Agriculture
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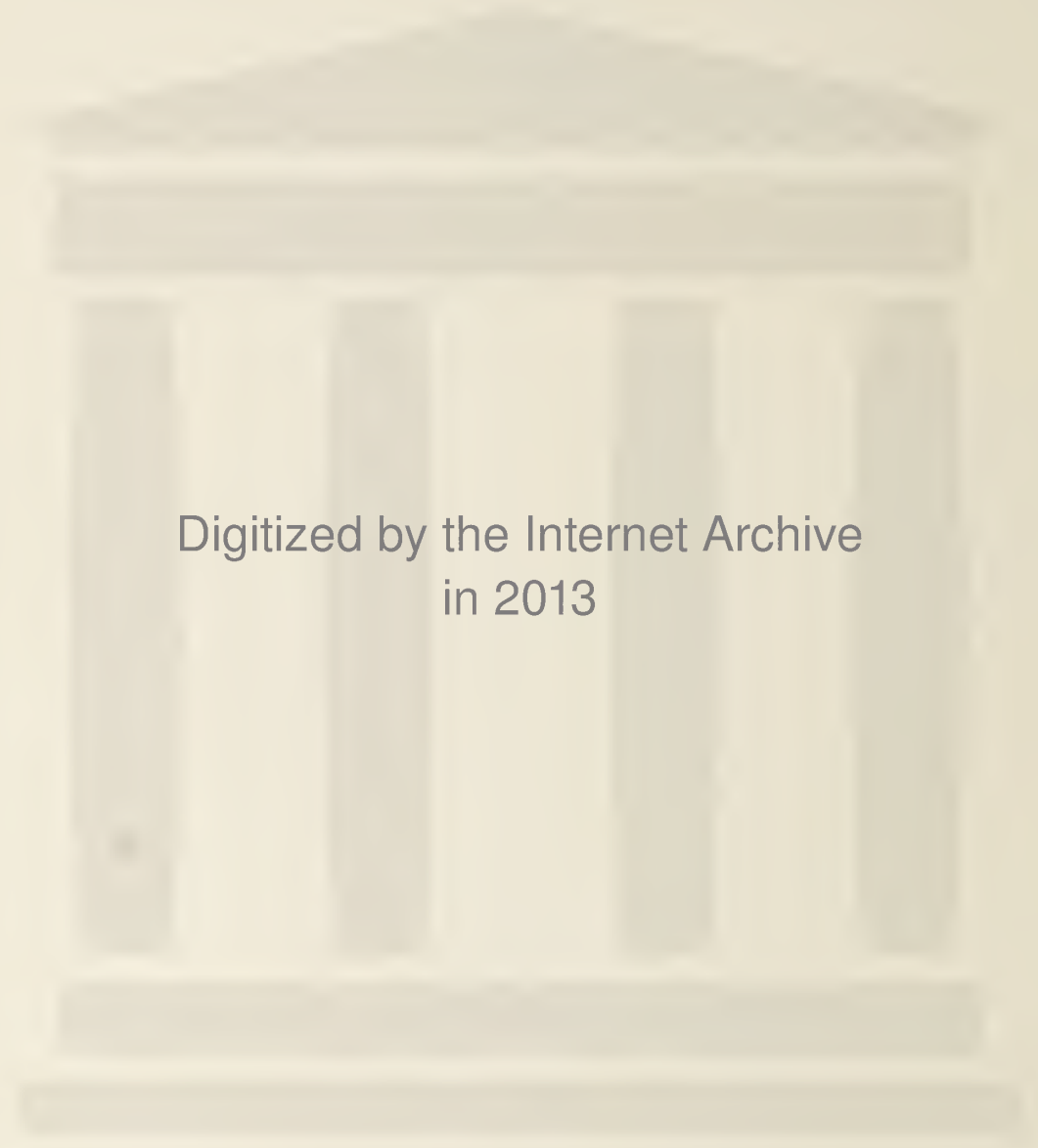
Research Branch
Direction générale de la recherche

Technical Bulletin 1987-8E

Laboratory safety course manual

Canada



Laboratory safety course manual

2nd Edition

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Technical Bulletin 1987-8E

Research Branch
Agriculture Canada
1987

Produced by Research Program Service

Cat. No. A54-8/1987-8E
ISBN 0-662-15366-9

First printed 1985
Revised 1987
Reprinted 1988

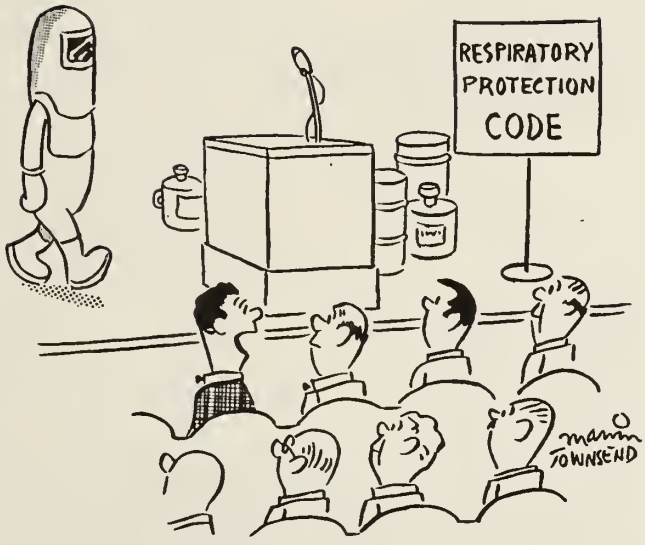
cover
The dots on the map represent Agriculture Canada research establishments.

LABORATORY SAFETY

COURSE MANUAL

2nd EDITION

CHEMICAL SECTION



"I'm getting out of here! I understand he's great on live demonstrations."

TABLE OF CONTENTS

FORWARD TO FIRST EDITION

The injury experience in our laboratories has never been bad, but considering the varieties and quantities of chemicals being used, the potential for serious injury and damage is ever present. Training in the safe handling of chemicals is an on-going requirement.

Dr. W.B. Mountain, Director General, Central Region, introduced the first two-day seminar on hazardous chemicals, presented by Departmental personnel on October 17, 1979.

Instruction was provided by Dr. J.C. Young, Chemistry and Biology Research Institute, Mr. H. Popp, Fire and Premises Prevention Officer, Mr. P.H. O'Grady and Mr. M.C. Buckwell, Safety and Security Section. Five additional courses have been conducted, with Mr. R.B. Sanderson added to the roll of instructors.

Encouraged by Dr. E.J. LeRoux, Assistant Deputy Minister for the Research Branch, and with the aid of Mrs. J. Donaghue and Mr. W. Frewen of the Personnel Administration Branch, in 1983, lecture notes, training aids and a revised course manual were developed into the training module presented here.

Special acknowledgement is made to Dr. Chris Young for his special expertise and to Mrs. P.H. Burnett for her unflagging efforts in co-ordinating and assembling the final package.

We wish to acknowledge, with thanks, permission of the Industrial Accident Prevention Association Ontario, the J.T. Baker Chemical Company, and National Safety News to use material prepared by them.

PREFACE TO SECOND EDITION

In response to comments received from previous laboratory safety course participants and to changes in relevant legislation, this course manual has been updated to include material on biohazards, gas cylinders, pesticides, properties of some common laboratory chemicals, and where to go to get information on hazardous properties of chemicals. In addition, the bibliography has been expanded at least five-fold.

1.0 THE NEED FOR SAFETY

1.1 INTRODUCTION

Safety is a concern to all of us, or if not, it should be. Canada Safety Council's latest statistics revealed that in spite of increasing emphasis on safety, approximately 500 workers are killed on the job each year...in the year 1983 alone 500,000 suffered disabling injuries.

Until we deal with the real issue, i.e. helping people to perform their jobs more safely through adequate training and motivation, we will continue to see excessive accident frequencies and severity rates in the workplace. The key to the issue as we see it, is training & motivation.

Canada Safety Council reported that $2,500,000,000 in direct costs was paid out for on the job injuries in 1983. We have no way of costing the suffering and loss of production these injuries represented.

The basic purpose of this hazardous chemical safety course is to provide you with information and answer your questions, so that, hopefully, you will understand chemical hazards more fully and learn how to minimize exposure to them. This information can be used by you as part of a program to make your workplace safer, and also to increase your fellow worker's awareness of the hazards and concepts of preventive safety-----FORESIGHT VS HINDSIGHT.

Effective safety programs have proven that the disabling injury rate can be dramatically reduced. One such program --- Dupont U.S.A. --- reduced their injury rate to 0.2 injuries per one million man-hours. This should be compared to the U.S. national average of 10.2 per one million man hours worked.

All too often the problems of chemical hazards are highly publicized; the solutions to the problems are not. One of the results of the public conern has been the increased regulatory activity. A safety bureacracy has been created. Regulations and regulatory agencies now affect most safety programs.

This brings us to the basic question of --- "what is safety"? W. Lowrance, author of a publication entitled, "Acceptable Risk Science and Determination of Safety", defines safety as, "a judgement of the acceptability of risk". He goes on to say that risk is a measure of the probability and severity of harm to human health. Therefore, something can be said that nothing can be absolutely free of risk and consequently nothing can be said to be absolutely safe --- some caution is always required.

Others have defined risk as

$$\text{Risk} = \begin{matrix}\text{magnitute}\\ \text{of}\\ \text{hazard}\end{matrix} \times \begin{matrix}\text{frequency}\\ \text{of}\\ \text{hazard}\end{matrix}$$

For example, the frequency of nuclear reactors undergoing "melt down" is very slight, however the consequences (as in Chernobyl) are catastrophic.

Unfortunately, many things we are associated with on a daily basis can be hazardous. There are over 9,000 accidental deaths in Canada each year. Over 2000 of these occur in the home and approximately half occur as a result of motor vehicle accident. Close to 1000 lose their lives annually through

drowning. Accident victims alone are using 1500 hospital beds each day in Canada. Items as common as table salt, a drinking glass, a hair dryer and even water, can, and do cause injuries. A broken glass for example can cause a serious laceration, an improperly used hair dryer can result in a severe electric shock, salt in large quantities is toxic and water as was mentioned claims a 1000 lives a year.

Chemicals, in general, are hazardous. However, some are far more hazardous than others. The subject of this course is highly hazardous chemicals. What is a hazardous chemical? One definition is --- a substance which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritant or otherwise harmful, is likely to cause injury. The hazards can be classified into ten major groups. The hazard obviously is related to the nature of the substance. Toxicity, for example, is meaured using rats. The toxicity is rated by measuring the quantity required to kill 50% of a rat population. This number is the commonly used LD_{50}. It can be said that sodium cyanide is roughly 500 times more toxic than sodium chloride.

The purpose of this safety course is to provide you with information which can be used to train and motivate those you work with, so that they develop a respect for hazardous chemicals and learn to work with them safely.

For purposes of organization, the course is grouped into five areas:

1. Why there is a need for safety,
2. How to recognize the hazards,
3. How to reduce the hazards,
4. How to respond to laboratory emergencies, and
5. How to investigate accidents.

- - *Boss, I've a great idea for your safety campaign - "SAFETY IN THE WORK PLACE" !*

1.2 POLICIES

1.2.1 Agriculture Canada

In response to various internal and external reports and changes in several federal and provincial laws, in 1986 the deputy minister directed "that Branch Heads and departmental managers at each establishment will be held accountable for developing and implementing specific measures to deal with toxic chemicals and dangerous substances in the work place. It is essential that systems, procedures, and training programs be developed and implemented in order that each work site is in compliance with existing legislation in the handling, storage, transporting, and disposal of dangerous substances ..."

1.2.2 Treasury Board

To ensure a general application across the Public Service, Treasury Board was assigned the task of producing a safety policy, which it did in 1968. That policy has since been supplemented by additional policies, standards and guides. All subject matter pertaining to occupational health and safety has been incorporated into the Personnel Management Manual, chapter 055. This includes all standards, procedures and guides issued under treasury board authority. All responsibility centres have been provided with copies of this material and as new or amended versions are prepared they are kept informed.

One change that was made since 1968 was to issue a separate policy for safety and another for health. The objective of the safety policy is to achieve safe and healthful working conditions and procedures for all employees and to prevent or reduce the risk of employment injury. The health policy has for it's objective to provide appropriate levels of health services and facilities and to achieve and maintain healthful working conditions in order to prevent or reduce the risk of occupational illness. The overall objective then is to prevent or reduce the risk of employment injury or occupational illness.

In order to implement this policy, Treasury Board has spelled out a number of departmental requirements:

1. The active participation of management at all levels.
2. Management's acceptance of responsibility and provision of leadership.
3. The establishment and maintenance of an active safety program.
4. The enforcement of safety codes, rules and regulations.
5. The provision of safety training.
6. The proper investigation and reporting of injuries.
7. The establishment of management-employee safety committees.

1.2.3 Labour Canada

The 1986 proclamation of ammendments to the Canada Labour Code-Part IV have brought about changes in the administration of our occupational safety and health program. The Labour Code spells out responsibilities of:

1. The department, which must:
   a. Ensure safety and health of every employee.

b. Implement and enforce applicable safety and health standards and procedures.
c. Ensure each employee is made aware of every known or foreseeable safety or health hazard in work area.
d. Record, report and investigate accidents.
e. Monitor safety and health committees
f. 23 others are also listed.

2. Employees, who must:
a. Know and observe all relevant safety and health standards and procedures.
b. Use safety and protective equipment.
c. Ensure own or other's safety and health.
d. Report personal injury accidents.
e. Report safety and health hazards.
f. Many others.

3. Safety committees, which must:
a. Meet monthly.
b. Receive, consider and act upon employee complaints.
c. Maintain records of accidents, injuries, hazards.
d. Establish programs to protect workers.
e. Monitor programs and procedures.

1.2.4 Other Federal Policies and Regulations

Treasury Board relies on other federal agencies for inspection, technical and advisory services. These include:

1. Atomic Energy Control Board, which issues licences for use of radiolabeled materials under definite, and specified conditions.
2. Agriculture Canada, which regulates the use of pesticides.
3. Environment Canada, which regulates hazardous wastes.
4. Health and Welfare Canada, which provides certain medical services such as periodic medical examinations, nursing counsellors and inspections to determine health related conditions (eg. presence of mercury vapours).
5. Transport Canada which regulates the transportation of dangerous goods.

