting frequency across Canada. TDG Regulations should do this for transportation incidents. Other measures may be required for on-site spills.

Working Group 1 supports the stand taken by the U.S. Science Advisory Board that a short priority list of Bhopal type chemicals may be misleading and counterproductive, giving society a false sense of security (Bureau of National Affairs, Aug. 85).

In light of this, Working Group 1 recommends that Canadian industries, communities and safety agencies conduct site specific assessments based on risk factors and hazard criteria identified in Table 1 of this report, rather than relying solely on the chemicals listed in Table 2 or in Appendix I-3.

Excellent reference documentation is available for use by communities and local industries on this subject. We would particularly like to draw attention to the following:

1) "Evaluation of Public Health Hazards Associated with Chemical Accidents", 2nd Edition, V. Silvano (1985).
2) "Chemical Emergency Preparedness Program: Interim Guidance". U.S. Environmental Protection Agency (November 1985).
3) "Community Awareness and Emergency Response". Chemical Manufacturers Association (April 1985).
4) "Guidelines for Hazard Evaluation Procedures". American Institute of Chemical Engineers, Batelle, Columbus (December, 1985).