1.2.5 Provincial Policies and Regulations

In addition to an ever increasing number of laws that regulate occupational safety and health, waste disposal, and other related matters, most provinces have:

1. Workmans Compensation Boards, which provide compensation to injured workers,
2. Environment Departments that regulate waste management,
3. Labour Departments, and
4. Industrial Accident Prevention Associations.

1.2.6 Other Agencies that make Policies and Regulations

1. Canada Safety Council.
2. Canadian Centre for Occupational Health and Safety (see also section 2.11.6).

3. Canadian Standards Association.
4. Joint Occupational Safety Committees at the departmental and establishment levels.

1.2.7 Summary

That gives you an outline of the policies and in very general terms the requirements for implementation. The departmental safety section is responsible for planning and developing programs and for providing guidance and advice in the health and safety field. The basic program is contained in our safety manual. However, it is you as managers and supervisors who are responsible for implementation and administering the program --- tailored of course to fit your own area of concern.

April 1977, NATIONAL SAFETY NEWS

1.3 FUNDAMENTALS

Safety in the laboratory or industrial facility is not a subject that can be dealt with in a light-hearted or lackadaisical manner. Nor, can it be assumed that workers will have respect for hazardous substances and work safely with them. (In many cases, the hazards are unknown to the worker). Safety must begin with a responsible safety program, and a good safety program can only be effectively initiated by responsible management.

The ten basic elements of a safety program have been delineated in the Departmental Safety Manual and are presented here:

1. Mananagement Leadership.
2. Unit Safety Officer.
3. Safety Committees.
4. Safety Training.
5. Technical Standards.
6. Safe Working Conditions.
7. Surveys & Inspections.
8. Accident Reporting & Investigations.
9. Accident Response.
10. Acceptance of Personnel Responsibility.

Each of the ten points will be dealt with in turn. The keys to an efficient, effective safety program are: leadership, surveys & inspections and training.

1.3.1 Management Leadership

Safety must begin at the top. Management must accept the responsibility for safety and set policy and goals in this area. Without support from management, a safety program cannot function.

1.3.2 Unit Safety Officer

There should be one person appointed as unit safety officer -- responsible and reporting directly to upper management, this position should be such that all organizational channels are open to it.

1.3.3 Safety Committees

Safety committees should involve personnel from all unit facilities and should include both supervisory and non-supervisory personnel. It should be small enough to work efficiently and yet large enough to "cover all the bases". The purpose of a safety committee is to provide effective, co-ordinated action on safety matters; to discuss problems and problem areas, and to devise, initiate, implement, and follow-up on recommended correction actions.

1.3.4 Training

It was mentioned earlier that one of the keys to an effective safety program was safety training. We will be looking at training in more detail later. Safety training for personnel at all levels is probably the single most important facet of any safety program. It should include both the classroom approach and on-the-job training.

1.3.5 Technical Standards

Technical standards for workmanship, performance, equipment and materials used must be available and communicated to employees requiring them. Processes and procedures are constantly changing and the standards must be up-dated and changed as necessary. Employees must be made aware of the hazards associated with their work and the means to protect themselves and their environment from such hazard.

1.3.6 Safe Working Conditions

The maintenance of safe working conditions involves all personnel from the unit safety officer through engineering, purchasing, supervisory and the individual employee. Funneling all relevant information on unsafe work practices and unsafe working conditions to a common source helps to maintain safe working conditions. Maintenance of safe working conditions is both preventive and after the fact. Routine surveys of facilities and periodic health examinations are obviously preventive. An engineering review of facilities could be both. Accident investigation is after the fact -- but very effective in resolving hazardous situations nonetheless.

1.3.7 Surveys & Inspections

Another of the key elements in a safety program. We will cover this area in more detail later.

We make a distinction between surveys and inspections and maybe it should be clarified at this time. We look upon an "inspection" as that done by an outside agency, whether it be a Labour Canada safety inspector, a Health & Welfare environmentalist, or the local fire department. A survey on the other hand is an in-house audit of conditions and procedures but more of that later.

1.3.8 Accident Reporting & Investigation

Apart from the fact that accident reports are required by the various Provincial Workmen's Compensation Boards to verify the legitamacy of compensation claims, adequate records are necessary in order to make an objective evaluation of your overall safety program.

An accident investigation on the other hand is required in order to determine the cause of the incident and to determine the ways and means to prevent its recurrence. Accident investigations will be covered as a separate topic.

1.3.9 Accident Response

The purpose of accident response is to:

1. Provide immediate and adequate treatment of the injured.
2. Limit, where possible, the effects of the accident.
3. Provide means for dealing with results of an accident.

A functioning, well organized safety program will reduce the number of accidents and injuries, but it would be unrealistic to expect to eliminate

them completely. This is the reason why plans and preparations must be made to deal with accident conditions. The requirements of such an accident response preparation will be determined by the type of activity being performed by the unit concerned - the inherent hazards of the various jobs - the environment, etc.

1.3.10 Acceptance of Personal Responsibility

All employees must accept personal responsibility for safety. This can only be achieved through good training, motivation and example. Alerting employees to hazards is more impressive. No safety program can work if personal responsibility is not accepted.

Accidents don't just happen -- they are caused, and by far the largest percentage by unsafe acts. Safety instructions, procedures, techniques and protective equipment are of little value unless they are used by the individual employee when carrying out his functions.

"THE LAST THING I REMEMBER WAS SOMEONE IN THE LAB SAYING 'OOPS' "

1.4 TRAINING

Chemicals can be used safely only if their hazards and properties are fully understood and the necessary precautions employed, including the use of proper safeguards and personal protective equipment. No safety program can be effective unless personnel are adequately trained to appreciate this fact.

1.4.1 Safety Training

Safety training can be divided into two separate aspects:

TRAINING IN SAFETY
AND
TRAINING FOR SAFETY

1. Training in safety covers those subjects dealing with safety as a subject - for example - hazard recognition, conducting a survey, accident investigation, accident reporting, safety committee functions, job safety analysis and so on. Supervisors and other members of the management chain should be trained in safety in the same way that they are trained in their other specific duties. Training in safety is best acquired by attendance at courses, conducted by WCB's, IAPA's, etc. Formal training from recognized experts. This training can be supplemented by the study of safety literature and the practical application of knowledge and skills so obtained.

2. Training for safety implies training the employee in correct safe job procedures, developing a safety consciousness and trust in safety rules and regulations. Safety training for the individual worker is primarily the responsibility of the first line supervisor, it commences with the new employee and is a continuing process. Since work procedures are constantly changing - new technology, new processes, new machines - safety knowledge must keep abreast, even though many of the fundamentals of safety remain the same.

1.4.2 New Employee Training

"Because you're new, be especially careful".

How often are these few words the only safety instructions a new employee gets? Such a casual introduction to safety is of little value and in fact is possibly detrimental. If a lasting impression of the importance of accident prevention is to be made, a much more positive and planned approach is required.

The new employee is especially receptive to instruction and guides which will help him perform his job satsifactorily, and the time is ripe for a thorough safety orientation. This is the time to impress upon the new employee - or for that matter the recently transferred employee - that management considers safety a vital element of every job or operation.

No matter how highly motivated that new employee is, after a period of a few months he will gradually tend to reach the level of those he is working

with. If the safety conscious level or attitude of his new environment is above his initial level, he will tend to climb toward it. If, however the safety conscious level of the unit is lower than his, he will waste little time in dropping to that level.

All employees should be introduced to accident prevention, even if only briefly, on their first day, they should be told of the general safety problems and the accident prevention program. Ideally this first day orientation should be given to the new employee by the unit safety officer. He might wish to cover four (4) general areas:

1. Safety policy:

2. Hazards that may be anticipated:
   a. Common hazards.
   b. Unique hazards.

3. Accident prevention program:
   a. Rules and regulations.
   b. Protective equipment.
   c. Safety committee members.

4. If accident occurs:
   a. Prompt report to supervisor.
   b. First aid.
   c. Showers & eye wash.
   d. Fire alarms.
   e. Emergency exits.

1.4.3 Supervisor Responsibility

The detailed safety training for any specific job is ultimately the responsibility of the immediate supervisor. No one else can or should do it for him. As mentioned earlier, on the job training by the supervisor is a continuing process. The supervisor must instill in the employee a safety consciousness and a trust in the safety rules and regulations that will keep him and his co-workers free of work-related injury or illness.

How is the supervisor to achieve this? Various methods of training in safety have been tried with varying degrees of success. In general, their success appears to be proportional to the degree to which and the thoroughness with which they apply the principle that skill is achieved only doing. Telling is not training.

1.4.4 Training Procedure

One highly successful safety training procedure developed during World War II involves the following elements:

1. A safe method of performing each job is developed.
2. The hazards are brought to light and clearly described.
3. The actual training is systematic and thorough.
   a. Tell employee.
   b. Show employee.

c. Have employee do it.
d. Correct until done properly.
e. Supervise to see that it is retained.

During the instruction, the specific safeguards needed for the protection of the employee and fellow employees are explained and their correct use taught. In summary, training in safety for the new or recently transferred employee must be given, as it is in other arts, by instruction, demonstration, and repetition under supervision.

1.4.5 Special Safety Training

New and particularly hazardous situations require special training. High pressure, biohazards, explosives, and extremely toxic materials are topics requiring special training by experts who are familiar with the safety aspects of the hazard.

At least one individual should be specially trained and then in turn should provide safety instructions to all who may be exposed to the hazard. This special training would normally be received at an outside facility.

2.0 HAZARD RECOGNITION - MATERIALS

2.1 CORROSIVE CHEMICALS

2.1.1 Definition

Those substances that, by direct chemical action are injurious to body tissue or corrosive to metal.

2.1.2 Corrosive Action

Corrosive action on body tissues may be by eye contact, skin contact, inhalation, or injestion. Tissue corrosion occurs by:

1. Direct chemical reaction, which may destroy proteins and disrupt cell membranes. Eg.
   a. Peptide bond cleavage.
   b. Loss of hydrogen bonding.
   c. Oxidation of -SH.
   d. Dehydration.

2. Dissolution of essential components. Eg. Defatting of lipids by solubilizing, especially with chlorinated hydrocarbon solvents.

2.1.3 Chemical Types

1. Acids
   a. Inorganic (eg. H_2SO_4, HCl, HNO_3, $HClO_4$)
   b. Organic (eg. CH_3COOH, $(CF_3CO)_2O$, C_6H_5OH)
   c. Lewis (eg. $AlCl_3$, BF_3)

2. Bases
   a. Hydroxides (eg. NaOH, KOH, NH_4OH, $Ca(OH)_2$)
   b. Oxides (eg. CaO, Na_2O)
   c. Carbonates (eg. $CaCO_3$)
   d. Alkoxides (eg. $NaOCH_3$)

3. Strong electrophiles - skin corrosives and lacrimators.
   eg. $R{\equiv}C\text{-}X$, $-C{=}CH_2\text{-}X$, $(CH_3)_2SO_4$, $(CH_3O)_3PO$, $S(CH_2CH_2Cl)_2$

4. Stress corrosives - a hazard to certain metals.
   a. NaBr will corrode high carbon steel that is stressed.
   b. Cl^- produced from CCl_4-tehahydrofuran-H_2O over two years attacked stainless steel and caused explosion.

2.1.4 Corrosive Gases

1. Very soluble in respiratory tract.
   (eg. NH_3, HCl, HF, HCHO, $SOCl_2$, SO_2Cl_2).

2. Soluble in respiratory tract.
   (eg. Br_2, Cl_2, I_2, $AsCl_3$, PCl_3, PCl_5, SO_2).

3. Least soluble, but have severe long term effects.
   (eg. $COCl_2$, NO_2, O_3).

4. Others - acrolein, dimethylsulfate, mustard gas, nerve gases.

2.1.5 Corrosive Liquids

1. Mineral acids (eg. HCl, HF, H_2SO_4, HNO_3).

2. Aqueous alkali (eg. NaOH, NH_4OH, R_4NOH).

3. Others
   a. Liquified phenol.
   b. Bromine.
   c. Chlorinated solvents.
   d. Organic acid, anhydrides, and halides.

2.1.6 Sulfuric Acid

1. Physical & Chemical Properties:
   a. Dense, corrosive liquid.
   b. Zero friction - very slippery.
   c. Very reactive, strong oxidizer.
   d. Strong dehydrating action.
   e. Liberates heat when mixed with H_2O.
   f. Dissolves most metals with release of hydrogen. Heat of reaction can ignite H_2.

2. Toxicity - vapor is about 10X more toxic than HCN.

3. Effects:
   a. Destruction of skin & eye tissue.
   b. Respiratory. Irritation or destruction of lining of nose, throat, bronchia, lungs. Can induce bronchitis, pneumonitis & pulmonary edema.
   c. Gastrointestinal. Dissolves teeth. Destruction of lining of mouth, throat, abdomen. Perforation of gastrointestinal tract.

2.1.7 Corrosive Solids

1. Caustic Alkalies:
   a. Hydroxides (eg. NaOH, $Ba(OH)_2$).
   b. Carbonates (eg. Na_2CO_3, $CaCO_3$).
   c. Oxides (eg. CaO, P_2O_5).

2. Elements (eg. Na, K, P).

3. Salts (of Antimony, Arsenic, Chromium).

4. Others (Phenol).

5. Effects are largely dependent upon:
   a. Solubility in moisture in skin, respiratory tract, or elementary tract.
   b. Duration of contact.

6. Damage to eye greater by caustics than by acids since protein barrier not formed by caustics.

2.1.8 Special Hazards of Solid Corrosives

1. Solutions are readily absorbed through skin.
2. Apparent injury (eg. pain) is often delayed.
3. Dusting & inhalation.
4. Molten corrosives act as liquids.
5. False security - can be removed more easily than liquids.

2.1.9 Personal Control Measures for Corrosives

1. Wear adquate protective equipment.
2. Use adequate exhaust ventilation.
3. Don't wear contact lenses.
4. Have easy access to eyewash stations.
5. Have easy access to safety showers.
6. Have easy access to immediate medical attention.
7. Have periodic medical checkups.
8. Be thoroughly trained in the hazards of the materials worked with and first aid measures to be taken.

"All the pollutant gases have been removed, with the exception of nitrous oxide. Say, isn't that 'laughing gas'?"

National Safety News, February 1972

2.2 TOXIC CHEMICALS

2.2.1 General

A toxic substance has the potential of injury by direct chemical action with body systems. It interferes with the function of cells in body tissues and disrupts biological processes.

Almost any chemical is toxic when taken in excess of "tolerable" limits. 1 gram of table salt will kill a rat.

2.2.2 Toxicological Symptoms

Short term (acute) symptoms include irritation, pain, headaches, weakness, dizziness, drowsiness, unconsciousness, gastrointestinal upset, nausea and vomiting, convulsions and death.

Long-term (chronic) symptoms include mutagenic, carcinogenic, and teratogenic (birth) effects.

2.2.3 Physiological Effects of Toxic Substances

They may interfere with:

1. Enzyme systems (Cholinesterase by pesticides).

2. General function of cells:
   a. Anesthetic (ether, chloroform).
   b. Neurotransmission (LSD).

3. RNA and DNA synthesis:
   a. Mutagens.
   b. Teratogens.
   c. Carcinogens.

Toxic substances may:

1. Block oxygen transport (carbon monoxide).

2. Directly irritate tissues:
   a. Corrosives.
   b. Lacrimator.
   C. Stenches.

3. Accumulate to toxic levels:
   a. Organochlorine (PCB) in fatty tissues.
   b. Heavy metals (lead).

4. Cause hypersensitivity (diazomethane).

2.3.4 Toxicity Types

1. Local - area of body exposed to toxicant.

2. Systemic - area of body affected by toxicant that has been adsorbed into blood stream and transported from site of exposure.

3. Acute - effect from short or single exposure.

4. Chronic - effect from extended or multiple exposure.

2.2.5 Toxic Doses and their Measurement

1. LD_{50} - Lethal Dose, 50% killed (mg/kg). Test route usually oral, intravenous, intramuscular, subcutaneous.

2. LC_{50} - Lethal Concentration, 50% killed (ppm/time).

3. TLV - Threshold Limit Value (ppm/8hr, mg/m^3/8hr). Estimate of "safe" level when exposed on a continuing basis.

4. TWA - Time Weighted Average (ppm/8hr). The average exposure over a working shift. Related to TLV.

5. STEL - Short Term Exposure Limit - the maximum concentration that is "safe" for up to 15 min exposure.

2.2.6 Sample Toxicities

Substances	LD_{50} [1]	LD_{man} [2]	LC_{50} [3]	TLV[4]	TWA[4]
NaCN	6	= 450mg		5mg/m^3	
HCN		50mg 300ppm	544/5	10	15
H_2S		800	713/60	10	15
Benzene	3.3			5	1
Toluene	6.5			200	100
Methanol		30mL		200	250
Ethanol	13700			1000	

1. mg/kg, oral, rat
2. 75 kg
3. ppm/min inhalation, rat
4. ppm (1979)

2.2.7 Sample Hazard Ratings, Inhalation

Substances	Acute		Chronic	
	Local	Systemic	Local	Systemic
HCN	2	3	U	U
H_2S	3	3		3
Benzene	1	2	0	3
Toluene		2		2
Methanol	1	2	1	2
Ethanol		2		1

0 - None; 1 - Slight; 2 - Moderate; 3 - High; U - Unknown.

2.2.8 Types of Exposure

1. Skin.
2. Eyes.
3. Inhalation.
4. Injestion.

2.2.9 Detection of Toxicants

1. Senses.
   a. Smell (H_2S, NH_3, O_3, R-SH). Fatigue!
   b. Vision (Br_2, NO_2).
2. Color indicating tubes.
3. Instrumental monitors (conductivity, spectroscopic).
4. Absorbent badges:
   a. Gold foil (Hg).
   b. Carbon.
5. Total organic → CO_2.

"Cartwright still doesn't trust our toxic gas detectors."

National Safety News, August 1970

2.3 REACTIVE CHEMICALS

2.3.1 General

These are substances that under cetain conditions undergo violent reaction with spontaneous generation of large quantities of heat, light, gases or toxicants that can be destructive to life and property.

2.3.2 Explosives

They result in the production of large quantities of gas and usually heat. The rapid expansion of surrounding air may be accompanied by burning gases and flying objects.

2.3.3 Reduction - Oxidation (Redox) Reactions

They usually generate heat and may be explosive. Both reductants and oxidants must be present. Thus, keep apart.

2.3.4 Inorganic Oxidizing Agents

Examples are: Oxygen (O_2, O_3), Oxides, Peroxides, Mineral Acids (HNO_3), Perchloric Acid, Halogens, Chromates, Nitrites, and Permanganate.

2.3.5 Inorganic Reducing Agents

Hydrogen, Metallic Hydrides, Alkali Metals, Metallic Catalysts, and Phosphorus.

2.3.6 Organic Oxidants and Reductants

Oxides, Peroxides, Ozonates, Peracetic & Peroxy Acids, and Hydrides.

2.3.7 Water Sensitive Substances

1. Heat is liberated with:
   a. Strong acids and bases.
   b. Acid anhydrides.

2. Flammable gases are liberated with:
   a. Alkali metals (Na, K, Li).
   b. Hydrides (NaH, $LiAlH_4$).
   c. Nitrides.
   d. Carbides (CaC_2).
   e. Anhydrous Metallic Salts.

Note: Heat generated may ignite gases.

2.3.8 Acid Sensitive Substances

Most metals, Alkali metals (Li, Na, K), Alkaline hydroxides (NaOH, $Ca(OH)_2$), Carbonates, Carbides, Nitrides, Cyanides, and Sulfides. Reaction may liberate heat, toxicants and flammable and/or explosive gases.

2.4 INSIDIOUS HAZARDS

More dangerous than seems evident. Like an ambush!

Since they are not usually seen, smelled, tasted or felt, they may be overlooked and ignored.

2.4.1 Mercury

(TWA = 0.05 mg/m^3)

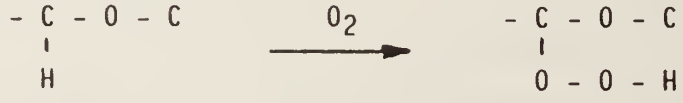
Causes severe acute and chronic effects such as: inflammation of respiratory and gastrointestinal tracts, cardiac arrest, nerve damage, loss of muscle control. Mercury can form stable, very finely divided droplets that can hide in both horizontal and vertical surfaces.

Control of mercury hazards involves eight steps:

1. Store mercury in unbreakable plastic bottles.
2. Keep containers SEALED in a cool, well-ventilated area.
3. Provide catch-trays beneath set ups using large amounts of (1 g) of mercury.
4. Use care in handling mercury and instruments containing mercury.
5. Immediately cleanup spills.
6. Use a positive means for controlling mercury vapor from uncollected droplets.
7. Cleanup should be immediate and thorough.
8. Where mercury is routinely used, secure periodic medical checkups for possible mercury poisoning.

2.4.2 Ether Peroxides

Especially hazardous in old and improperly stored ethers. Detect with starch-iodide. Fe(II) (eg. $FeSO_4$aq.) wash removes peroxides. Inhibit with alkali metals.



2.4.3 Perchlorates

Shock sensitive, very Explosive! Can form in fume hood ducts. Wash down with water.

2.4.4 Heavy Metal Azides

Copper & lead azides are explosive and can form in plumbing and heating coils (from Na, K azide slimicides).

2.4.5 Gas Cylinders

1. Leaks:
   Phosgene, Hydrogen cyanide, Nickel carbonyl, Chlorine, Ammonia.

2. Faulty or incorrect pressure control equipment.

2.4.6 Chemical Storage

Incompatible reactive chemicals stored on same shelf (see section 2.7).

2.4.7 Liquid Chemicals

In glass containers stored above eye level.

2.4.8 Mixed Chemicals

1. That react slowly to form toxic products or build pressure.

2. That have induction periods.
   a. organometallics (Grignard).
   b. free radical reactions.

2.4.9 Unlabelled Chemicals

They should be thrown out.

2.4.10 Incorrectly Labelled Chemicals

These are worse than unlabelled chemicals.

2.4.11 Ignition Sources

In flammable solvent areas.

2.4.12 Dirty Glassware

Organic "crud" on glassware placed in chromic acid baths.

2.4.13 Quenching Reactions

With water (eg. excess hydrides, metal). Instead use alcohols (eg. i-PrOH, t-BuOH).

2.4.14 Laboratory Drains

For example, when traps become dry.

2.4.15 Laboratory Ventilation

2.5 RADIOACTIVE HAZARDS

2.5.1 General

Radioactive chemicals contain one or more atoms capable of spontaneously emitting alpha particles, beta particles or gamma rays by the disintegration of the corresponding atomic nuclei. eg.

^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{60}Co, ^{125}I, ^{238}U

2.5.2 Radioactive Emissions

	Symbol	Mass	Nature
Alpha	α	4 amu	$^{4}He^{++}$
Beta	β	1/1800	electron
Gamma	γ	0	uncharged electromagnetic radiation

2.5.3 Biological Damage

Interaction of tissue with radioactive emissions results in ionization of some of the atoms in the exposed tissue. Thus, "ionizing radiation".

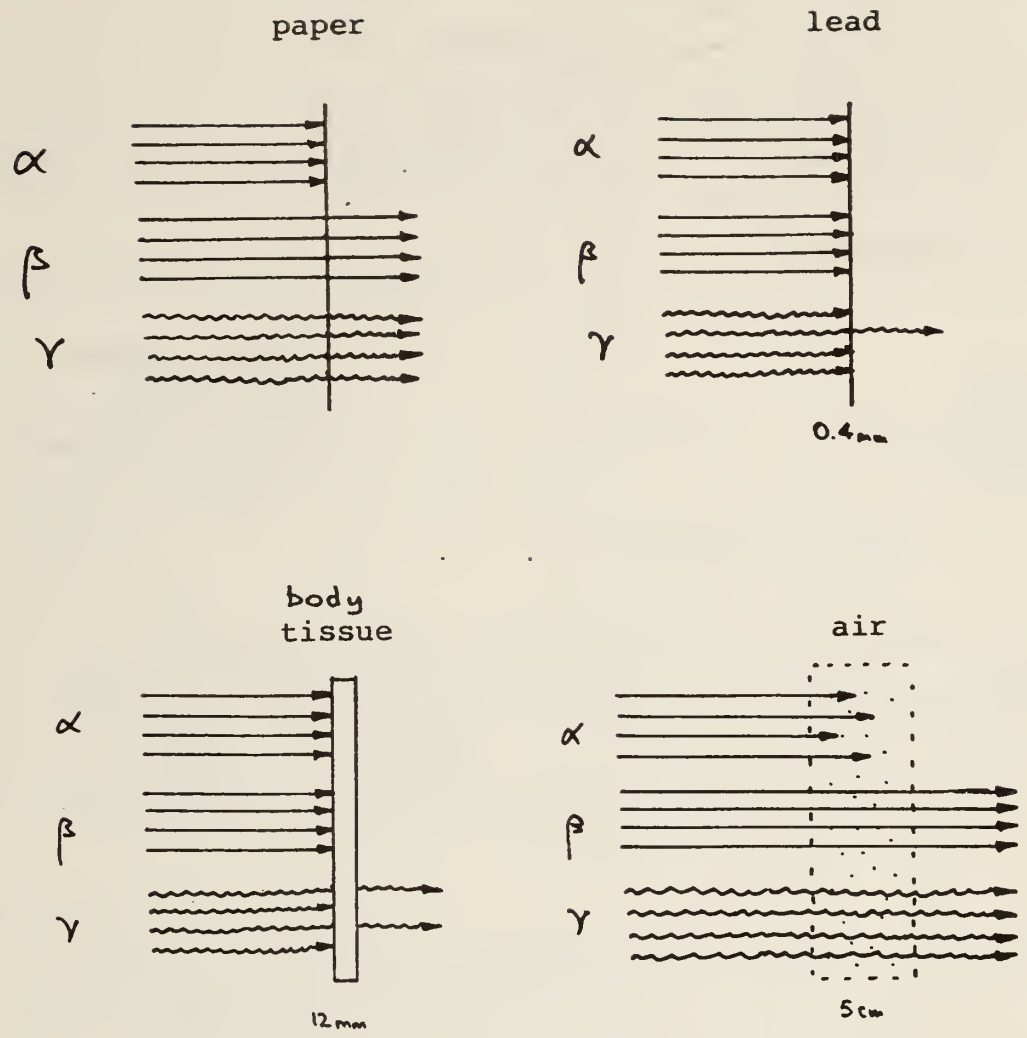
2.5.4 Radiation Detection

Radiation is detected and measured by the ionization it produces or by its conversion to light. Detectors include:

1. Electroscope.
2. Ionization Chamber (Geiger-Mueller Counter).
3. Liquid and crystal scintillation produce light.
4. Photographic film.
5. thermoluminescence.

2.5.5 Penetration

Penetration $\propto \dfrac{1}{\text{ease of ion formation}}$



2.5.6 Units of Radioactivity

1. Curie: That quantity of radioactive substance which undergoes 3.7 X 10^{10} disintegrations/sec.

2. Rad: That quantity of radioactivity which results in the absorption of 100 ergs of energy by 1 gram of material.

3. Roentgen: 83.3 ergs/g air.

4. REM: Roentgen Equivalent in Man. Used to equate biological effects.

5. RBE: Relative Biological Effectiveness. Proportionality constants for kinds of radiation.

α = 10-20 β = 1.7-6 γ = 1

REM = RBE x RADS

Under the SI units system, these units have been changed as follows:

1 rad (rad)	=	10 milligrays (mGy)
1 gray (Gy)	=	100 rad (rad)
1 curie (Ci)		37 gigabecquerel (GBq)
1 becquerel (Bq)		27 picocuries (pCi)
1 rem (rem)	=	10 millisieverts (mSv)
1 sievert (Sv)	=	100 rem (rem)

2.5.7 Biological Effects

	1000	Fatal
	100	Radiation Sickness
RADS	10	Genetic Damage
single	1	Changes in White Cell Number
whole body	0.5	0.01% Life Decrease
dose	0.1	No Detectable Effects

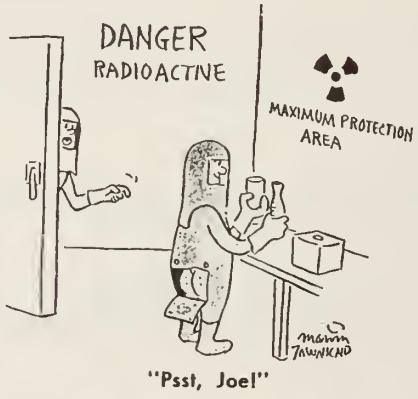
LD_{50}	one exposure	450 Rads
LD_{50}	repeated exposure	10 Rads

International Exposure Standard, Whole Body

REM_{max} = 5 x (age/yr - 18)

Canada REM_{max} = 5/yr Atomic Radiation Workers

= 0.5/yr Others



"Psst, Joe!"

September 1974, NATIONAL SAFETY NEWS

2.6 CRYOGENICS

2.6.1 General

Cryogenic materials include:
liquids having bp -60°C to -270°C and dry ice (sublimes -78°C).

Note that many properties of cryogenic liquids and compressed gases are common, therefore hazards are common.

2.6.2 Cryogenic Hazards

1. Contact with and destruction of living tissue. Effects are similar to steam burns.

2. Pressure buildup. 1 mL liquid expands to 750-1400 mL gas at STP.

3. Embrittlement.

4. Fire and explosions:
   a. Flammables (H_2, F_2, CH_4, acetylene).
   b. Combustion supporting. LOX can ignite organics by autoignition.

5. Asphyxiation:
   a. By expansion in gaseous form and displacement of air.
   b. By inate toxicity eg. CO, F_2, O_3, BF_3, HCl, CO_2, and NH_3.

6. Condensation of oxygen.

   Since boiling point of O_2 is -183°C, use of a cryogenic liquid with a lower bp. (e.g. N_2 - 196°, Ne - 246°, or H_2 - 253°) can cause oxygen in the air to condense.

"Never too late, sir."

National Safety News, October 1971

2.7 BIOLOGICAL HAZARDS

2.7.1 Introduction

All of the good laboratory practice precautions that one would employ when using chemicals generally apply to the use of biological hazards. However, because biological agents are generally invisible and not readily detectable, there are other special precautions that should be followed. Biologically active materials that may be encountered include:

1. Viruses, plant and animal.
2. Bacteria.
3. Moulds and fungi.
4. Tissues and cells.
5. Recombinant DNA molecules.

It should be noted that some organisms release substances that are not in themselves biological entities, but nonetheless may be extremely hazardous.

2.7.2 Medical Precautions

1. Hands must always be washed when leaving the laboratory.
2. Personnel with open wounds or eczema should not work with these samples.
3. Personnel with immunodeficiency diseases and those on immunosuppressive therapy should be excluded from work with certain infectious agents.
4. Personnel on antimicrobial therapy may be at increased risk.
5. Vaccination against an organism in use should be administered if the individual is not immune.

2.7.3 Laboratory Design

1. Proper ventilation is essential. HEPA filters may be required. Exhausted air must not be allowed to reenter the building.
2. All surfaces must be resistant to decontaminants and liquid penetration.
3. Doors to laboratory should be marked with the appropriate biohazard or containment sign.
4. Containment must be appropriate to the organism under investigation. This may range from Level A for a normal well designed laboratory to Level F for an isolation unit geographically separated from other areas. Consult the Medical Research Council of Canada Guidelines for the Handling of Recombinant DNA Molecules and Animal Viruses and Cells (1980) for the containment required for the various biological hazards.

2.7.4 Experimental Animals, Insects, or Plants

1. Infected organisms should be held separately from un-infected organisms.
2. Infected or treated animals and insects must be kept under the appropriate containment level.
3. Inoculated animals or insects must be kept from escaping.
4. Dead animals or insects and their refuse must be placed in a leak-proof container and autoclaved or incinerated.
5. Traps in floor drains must be filled with disinfectant.
6. Gloves, boots and laboratory surfaces should be disinfected frequently.

2.7.5 Decontamination

Routine disinfection or inactivation of potentially hazardous agents on laboratory work surfaces must be carried out at least once per working day. Other contaminated materials must be treated (eg. by autoclaving or disinfecting) in a manner appropriate to the hazard.

2.7.6 Transport of Specimens

Samples must be packaged according to the appropriate regulations. Those agents requiring the highest levels of containment should be transported only if absolutely essential.

2.7.7 Monitoring

Ventilation, filter, disinfection and decontamination systems should be monitored frequently to ensure their efficacy.

"I just wanted to show you my new respirator!"

September 1974, NATIONAL SAFETY NEWS

2.8 GAS CYLINDER HAZARDS

2.8.1 Hazards

1. High pressure (up to 157 atmospheres).
2. Potential rocket (if top knocked off).
3. Reactive (e.g. H_2, O_2).
4. Toxic (e.g. HCl, Cl_2, SO_2, NH_3).
5. Installing regulators.
6. Transport (use cart).
7. Loose cylinders (clamp in place).

2.8.2 Procedures for Safe Handling

1. Secure cylinders to cart or wall.
2. Blow out cylinder valves first (except H_2) and stand on opposite side.
3. Release regulator adjusting screw before opening cylinder valve.
4. Open cylinder valve slowly.
5. Use no oil on regulators or fittings.
6. Ventilate work area.
7. Keep heat, flames and sparks away from combustibles.
8. Check for leaks on regular basis using soapy water.
9. Label gas lines to apparatus.

2.9 PESTICIDES

2.9.1 General

These chemicals are meant to interrupt the life processes of or kill fungi, plants, and insects. However, they may also be highly toxic to humans and other animals. Thus they must be handled with great care and respect.

2.9.2 Classification by Purpose

Pesticides may be classed according to the target organism and their effect on such an organism.

1. Fungicide
   a. Protective
   b. Eradicant
   c. Systemic

2. Herbicide
   a. Contact
   b. Growth regularity
   c. Systemic

3. Insecticide
   a. Contact
   b. Stomach
   c. Systemic
   d. Fumgant

2.9.3 Classification by Formulation

Pesticides may also be classified according to how they are formulated.

1. Liquid
   a. Solution
   b. Emulsion
   c. Wettable powder
   d. Flowable suspension
   e. Water dispersable granules

2. Solid
   a. Granular
   b. Dust
   c. Pellet

3. Gas
   a. Fumgant
   b. Smoke

4. Other
   a. Pressurized spray
   b. Aerosol

2.9.4 Classification by Chemical Composition

Finally, pesticides may be classed according to their chemical structures. The table shows that there can be a considerable difference in toxicity even within a particular class.

CLASS/TARGET	EXAMPLE	LD_{50} ORAL, RAT	TOXICITY
Organochlorine (OC)			
Fungus	Captan	9000	V. Low
Weeds	Pentachlorophenol	27	V. High
Insect	DDT	113	Moderate
Orgaphosphorus (OP)			
Fungus	----		
Weed	Glyphosate	4300	V. Low
Insect	Parathion	13	V. High
Carbamate			
Fungus	Benomyl	10 000	V. Low
Weed	Triallate	>1 700	Low
Insect	Carbofuran	8	V. High
Chlorophenoxy			
Weed	2,4-D	300-1000	Medium
Urea			
Weed	Linuron	>1500	Low
Dinitrophenyl			
Fungus	Dinoseb	5-60	V. High
Weed	Dinoseb		
Insect	Dinitrophenol	30	High
Triazine			
Fungus	Anilazine	2700	Low
Weed	Atrazine	3000	Low
Pyridylium			
Weed	Paraquat	150	Medium
Botanical	Rotenone	132	Medium
	Nicotine	50	High
	Pytethrum	>1800	Low

2.9.5 Pesticide Hazards

Two major types of hazards to humans and animals are related to the persistance and biochemical effects.

CLASS	PERSISTANCE	HAZARDOUS EFFECT
Organochlorine	High	Cumulative Build Up In Fatty Tissue
Organophosphorus	Low	Lowers Acetyl Cholinesterase
Carbamate	Low	Lowers Acetyl Cholinesterase
Chlorophenoxy	Medium	
Urea	Low	
Dinitrophenyl	Low	
Triazine	High	
Pyridylium	Very High	Severe Lung Effects
Botanical	Low	

2.9.6 Hazards Associated with Various Stages of Use

1. Storage	a. Contamination of food, feed, humans, animals. b. Fire.
2. Mixing And Pouring	a. Contact with highly concentrated material. This is the most hazardous stage of use.
3. Spraying	a. Contact with mists, vapours, dusts. b. Wind drift to expose other plants, animals, humans, water supply. c. Improperly calibrated application equipment. d. Failure to wear appropriate protective equipment.
4. Disposal	a. Contaminated if "empty" containers are not properly rinsed and disposed of.
5. Reuse Of Clothing	a. Contamination of body or laundering equipment if improper or incomplete laundering.

2.9.7 Management of Pesticide Use

In order to protect operating personnel, the public, and the environment, the supervisor should ensure that:

1. The least toxic but most effective pesticide is used;
2. That application is at the minimum effective rate, and all on the target area;
3. Application equipment is regularly maintained and calibrated;
4. All personnel (including temporary personnel) are fully briefed on safe procedures, and are properly supervised and protected;
5. Liaison is pre-arranged with local medical facilities;
6. Personnel receive regular physical examination, including blood cholinesterase determinations, if necessary.
7. Arrangements are made so that if a poisoning or spill occurs, it is possible immediately to:
   a. decontaminate the individual, and
   b. deliver them to emergency treatment facilities.

2.9.8 Procedures for Safe Handling

Even though pesticides can be extremely toxic, they can be used safely if the following precautionary measures are followed:

1. Inspect pesticide containers for leaks before handling them.
2. Do not handle containers roughly or carelessly.
3. Should a leak or spill occur, keep people and animals away from the area; decontaminate thoroughly and report immediately to the supervisor, who in turn may have to report to the appropriate provincial or federal regulatory agencies.
4. Inspect vehicles for contamination after unloading; do not permit a contaminated vehicle to leave before decontamination.
5. Do not store pesticides or empty pesticide containers anywhere near food or drink (including that for animals).
6. Do not keep food, drink, tobacco, cups or cutlery anywhere in the work areas or in work clothes.
7. Do not eat, drink, or smoke in a work area.
8. Do not rub the eyes or touch the mouth while working with pesticides.
9. Wash hands thoroughly before eating, drinking, smoking, or using the toilet.
10. Wear clean rubber gloves and protective clothing when handling pesticides, and a respirator whenever recommended.
11. Never fail to decontaminate contaminated clothing or to discard faulty protective clothing, especially gloves.
12. Read the label carefully; if seeking medical aid, take the label and/or the container with you.

2.10 PROPERTIES OF SOME COMMON LABORATORY CHEMICALS

The tables below list properties of some of the more common hazardous chemicals that may be found in typical lab. For details on other chemicals, refer to section 2.11, which lists a wide variety of information sources.

2.10.1 Hazardous Gases

GAS	NFPA RATING HLTH	FIRE	REACT	DL	TLV ppm	IDLH ppm	BP °C	HAZARD	TDG	RD	CAS #	RTECS #	UN #
ACETYLENE	2	4	3		*		- 84	E F	2.1	19	74-86-2		UN1001
AMMONIA	2	1	0	50	25	500	- 33	C F I	2.4	11	7664-41-7	BO0875000	UN1005
BORON TRIFLUORIDE	3	0	1		1	100	-111	C I T	2.3 8	22	7637-07-2	ED2275000	
CARBON DIOXIDE					5000	50000	- 78	O	2.2	1A	124-38-9	FF6400000	UN2187
CARBON MONOXIDE	3	4	0		50	1500	-191	E F T	2.1 6.1	1A	630-08-0	FG3500000	UN1016
CHLORINE	3	0	0	5	1	25	- 35	C F O	2.4 9.2	13A	7782-50-5	FO2100000	UN1017
DIAZOMETHANE	4	-	4		0.2	10	- 23	E T			334-88-3		
ETHYLENE OXIDE	2	4	3	300	10		11	N T	2.1 6.1	16	75-21-8		UN1040
FLUORINE	3	0	3		1	250	-187	C F O T	2.3 5.1	13A	7782-41-4		UN1045
FORMALDEHYDE	3	4	0	1	3	100		F T N	9.2	3	50-00-0	LP8925000	
HYDROGEN	0	4	0		*		-253	E F	2.1	1A	1333-74-0	MW8900000	UN1049
HYDROGEN CYANIDE	4	4	2		10	50	26	F T	2.1 9.2	15	74-90-8		
HYDROGEN CHLORIDE	3	0	0	10	5	100		C I		1A	7647-01-0	MW4025000	UN1050
HYDROGEN SULFIDE	3	4	0	0.005	10	300	- 60	E F T	2.1 6.1 9.2	1A	7783-06-4	MX1225000	UN1053
METHANE (NAT GAS)	1	4	0		*		-162	E F	2.1	19	74-82-8	PA1490000	UN1971
METHYL AMINE	2	4	0	0.02			- 6	C F	9.2	8A	74-89-5	PF6300000	
METHYL BROMIDE	3	1	0		20	2000	3	C T	2.3	5B	74-83-9	PA4900000	UN1062
NITRIC OXIDE	3	-	-		25	100	-151	C I T			10102-43-9	QX0525000	UN1660
NITROGEN DIOXIDE	3	0	0	1	3	50	21	C O T	2.3 5.1 9.2	22	10102-44-0	QW9800000	UN1067
OXYGEN	-	0	0		-		-183	E O	2.2 5.1	1A	7782-44-7	RS2060000	UN1072
OZONE	4	0	0	0.015	0.1	10	-111	I O T			10028-15-6		
PHOSGENE	4	0	0	1	0.1	2	8	T	2.3 8 9.2	22	75-44-5		UN1076
PHOSPHINE	4	4	1	0.02	0.3	200	- 88	F T			7803-51-2		UN2199
PROPANE	1	4	0		1000*	5000	- 42	E F	2.1	19	74-98-6	TX2275000	UN1075
SULFUR DIOXIDE	3	0	0	0.3	2	100	- 10	C I	2.3	13B	7446-09-5	WS4550000	UN1079
HYDROGEN FLUORIDE					3								UN1052

* - asphyxiant when oxygen is displaced
DL - nasal detection limit
NFPA Rating: 0 - no hazard to 4 - extreme hazard
TLV - Threshold limit value ('safe' for 8 hr exposure)
IDLH - immediately dangerous to life or health (within 30 min)
N - cancer suspect C - corrosive O - displaces oxygen
E - explosive F - fire I - irritant
O - oxidant T - toxic W - water sensitive
TDG - Transportation of Dangerous Goods regulation classification (see 2.10.5)
RD - Recovery and Disposal Method (See Technical Manual for the Management of Chemical Wastes in Laboratories, Environment Canada.)
CAS # - Chemical Abstracts Service registry number
RTECS # - Registry of Toxic Effects of Chemical Substances number
UN # - United Nations product identification number

LIQUID	NFPA RATING HLTH	FIRE	REACT	OL	TLV ppm	IOLH ppm	BP °C	FLASH °C	HAZARD	TDG		PG	RD	CAS #	RTECS #
ACETALDEHYDE	2	4	2	0.2	100	10000	21	-39	F	3.1	9.2	I	3	75-07-0	AB1925000
ACETONE	1	3	0	20	750	20000	56	-13	F	3.1		II	19	67-64-1	AL3150000
AMMONIUM HYOROXIDE	2	-	-	50	25	500			C I	2.4	9.2	X	11	7664-41-7	BQ9625000
ACETONITRILE	2	3	1		40	4000	80	6	F T	3.2	6.1	II	15	75-05-8	AL7700000
BENZENE	2	3	0	5	10	2000	80	-11	N F T	3.2	9.2	II	19	71-43-2	CY1400000
BROMINE	4	0	0	0.05	0.1	10	59		C O	8	6.1	I	13A,22	7726-95-6	EF9100000
BUTANOL	1	3	0	0.3	50	8000	119	10	F	3.2		II	19	71-36-3	EO1400000
CARBON TETRACHLORIDE	3	0	0	79	5	300	77		N T	6.1	9.2	II	5B	56-23-5	FG4900000
CHLOROFORM	3	-	2	200	10	1000	61		N T	6.1	9.2	II	1J	67-66-3	FS9100000
CYCLOHEXANE	2	3	0		300	10000	81	-20	F	3.1	9.2	II	19	110-82-7	GU6300000
OIETHYL AMINE	2	3	0	0.02	3	2000	134	-26	T	3.1	9.2	II	8A	109-89-7	HZ8750000
DIETHYL ETHER	2	4	1	0.7	400	19000	35	-45	F	3.1		I	16	60-29-7	KI5775000
ETHANOL	0	3	0	10	1000		78	12	F	3.2		II	19	64-17-5	KQ6300000
ETHYL ACETATE	2	3	0	6	400	10000	77	- 4	F	3.2		II	19	141-78-6	AH5425000
FORMALDEHYDE (AQ)	2	2	-	1	2	100	101	85	C I T	3.3	9.2	II	3	50-00-0	LP8925000
GASOLINE	2	3	0		-			-43	F	3.1		II	19	- -	
HEXANE	1	3	0		50	5000	69	-22	F	3.1		II	19	110-54-3	MN9275000
HYDROGEN PEROXIDE	3	0	1		1	75	107		C O	5.1	8	II	23A	7722-84-1	MX0899000
ISOPROPYL ALCOHOL	1	3	0	3.2	400	20000	82	4	F	3.2		II	19	67-63-0	NT8050000
MERCURY	3	0	0		0.05*	28*	357		T	8		I	1B	7439-97-6	OV4550000
METHANOL	2	3	0	100	200	25000	65	12	F	3.2	6.1	II	19	67-56-1	PC1400000
METHYLENE CHLORIDE				300	200	5000	40		T	9.2		III	58	75-09-2	PA8050000
PYRIDINE	2	3	0	0.02	5	3600	115		T	3.2	6.1	II	6	110-86-1	UR8400000
TOLUENE	2	3	0	0.2	100	2000	110	4	F	3.2	9.2	II	19	108-88-3	XS5250000
XYLENE	1	3	0	0.08	100	10000	139	29	F	3.2	9.2	II	19	1330-20-7	ZE2100000

2.10.3 Hazardous Liquid Acids

ACID	NFPA RATING HLTH	FIRE	REACT	TLV ppm	LD mL	IDLH ppm	HAZARD	TDG			PG	RD	CAS #	RTECS #
ACETIC	2	2	1	1.0	5	1000	C	8	9.2		II	25A	64-19-7	AF1225000
CHROMIC (CLEANING)	3	0	1	0.1			C O T	5.1	8	9.2	II	13A	- -	GB6650000
FORMIC (37%)	3	2	0	2	30	100	C T	8	9.2		II	25A	64-18-6	LQ4900000
HYDROCHLORIC	3	0	0	5	1	100	C	8	9.2		II	25B	7647-01-0	MW4025000
HYDROFLUORIC	4	0	0	3		20	C T						7664-39-3	MW7875000
NITRIC	3	0	0	2	1	100	C O	8	9.2		I	25B	7697-37-2	QU6000000
PERCHLORIC	3	0	3		1		C O	5.1	8		I	13A	7601-90-3	SC7500000
PHOSPHORIC	2	0	0	1 mg	1		C	8	9.2		III	25B	7664-38-2	TB6300000
SULFURIC	3	0	2	1 mg	1	80	C O	8	9.2		II	25B	7664-93-9	WS5600000

2.10.4 Hazardous Solids

SOLID	NFPA RATING HLTH	FIRE	REACT	TLV mg/m^3	IDLH mg/m^3	HAZARD	TDG		PG	RD	CAS #	RTECS #
CHROMIC ACID	4	0	2	0.1	30	C	5.1	8	II	13A	1333-82-0	GB6650000
IODINE	3	0	-	0.1	10	C T				13A	7553-56-2	NN1575000
OSMIUM TETROXIDE	4	0	-	0.002	1	C T		6.1	I	13A	20816-12-0	RN1140000
PERCHLORATES	2	2	2			E					- -	
PHENOL	3	2	0	5	100	C T	6.1	9.2	II	19	108-95-2	SJ3325000
PHOSPHORUS, RED	0	1	1				4.1	9.2	III	1C	7723-14-0	TH3495000
PHOSPHORUS, WHITE	3	3	1	0.1		C F T				1C	7723-14-0	
PICRIC ACID	3	4	4	0.1	100	E T				30	88-89-1	TJ7875000
POTASSIUM HYDROXIDE	3	0	1	2	200	C	8	9.2	II	11	1310-58-3	TT2100000
SODIUM	3	1	2			C W	4.3	9.2	II	4	7440-23-5	VY0686000
SODIUM CYANIDE	4	0	0	5	50	T	6.1	9.2	I	15	143-33-9	VZ7525000
SODIUM HYDROXIDE	3	0	1	2	200	C	8	9.2	II	11	1310-73-2	WB4900000

2.10.5 Transportation of Dangerous Goods Act Classification

Dangerous goods are given the following classifications

1. Explosives
2. Gases
   - 2.1 Flammable
   - .2 Non-flammable, non-poisonous, non-corrosive
   - .3 Poisonous
   - .3 Corrosing
3. Flammable Liquids
   - 3.1 Closed-cup flash point <-18°C
   - .2 Flash point between -18° and 23°C
   - .3 Flash point between 23° and 37.8°C
4. Flammable Solids
   - 4.1 Readily ignitable and burns vigorously
   - .2 Liable to spontaneous combustion
   - .3 Limits flammable gases on contact with water
5. Oxidizing Substances
   - 5.1 Oxidizing substance
   - .2 Organic peroxide
6. Poisonous
   - 6.1 Solid or liquid that is poisonous (toxic) through inhalation, skin contact or by ingestion
   - .2 Infectious organisms
7. Radioactive Material
8. Corrosive Substances
9. Miscellaneous
   - 9.1 Miscellaneous dangerous goods
   - .2 Environmentally hazardous
   - .3 Dangerous wastes

2.11 SOME SOURCES OF INFORMATION ON HARZARDOUS PROPERTIES OF CHEMICALS

2.11.1 Label

Suppliers of laboratory chemicals have recently increased the amount and types of safety and health related information that may be found on the label. In addition to the name of the supplier, the contents and some physical data, the label should display information on:

a. the nature of the hazard (eg. flammable, corrosive, toxic, oxidizing, explosive, radioactive);
b. what kind of protective and safety equipment to use;
c. how to store the chemical;
d. what to do if exposed, ie. first aid information;
e. identification numbers, eg. the United Nations product identification number and the Chemical Abstracts Service registry number.

2.11.2 Material Safety Data Sheets (MSDS)

Chemical suppliers are required to provide an MSDS for each of their products. They are free if you request them at the time of purchase. The format may differ from company to company, however they must all supply the same basic information: product identification, hazardous ingredients, physical data, fire and explosion hazard data, health hazard, reactivity data, spill and disposal procedures, protection information, handling and storage precautions, and other miscellaneous information.

2.11.3 Books

There are many good sources in print. See attached bibliography. (Section 7.0)

2.11.4 Wall Charts

There are a number of good charts that summarize alot of information on commonly encountered chemicals, their properties and storage, spill, and disposal procedures.

2.11.5 Catalogues

Some suppliers are now including safety and health information in their catalogues. These range from citations to other references to specific details. These are FREE.

2.11.6 Canada Centre for Occupational Health & Safety (CCOHS)

250 Main St. E., Hamilton, Ontario L8N 1H6, phone (416) 572-2981 or 1-800-263-8276.

This is a national service for information on occupational health and safety for the workplace. Information is available from their Inquiry Service or from computerized data bases. In addition, they are generating detailed pamphlets on particular chemicals.

2.11.7 Bibliographic Computer Data Bases

This type of data base gives citations to the primary published data. Although very useful, it may be fragmented and be very detailed in the information given. Some of the data bases available include: CIS/ILO, CHEMICAL EXPOSURE, HSELINE, MEDLINE, NIOSHTIC, and TOXLINE. Good information searching skills are needed to effectively use these bases.

2.11.8 Informational Computer Data Bases

These data bases are more useful than the bibliographic type since they contain condensed and summarized information on various chemicals. They include CIOL (Chemical Information on Line - available from CCOHS), HAZARDLINE, RTECS (the Registry of Toxic Effects of Chemical Substances Online), TDB/HSDB (Toxicology Data Bank/Hazardous Substances Data bank).

2.11.9 CANUTEC

The Canadian Transport Emergency Centre (CANUTEC) is open 24 hours a day, year round, and is designed primarily to provide information and communications assistance in case of transport emergencies involving dangerous goods. CANUTEC can also provide information for non-transport emergencies. For emergencies call (613) 996-6666, and for information, call (613) 992-4624.

2.11.10 Pesticide Information

Agriculture Canada has an information service at 1-800-267-6315.

2.11.11 Poison Control

These centres located in major hospitals across the country can provide current information on many common materials. However, for specialty substances (eg. pesticides), they may call you.

2.11.12 Workplace Hazardous Materials Information System (WHMIS)

This proposed system was put together by representatives of government, industry, and unions. When in place, it will require that for all hazardous materials used in the workplace:

a. each container be properly labelled,
b. MSDS sheets be provided, and
c. workers be properly educated in the hazards associated with the use of these hazardous materials.

2.12 INVENTORIES OF HAZARDOUS MATERIALS

2.12.1 Need

Various regulations now require that an up-to-date inventory of all hazardous materials be maintained in each lab. To assist in maintaining and accessing the inventory, computer formatting is recommended.

2.12.2 Uses

In addition to meeting the legislated requirements, such inventories can be used:

1. By others to locate small amounts of rare, expensive or uncommon chemicals. This obviates having to purchase quantities of material well in excess of those required.
2. In the event of an emergency (eg. fire), to warn response personnel of additional hazards within the area.

2.12.3 Categories

It may be useful to maintain several inventories according to type and degree of hazard, such as:

1. Radioactive
2. Carcinogen
3. Highly toxic (eg. $LD_{50} \leq 50$ mg/kg or TLV $\leq$ 10 ppm)
4. Designated materials, regulated by provincial law or federal law eg. by Environment Canada, or Transport Canada (Transportation of Dangerous Goods Act)
5. Pesticides

2.12.4 Format

The records for individual substances should contain the following information:

1. Inventory number (optional)
2. Chemical name (use Aldrich name for organics)
3. Empirical formula
4. Registry number(s) eg. CAS and/or UN product identification number
5. MSDS on file (yes or no)
6. Nature of hazard - perhaps TDG classification number. Note that the hazardous properties of many compounds have not yet been determined. These materials should be assumed hazardous until determined otherwise.
7. Quantity
8. Year received
9. Location - building and room

2.13 STORAGE

2.13.1 General

The most logical system for storage is alphabetical by name. However, for example, this might put sodium cyanide near sulfuric acid; should their containers break and the contents mix, highly poisonous hydrogen cyanide would form. The basic principle of storage is to keep incompatible (interreactive) chemicals as far apart as possible. It is important to know the properties of the materials being stored. (See section 2.13.3).

2.13.2 Storage Location

1. Chemicals should be stored away from offices, emergency exists, and in well ventilated areas.
2. Large bottles should be below eye level, preferably near the floor.
3. Flammables should be kept in special solvent cabinets.
4. Highly volatile flammable liquids should be stored only in refrigerators that are designated explosion-proof.
5. Food should be kept outside laboratory.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Inorganic Acids																								
2	Organic Acids	X																							
3	Caustics	X	X																						
4	Amines & Alkanolamines	X	X																						
5	Halogenated Compounds	X		X	X																				
6	Alcohols, Glycols & Glycol Ethers	X																							
7	Aldehydes	X	X	X	X		X																		
8	Ketones	X		X	X			X																	
9	Saturated Hydrocarbons																								
10	Aromatic Hydrocarbons	X																							
11	Olefins	X				X																			
12	Petroleum Oils																								
13	Esters	X		X	X																				
14	Monomers & Polymerizable Esters	X	X	X	X	X	X																		
15	Phenols			X	X			X							X										
16	Alkylene Oxides	X	X	X	X		X	X							X	X									
17	Cyanohydrins	X	X	X	X	X		X									X								
18	Nitriles	X	X	X	X												X								
19	Ammonia	X	X					X	X					X	X	X	X	X							
20	Halogens			X			X	X	X	X	X	X	X	X	X	X									
21	Ethers	X													X										
22	Phosphorus, Elemental	X	X	X																					
23	Sulfur, Molten									X	X	X	X				X								
24	Acid Anhydrides	X		X	X		X	X							X		X	X	X	X					

X Represents unsafe combinations.

2.14 HAZARDOUS WASTE DISPOSAL

2.14.1 General Principle

As a general principle NO WASTE CHEMICALS ARE TO BE DISPOSED OF VIA THE SINKS, DRAINS OR REGULAR GARBAGE SYSTEM unless specific approval in writing has been local given by the local Co-ordinator for Waste Chemical Disposal. This restriction is necessary because many chemicals are harmful to:

1. the environment (e.g., heavy metals).
2. the sewage treatment system (e.g., acids and alkalies).
3. the plumbing (e.g., corrosives).
4. the building (e.g., flammable solvents).
5. the occupants (e.g., volatile toxic fumes).

2.14.2 Hazardous Waste Management System

Effective management of hazardous wastes is essential to protect health, property, and the environment. The components of management system include:

1. Waste generation
2. Waste collection
3. Storage containers
4. Storage areas
5. Waste treatment/recovery
6. Transportation

2.14.3 Waste Generation

Since hazardous waste disposal is expensive, one should endeavour to minimize waste generation as much as possible by:

1. Purchasing minimum quantities necessary for the intended use.
2. Reducing the scale of experiments or analyses through microtechnology.
3. Replacing with less hazardous materials, eg. toluene for benzene.
4. Separating hazardous wastes from non-hazardous waste to reduce volume.
5. Treating wastes to render them less hazardous.

2.14.4 Waste Collection

The waste collection must be done safely, so it is essential that:

1. All personnel are adquately trained in the procedures to be followed.
2. All appropriate personal protective and safety equipment is used.
3. All waste is segregated according to chemical type (eg. acid, alkali, corrosive, oxidizer, organic, inorganic, highly toxic, carcinogenic, radioactive, pathological, pesticide, etc).
4. The proper waste containers are used.
5. Filled containers are properly transported to the storage site.
6. An inventory of all hazardous wastes is maintained.

2.14.5 Waste Containers

Containers must be:

1. compatible with wastes (eg. inert plastic or metal).
2. tightly closed.
3. of suitable size and condition to be easily handled.
4. properly labeled to contain
   a. originator's name
   b. building and room number
   c. phone number
   d. date of removal from room
5. accompanied by an inventory when several are boxed together.

2.14.6 Storage Areas

The general design of storage areas should meet all legislative requirements, particularly with respect to fire safety. They should be designed to contain the particular hazardous wastes being generated. Segregation of non-compatable materials is essential. Storage should be in a detached building, although with proper design, attached storage areas or inside storage rooms can also be used. Design critieria should include:

1. Adequate ventilation that is explosion proof.
2. Fire resistance construction.
3. Grounding to prevent static electrical discharges.
4. Temperature control.
5. Drainage with traps and not connected to public drainage systems.
6. Floors smooth and pitched toward the drains.
7. Doors should be open outward and openings be provided with non-combustable and liquid-tight raised sills.

2.14.7 Waste Treatment/Recovery

In instances where waste materials may be excess chemicals, attempts should be made to find potential users for those materials. Waste quantities can sometimes be reduced by:

1. Neutralizing waste acids with waste bases.
2. Precipitating heavy metals from dilute solutions.
3. Chemically converting or destroying hazardous materials to less hazardous ones.
4. Using oils and solvents as fuels.
5. Redistilling solvents, if not in mixtures.

2.14.8 Waste Solvent Disposal

Waste solvents that are free of solids, and corrosive or reactive substances, may be collected in a common non-glass container that can be filled up before disposal. Include:

1. originator's name,
2. room number and building,
3. phone number,

4. date the container is being disposed of, and
5. the approximate percentages (± 10%) of the contents.

Know the compatibility of the substances. For example, chlorinated and non-chlorinated solvents should be in separate containers. Glass containers should not be used. The reason for keeping chlorinated/non-chlorinated solvents separate is that, while generally both are incinerated, only chlorinated solvents generate hydrogen chloride (an acid); this acid must be treated, or else the incinerator and/or environment could be adversely affected.

When large quantities of a solvent are involved, sometimes recycling them is less expensive although it could be hazardous.

Just remember - separate and well-defined waste is easier and less expensive to dispose of.

2.14.9 Use of Sinks or Drains for Disposal

Learn the municipal, regional, provincial and federal regulations for disposal of chemicals into the sewer system. If it is safe to use sinks, then:

1. pour only water-soluble substances down the sink;

2. dilute solutions of flammable solvents so they don't impose a fire hazards;

3. neutralize and/or dilute strong acids and bases to the pH 5.5-9 range before disposing.

DO NOT POUR highly toxic, malodorous or lacrymatory chemicals or heavy metal compounds down the drain.

REMEMBER - Laboratory drains are interconnected. The substance you pour down your sink may react with a substance someone else has poured down his or her sink.

2.14.10 Waste Transportation

Ultimately, all wastes will leave the storage site. The waste manager must ensure that all local, provincial and federal requirements for labeling and packaging be met. Where the local establishment is not able to dispose of its wastes on site, it may be necessary to contract with a commerical waste disposal firms for some, if not all of their hazardous wastes. The waste manager should ensure that an approved firm is used, since the generator may be liable should injury or damage occur after the firm has removed the wastes.

"Waste disposal is no problem with us. We just put it in a fancy package and sell it as fertilizer."

National Safety News, August 1971

3.0 HAZARD RECOGNITION - FACILITIES AND PROCEDURES

3.1 SAFETY SURVEY - INTRODUCTION

A safety survey is a full job hazard analysis, conducted on a regular basis. Depending on the size of the unit, arrangements should be made to cover the various work stations at least once a year.

3.1.1 Purpose

The purpose of the safety survey is to:

1. Define hazards.
2. Report them.
3. Highlight severe hazards.
4. Recommend corrective action.
5. Provide for an effective (persistent) follow-up.

On the positive side it could be said that a safety survey is conducted not to find out how many things are wrong, but rather to determine if everything is satisfactory.

Our safety committee guide suggests that safety surveys should be a function of the safety committee as a whole, or a sub-committee of that group. Regardless of the composition of the survey team, they should be familiar with the area being surveyed and the work being performed in that area. Safety of assigned areas is inherently the responsibility of the supervisor, therefore he must be an active participant in any survey within the area of his responsibility.

3.1.2 Preparation

Before conducting a safety survey, the survey personnel should:

1. Review accident injury experience.
2. Review previous survey reports.
3. Prepare a check list. The check list should be reviewed periodically to verify that it still serves its purpose).

There are two basic elements in hazard recognition:

1. What to look at.

2. What to look for.

3.1.3 What to Look at

You will be looking at:

1. The physical environment -- Trying to recognize or visualize unsafe conditions. For example:
   a. Mechanical -- Sharp objects, unguarded machines.
   b. Chemical -- Corrosive chemicals, flammable solvents, toxic substances.
   c. Thermal -- Open flames, hot surfaces, Cryogenic liquids.
   d. Electrical -- Faulty wiring, lethal voltages, unsafe equipment.
   e. Pressure -- Unchained cylinders, unshielded vacuum equipment, faulty high pressure gas regulators.

2. Working surfaces -- Clear, Clean.

3. House keeping -- Tidiness.

4. Storage areas --

5. Laboratory lay out -- a. Blocked passages, alarms and emergency exits.

6. Safety equipment -- a. Eye wash fountains,
   b. Emergency showers,
   c. Fire blankets,
   d. Respiratory equipment.

3.1.4 What to Look For

You will be looking for hazards associated with people and procedures.

1. Hazardous motions - positions - actions such as:
   a. Throwing - Not carrying or passing.
   b. Improper lifting techniques.
   c. Insecure footing.

2. Use of improper tools/equipment.

3. Using tools incorrectly.

4. Failure to use guards/safety equipment such as goggles, face shields, gloves, and aprons.

5. Unnecessary chances such as short cuts or not testing purity of chemicals.

6. Untidiness -- eg. cluttered work benches, cluttered work area, not cleaning up.

7. Out-of-date methods.

8. Horse play -- eg. practical jokes and noise.

9. Personal defects -- physical and mental.

3.1.5 Summary

1. The objective is to define the hazards -- not to go through the motions.

2. Should you find something hazardous, discuss it with the persons involved -- their safety suggestions may be just the right answer to the problem.

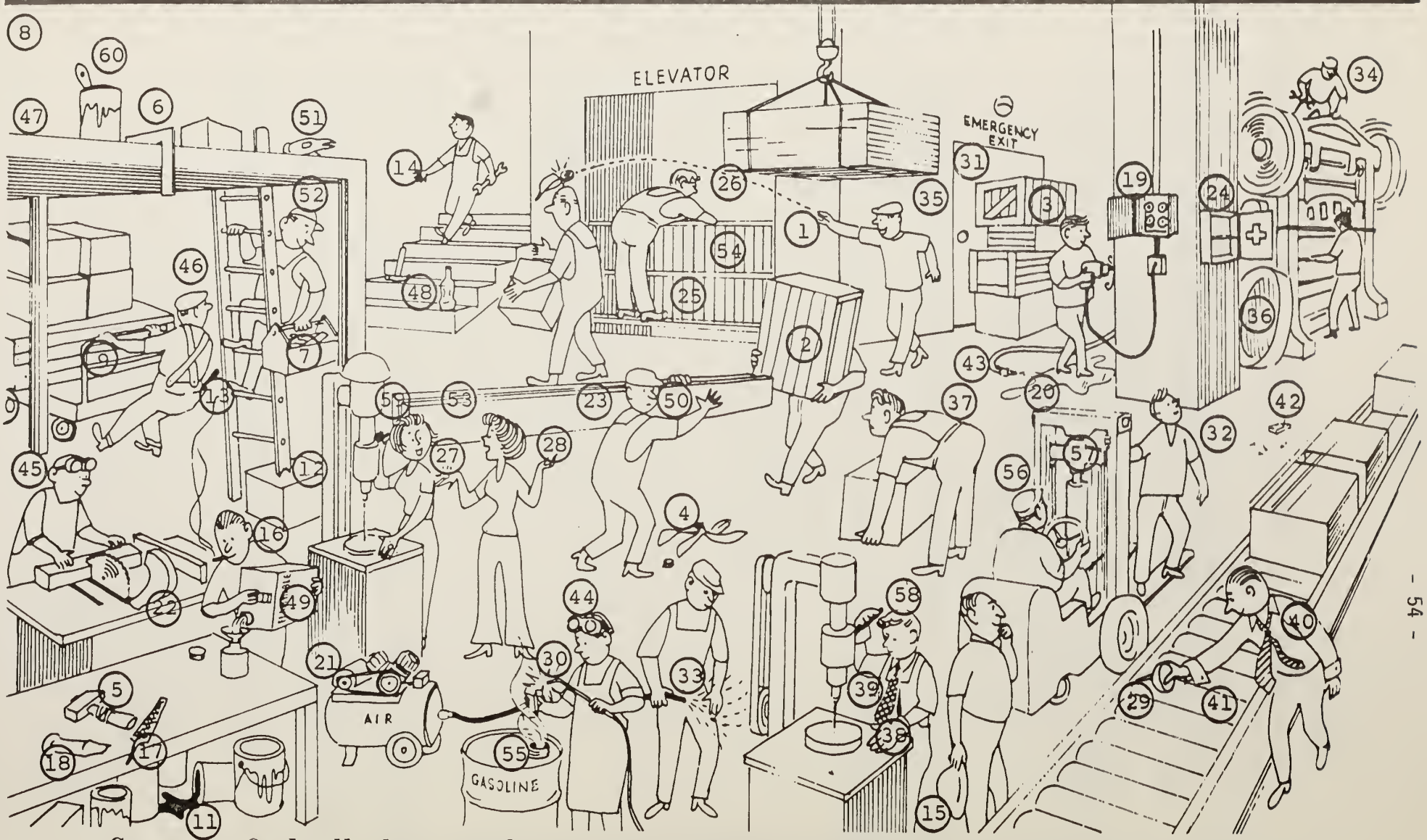
3. The survey is of little value unless some action is taken on any hazards noted.

4. Correction is the name of the game.
   a. Correct basic cause under your control - Immediately.
   b. Report with recommendations.
   c. Take intermediate action.

5. Nothing is accomplished until corrective action is completed.

PUZZLE POSTER

THE
INDUSTRIAL ACCIDENT PREVENTION ASSOCIATION
OF ONTARIO



Can you find all the unsafe acts and unsafe conditions in the above picture?

Here are some of the actions and conditions which, time after time, result in lost-time injuries — sometimes very serious ones — sometimes fatal ones.

As you recognize the dangerous conditions in the drawing, watch out for similar traps in your own work. Get them corrected before somebody gets hurt.

3.2 SAMPLE SAFETY SURVEY CHECKLIST FOR LABORATORIES

3.2.1 Introduction

It is recommended that a copy of the safety survey be circulated to each lab prior to a survey so that the personnel will know what will be checked. The main idea is to catch them doing something right.

3.2.2 Guidelines for Completing Safety Survey Results

1. Questions should be interpreted such that a yes answer (✓ on Results charts) means that the item being surveyed is acceptable and a no answer (X) means "needs improvement".

2. Items 2.1, 5.3, 8.2, 8.3, & 9.2 are numbers & dates. If the date of last inspection is more than 1 year ago, then consider it as "needs improvement".

3. Explain reason for any X (if not obvious) under comments.

4. The absolute value of the safety score has no real meaning, however it can be used to compare different labs and identify those that are in greatest need of improvement.

3.2.3

SAFETY SURVEY CHECK LIST

Laboratory No. _____ Date _____ Surveyed by _____

	YES (✓)	NO (x)	N.A. (–)
1. MATERIAL HANDLING			
1.1 Handcarts available and used for moving gas cylinders			
1.2 Hazardous materials (eg. carcinogens, pathogens, highly toxic, radiolabeled) monitored step by step from receipt to disposal			
1.3 Personnel trained in handling of hazardous materials			
1.4 Liquid acids, bases, corrosives carried from stockroom to lab in safety containers			
1.5 Toxic gases and cylinders (eg. chlorine, hydrogen sulfide) handled by more than one person			
1.6 Gloves, goggles, and lab coat always worn when handling liquid acids, bases, corrosives			
1.7 Acids always diluted by being poured into water			
1.8 Heating mantles available and always used to heat flammable liquids			
1.9 Mechanical pipeting devices available and always used			
1.10 Containers always properly labeled before filling			
1.11 Inventory maintained for all hazardous materials in laboratory (eg. toxic, flammable, reactive, corrosive, radiolabeled, compressed gases, infectious)			
1.12 A file containing a Material Safety Data Sheet (MSDS) for each hazardous material maintained in laboratory			

	YES (✓)	NO (x)	N.A. (–)
2. MATERIAL STORAGE			
2.1 Number of gas cylinders			
2.2 All cylinders properly supported and stored			
2.3 Inter-reactive chemicals (eg. acids, bases, corrosives, oxidizers, flammables, sulfides, cyanides) stored separately			
2.4 Hazardous chemicals stored properly			
2.5 Amounts of hazardous chemicals used kept small			
2.6 Flammable solvents stored in special cabinets			
2.7 Flammable volatile liquids kept away from heat, sunlight, electrical switches			
2.8 Refrigerators used for volatile and flammable liquids, explosion-proof			
2.9 Mercury stored properly in plastic bottle			
2.10 Food, utensils, etc. not stored in refrigerator or near chemicals			
2.11 Shelves not crowded			
2.12 Shelves strong enough for load and securely fastened			
2.13 Material not stored on top of cabinets and files			
2.14 Materials not piled too high or insecurely			
2.15 Large bottles and those containing hazardous or reactive materials on shelf below eye level.			

	YES (✓)	NO (x)	N.A. (–)
3. MATERIAL LABELING			
3.1 All containers labeled	...		
3.2 All containers labeled properly	...		
3.3 Contents of unlabeled containers always thrown away	...		
3.4 Ether and other peroxide forming chemicals labeled with date received and opened	...		
3.5 All cancer suspect agents are so labeled	...		
3.6 All radiolabeled material properly labeled	...		
3.7 All other hazardous material well labeled	...		
3.8 Gas lines labeled	...		
4. MATERIAL CLEANUP AND DISPOSAL			
4.1 Spills of flammables, volatile liquids, acids, bases, corrosives, hazardous chemicals and mercury cleaned upimmediately	...		
4.2 Personnel trained in proper methods of cleaning up and disposal of flammables, volatile liquids, acids, bases, corrosives, hazardous chemicals, and mercury	...		
4.3 Special materials for neutralizing, adsorbing, cleaning up spills available	...		
4.4 Waste materials are never poured down a sink unless given specific approval	...		
4.5 Acids and bases are neutralized before washed well with water down a sink	...		
4.6 Special containers for waste chlorinated and non-chlorinated solvents available and used properly	...		
4.7 Waste mercury stored properly	...		
4.8 Other waste material not accumulated	...		
4.9 Labeled containers for broken glass available	...		

See also 11.

	YES (✓)	NO (x)	N.A. (–)
5. SAFETY EQUIPMENT			
5.1 Eye wash facilities available	...		
5.2 Safety shower available	...		
5.3 Date of last shower inspection	...		
5.4 Safety shield used in front of glassware apparatus subject to heat shock or contain flammable or explosive chemicals	...		
5.5 Vacuum desiccators shielded with guards	...		
5.6 Vacuum pump pulley guarded	...		
5.7 Dewar flasks taped	...		
5.8 Personnel know location and proper use of all safety equipment	...		
5.9 Emergency telephone numbers in a conspicuous place in each lab and office	...		
6. PERSONAL PROTECTION			
6.1 Eye protection (safety glasses, goggles, or mask	...		
6.2 Eye protection worn	...		
6.3 Hand protection (gloves) available	...		
6.4 Hand protection worn	...		
6.5 Body protection (coat or apron) available	...		
6.6 Body protection worn	...		
6.7 Lung protection available	...		
6.8 Personnel not wearing hazardous items (eg. jewellery)	...		
6.9 Personnel receive periodic medicals	...		

	YES (✓)	NO (x)	N.A. (–)
7. ELECTRICAL SAFETY			
7.1 All wires, cables, switches in good condition	...		
7.2 Electrical equipment used in areas exposed to flammable vapors is explosion-proof	...		
7.3 Electrical outlets for fume hoods on outside	...		
7.4 Electrical outlets not overloaded	...		
7.5 Electrical equipment grounded	...		
8. LABORATORY DESIGN & HOUSEKEEPING			
8.1 Fume hoods effective to remove all strong odors	...		
8.2 Date fume hood last checked	...		
8.3 Measured air volocity at opening	...		
8.4 Fume hoods have safety glass or shields for use with potential explosives	...		
8.5 Fume hoods unblocked and uncluttered	...		
8.6 All areas of lab well ventilated	...		
8.7 Working space uncrowded	...		
8.8 Aisles unobstructed	...		
8.9 Temperature control adequate	...		
8.10 Humidity control adequate	...		
8.11 Good floor condition	...		
8.12 Sufficient lighting	...		
8.13 Good housekeeping	...		

See also 9.4

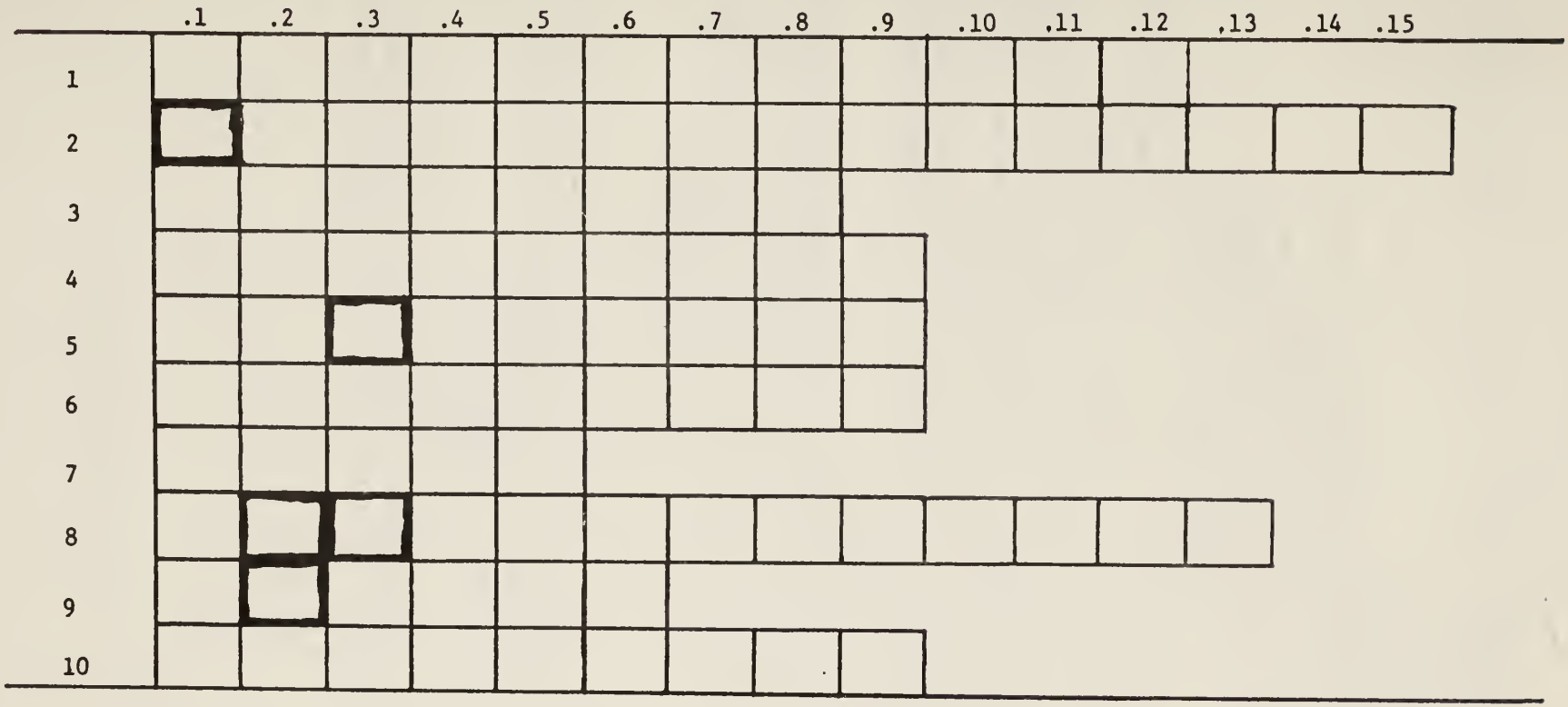
	YES (✓)	NO (x)	N.A. (–)
9. FIRE PROTECTION			
9.1 Proper fire extinguishers available	...		
9.2 Date of last extinguisher inspection	...		
9.3 Open flames and spark producers kept away from flammable vapors and liquids	...		
9.4 At least two exits	...		
9.5 All exits clear	...		
9.6 "No smoking" areas clearly identified	...		

See also 1.8, 2.6, 2.7, 2.8, 3.4, 4.5, 7.2.

10. POTENTIAL HAZARDS			
10.1 No tripping hazards	...		
10.2 No falling object hazards	...		
10.3 Drawers closed	...		
10.4 No protruding objects from shelves, benches, etc.	...		
10.5 No structural defects	...		
10.6 No sharp objects	...		
10.7 Hazardous areas well designated	...		
10.8 No evidence of leakage or spillage	...		
10.9 Ultraviolet and other light sources visually shielded	...		

SAFETY SURVEY RESULTS

Laboratory No. _____ Date _____ Surveyed by _____



✓ Acceptable =

X Needs Improvement =

— Not Applicable =

COMMENTS:

Total = 95

Safety Score = $\frac{\checkmark}{\checkmark + X} \times 100 =$

4.0 HAZARD REDUCTION

4.1 INTRODUCTION

It is possible to handle extremely hazardous materials in nearly complete safety. However advanced planning is required and a necessary first step is to recognize the hazards of a particular material. Following that, to reduce hazards one should:

1. Use the smallest amounts of material possible.
2. Develop procedures that keep handling to a minimum.
3. Substitute with a less dangerous substance.
4. Wear the appropriate personal protective equipment.
5. Conduct the work using appropriate safety equipment.

4.2 PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment is the last line of defence. Ideally, hazards should be designed out - eliminated - or controlled.

This of course, is not always practical, and to prevent or significantly lessen the severity of an injury, protective clothing and/or equipment is required. Care must be taken to ensure that the item selected will in fact provide the degree of protection desired. For example - for protection against chemical splash, ordinary safety glasses are not as effective as goggles. And while goggles may protect the eye, a full face shield would be an even better choice of equipment.

The Treasury Board policy and guidelines on the provision of clothing contains a selection guide of items for occupational safety, health and cleanliness. This policy also lays down that employees will normally be expected to provide, wear and maintain personal clothing as appropriate and necessary for their duties. Loose hair - loose clothes, certain items of jewellery, open-toe sandals, etc. will not enhance safety.

Personal Protective Equipment could include:

1. gloves, the type worn will depend upon the hazard. Note that some materials will dissolve in particular solvents, and others may greatly reduce manual dexterity, thus possibly increasing the hazards.
2. apron, lab coat or special pants and jacket.
4. protective glasses, goggles or shield.
4. boots.
5. respirator. This is to filter out dusts, aerosols, or harmful vapours. Note that if the oxygen content of the air is less than 19.5%, then a self contained breathing apparatus with its own air supply will be necessary.
6. Hard hat.

4.3 SAFETY EQUIPMENT

Safety Equipment in the work area should include:

1. eye and face wash showers,
2. fume hoods,
3. cylinder restraining devices,
4. acid bottle carriers,
5. tongs,
6. safety pipet fillers,
7. explosive-proof fridges,
8. solvent storage cabinets,
9. safety cans,
10. fire blanket,
11. fire extinguisher,
12. explosion shields.

4.4 RESPONSIBILITY FOR USE

Should protective items be required, you are responsible to ensure that:

1. The items selected will in fact provide the degree of protection required.

2. The equipment is properly maintained and in a safe and fully effective condition at all times.

3. Records are kept of purchase, inspection, tests and repair.

4. User employees are fully instructed in the procedures for use and care of the items.

5. Employees do in fact utilize the items under the circumstances prescribed for their use.

"Just a moment, fella. This goes with it."

5.0 EMERGENCY RESPONSE

5.1 INITIAL RESPONSE

If an accident does occur in the lab, there are four basic procedures to follow to limit injuries and minimize damage:

5.1.1 Assist Those Involved

Assist those who are involved and remove them from exposure to any further injury if necessary.

5.1.2 Alert Others

Yell for HELP. Warn other people nearby of any potential danger to their safety.

5.1.3 First Aid

If there is a Medical Emergency, remain calm and do whatever is necessary to protect life. Render immediate First Aid; e.g., apply artificial resusitation if breathing stops, and whatever measures are required such as direct pressure on bleeding wounds and treating for shock. Call for an ambulance.

5.1.4 Fires

Extinguish small fires with appropriate extinguisher. Turn off nearby apparatus and remove combustible materials from the area. If the fire cannot be contained, call the fire department immediately. If the person is on fire, throw them on the floor and roll them around to smother the flames. If a safety shower is nearby, douse them under it. Get burn patients to hospital as quickly as possible.

5.2 FIRST AID

First aid is the immediate care of a person who has been injured or has suddenly taken ill. It is intended to prevent death or further illness and injury and to relive pain until medical aid can be obtained. The objectives of first aid are (1) to control conditions that might endanger life; (2) to prevent further injury; (3) to relieve pain, prevent contamination, and treat for shock; and (4) to make the patient as comfortable as possible.

The initial responsibility for first aid rests with the first person(s) at the scene, who should react quickly but in a calm and reassuring manner.

5.2.1 Summon Help

Summon medical help immediately.

5.2.2 Reassure Patient

Keep patients warm and make sure someone is with them at all times. Don't move them unless they may be further injured where they are. Reassure them.

5.2.3 Chemical Spill on Body

If chemicals have been spilled on the body, flood the exposure under a safety shower washing the chemicals away. Remove any contaminated clothing, rings, watches, belts, shoes and socks where corrosives may be held. Do not neutralize chemical burns, wash them off.

5.2.4 Chemical Spill in Eyes

Where corrosives have entered the eye area, wash the eyeball under flowing water for a least 15 minutes, forcibly holding the eyelids open. A eye wash fountain should be used, if available. Check, ask, about contact lenses and remove. A lot of damage may be caused to the eye if chemicals get under contact lenses, even fusing the lense to the cornea, if not immediately removed. Get the patient to professional medical help.

5.2.5 Injestion of Chemicals

When chemicals have been ingested, dilute with water or milk. If the chemical is a corrosive, i.e., acid, base, petroleum product, etc., DO NOT induce vomiting. Mild, non-corrosives may be regurgitated by tickling the back of the throat. Where the poison has been absorbed, inhaled, or injected, call for medical help or poison control centre, describe symptoms and materials causing the poisoning and follow their directions. Again, if breathing becomes difficult or stops begin Artificial Respiration and evacuate immediately to Medical Facilities. Take the chemical container along to the Medical Facility.

5.3 FIRES AND EXPLOSIONS

Small fires can be extinguished easily but, the first few minutes could turn a small fire into a larger, out-of-control emergency.

5.3.1 Types of Fire

The main types of fire that can occur in the lab are:

A- Ordinary fire, e.g., paper, wood.
B- Solvents/flammables, e.g., alcohol, ether.
C- Electrical fires.
D- Combustible or reactive metals, e.g., sodium and potassium, metal hydrides.
BC- Solvents/electrical fire.

5.3.2 Extinguishers

The proper extinguisher to use on these fires is:

A- Water or dry chemical.
B- Carbon dioxide (CO_2).
C- Dry powder (contains sodium bicarbonate or ammonium phosphate).
D- Special extinguisher with granular formulations such as Met-L-X (R) extinguisher.
BC- Dry chemical.

In areas where the fire potential and risk of injury are high, sometimes automatic fire extinguishers are built in. They may contain water, carbon dioxide, a dry chemical or halogenated hydrocarbons. All lab personnel should know if there are any in their building and what they contain.

5.3.3 Minor Fire

In case of a minor fire, follow these steps:

1. Alert others in the lab and Send someone for help.

2. Attack the fire immediately BUT never attempt to fight a fire alone. A fire in a small vessel can be suffocated by covering the vessel with an inverted beaker or a watch glass. Use the proper extinguisher as shown above, directing the flow towards the base of the flame. Read the label of the extinguisher if you're not sure it's the right one.

3. Avoid being trapped in the fire; ALWAYS FIGHT A FIRE FROM A POSITION ACCESSIBLE TO AN EXIT.

5.3.4 Major Fire

In case of a major fire, or one that cannot be controlled:

1. Sound the alarm.
2. Notify the fire department.
3. Confine the fire by closing hood sashes, fire doors, doors between labs, windows, etc.
4. Evacuate the building.
5. Assist injured people.

5.3.5 Explosion

In case of an explosion:

1. Turn off burners and other heat and ignition sources.
2. Stop any reactions in progress.
3. Assist injured people.
4. Evacuate the area until it has been decontaminated.

"They're developing a foam that finds fires and fights them."

National Safety News, August 1970

5.4 CHEMICAL SPILLS

5.4.1 Initial Response

1. Yell for help. Warn other people nearby of any potential danger to their safety. Post signs if necessary.

2. Determine
   a. If anyone has been contaminated or injured. Assist those involved by removing them from danger, render immediate first aid, and get medical help.
   b. The identity of the spilled material and if solid, liquid, or gas and hazardous/non-hazardous. Hazardous materials include those that are radioactive, reactive, flammable, corrosive, toxic, or unknown.
   c. The amount of material spilled.
   d. The location of the spill.
   e. The nature of all the hazards involved.

3. Contain the spill if safe to do so:
   a. Turn off spill source.
   b. Close doors, windows, hood sashes, etc.
   c. Remove reactants if reactive.
   d. Turn off ignition and heat sources if flammable.
   e. Ventilate if safe to do so.
   f. Evacuate non-essential personnel.
   g. Call fire department if reactive or flammable.

4. Notify supervisor and then JOSH and/or chemical emergency response team if necessary.

5.4.2 Cleanup Preparation

1. If you are uncertain as to how best to cleanup the spill, send someone to a terminal connected to the departmental VAX computer system and run through the CHEMSPILL program for details.

2. Obtain clean-up supplies. Depending upon the material, these could include:
   a. Neutralizing agents.
   b. Absorbents, e.g., vermiculite, sand, kitty litter, sawdust, commercial materials.
   c. Paper towels, sponges, mops.
   d. Safety pails.
   e. Vacuum devices.
   f. Disposable bags, ties, labels.

3. Put on protective equipment. Depending upon the material, these could include:
   a. Gloves.
   b. Boots.
   c. Apron, lab coat, or special pants and jacket.
   d. Protective glasses, goggles or shield.
   e. Respirator.
   f. Hard hat.

4. Obtain fire extinguisher, first aid kit, and antidote kit if necessary.

5. Enter spill area in pairs.

5.4.3 Non-Hazardous Material Cleanup

1. Solids
   a. Sweep or shovel up material and remove.
   b. Dispose of waste properly.
   c. Decontaminate spill area.

2. Liquids
   a. Turn off source.
   b. Prevent from spreading.
   c. Dilute with water if necessary and drain, or.
   d. Absorb, mop up, or vacuum, or
   e. Allow to evaporate.
   f. Dispose of waste properly.
   g. Ventilate area.
   h. Decontaminate spill area.

3. Gases
   a. Turn off source.
   b. Ventilate area.

5.4.4 Hazardous Solid Cleanup

1. Neutralize on site if possible or,

2. Remove and neutralize.

3. Dispose of waste properly.

4. Decontaminate spill area.

5.4.5 Hazardous Liquid Cleanup

1. Turn off spill source.

2. Prevent spill from spreading.

3. Neutralize if possible.

4. Dilute with water if necessary.

5. Let volatile material evaporate if safe to do so and ventilate through hood or filter.

6. Pick up by absorption, mopping or vacuuming. (Note: Exhaust of vacuum cleaner may create aerosols).

7. Dispose of waste properly.

8. Ventilate area.

9. Decontaminate spill area.

5.4.6 Example of How to Deal With a Corrosive Chemical Spill

Method	Advantages	Disadvantages
Wash with water	Simple Inexpensive Quick	Messy Transfers problem Traces of chemical may remain
Neutralize eg. acids with $NaHCO_3$ alkalis with citric acid	Reduces corrosion Simple	Difficult to know if all is neutralized. May be disposal problem for residues
Ordinary absorbents eg. paper, sawdust, kitty litter, sand, vermiculite	Localizes spill	Disposal problem. Still corrosive
Specialized absorbents	Localizes spill Eliminates corrosion Neutrality indicators No disposal problems	Cost

5.4.7 Hazardous Gas Cleanup

1. Turn off source if possible.

2. Move source to well ventilated area if leak persists and, if possible, (e.g., for leaking gas cylinders),
   a. Detect location of leak with soapy water or a flammable gas leak detector.
   b. Do not attempt to repair a leak at the valve threads or safety device.
   c. Place a plastic bag or a rubber shroud over the top and tape it with duct tape if the cylinder has to be removed from the location.
   d. Move flammable, inert or oxidizing gas cylinders to an isolated area. Put up warning signs.
   e. Move corrosive and toxic gas cylinders to an isolated, well-ventilated areas and put the gas into a chemical neutralizer. Corrosive gases may increase the size of the leak and some are oxidants or flammable.
   f. Wear proper protective apparel including self-contained breathing apparatus if the gas is dangerous.

3. Direct leak to ventilation if safe.

4. Neutralize if possible.

5. Ventilate.

6. Decontaminate leak area.

5.4.8 Radioactive Material Spill

Contact Atomic Energy Control Board of Canada Ltd. for detailed instructions.

5.4.9 Summary

This is an aid to help remember the steps to a spill response. Just think of C H E M I C A L.

C CLEAR Affected Area/CONTACT Emergency Assistance/CHECK for Involved Personnel

H Determine the HAZARDS by (1) identifying the material; (2) determining the quantity released, and (3) determining the location

E Use the proper Personal Protective EQUIPMENT

M Use the proper Spill Control MEDIA

I INSPECT spill responders for personal safety

C CLEAN-UP and CONTAINERIZE the spill residue

A ANALYZE area for contamination

L Prepare required LETTERS and reports

5.5 REPORTS

1. Advise supervisor immediately.

2. After cleanup, send reports to:
   a. Joint Occupational Safety and Health Committee.
   b. Departmental Safety Office.
   c. Workmen's Compensation Board if personal injury.
   d. Others.

5.6 PREVENTION

1. Be aware of hazards associated with material, equipment, and procedures being used.

2. Wear appropriate protective clothing and equipment.

3. Keep chemicals to the minimum amount required for daily operation.

4. Store chemicals properly:
   a. Use approved storage cabinets, especially flammables.
   b. Keep inter-reactive chemicals separate.
   c. Store only non-flammable chemicals in standard refrigerators.
   d. Keep away from exits.

5. Get rid of old chemicals.

6. Dispose of contents of non-labelled containers. Treat as dangerous.

7. Regularly inspect or survey work and storage area for potential hazards.

8. Develop specific emergency response plans.

5.7 EMERGENCY RESPONSE PLANNING

5.7.1 Anticipation

1. Anticipate personal injury emergencies, e.g.
   a. Thermal and chemical burns.
   b. Cuts and puncture wounds from glass or metal, including possible chemical contamination.
   c. Skin irritation by chemicals.
   d. Poisoning by ingestion, inhalation, absorption or injection.
   e. Asphyxiation - chemical or electrical.
   f. Injuries to eyes from splashed chemicals.

2. Fire/Explosion emergencies.

3. Chemical spills, e.g.
   a. Potential location of the release (e.g., outdoors versus indoors; in a laboratory, corridor, or storage area, on a table, in a hood, or on the floor).
   b. The quantities of material that might be released and whether the substance is a piped material or a compressed gas.
   c. Chemical and physical properties of the material (e.g., its physical state, vapor pressure, and air or water reactivity).
   d. Hazardous properties of the material (its toxicity, corrosivity, reactivity, and flammability).
   e. The types of personal protective equipment that might be needed.

5.7.2 Emergency Plans

Establish specific emergency plans that include:

1. Evacuation procedures:
   a. Alarm system.
   b. Evacuation procedures - routes and assembly areas.
   c. Shutdown procedures.
   d. Return and start-up procedures - personnel do not return until emergency is ended.
   e. Drills.

2. Medical facilities:
   a. Everyone working in a lab should know where the nurse's office is located.
   b. Personnel in the area should be trained in first aid and C.P.R. (cardio-pulmonary resusitation) and maintain validation.

3. Safety equipment in laboratory and how to use:
   a. Fume hood.
   b. Shower.
   c. Eye wash.
   d. Fire extinguisher.
   e. Personal protection.
   f. Specific antidote kits, if necessary.
   g. Spill cleanup supples.

4. Spill cleanup procedures. For examples of specific procedures go to a terminal (with printer) connected to the departmental VAX computer system and run through the CHEMSPILL program.

5. Specially trained personnel to handle large spills, e.g. Chemical Emergency Response Team (CERT) with:
   a. Protective apparel.
   b. Safety equipment.
   c. Materials to contain, dissipate, absorb, neutralize and cleanup.

6. Procedures for reporting accidents and emergencies.

7. Simulated emergencies and frequent drills.

8. Outlines of tasks, responsibilities, lines of authority, and places to go for resources.

5.7.3 Publicity

Post in a conspicuous place:

1. Specific response procedures.

2. Emergency phone numbers for:
   a. Fire department.
   b. Ambulance.
   c. Nurse.
   d. First aid personnel.
   e. CPR personnel.
   f. CERT.

5.8 IN SUMMARY

Remember - the initial responsibility for emergency response rests with the first people on the scene:

REACT QUICKLY
REMAIN CALM
TREAT FIRST THINGS FIRST
and KEEP IT SIMPLE
REASSURE THE INJURED
SUMMON MEDICAL HELP
PREVENTION IS BETTER THAN CLEANING UP THE MESS

6.0 ACCIDENT INVESTIGATION

6.1 INTRODUCTION

6.1.1 Accident Prevention

There are two ways that accidents can be prevented: thru foresight or thru hindsight.

What we have discussed so far are ways to prevent accidents before they happen -- training, planning, safety audits, etc. -- using foresight (preventive maintenance). But the hazards that were missed -- the unsafe acts and unsafe conditions -- that resulted in accidents, can only be identified by proper investigation.

An accident is an unanticipated occurrence that has or could have caused personal injury or property damage or both. It may have one or more causes. The condition that caused the accident is the primary cause. Other conditions that did or may have contributed are secondary causes. Primary and secondary causes may be related and at times difficult to separate.

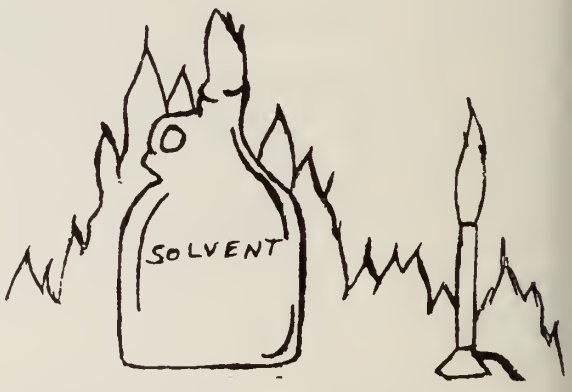
6.1.2 Accident Example

In the incident presented here, there were two causes:

1. Primary cause
   Ignition source
   (Bunsen flame)

2. Secondary cause
   Open solvent bottle

The resulting accident was a fire.



The fire could not have started without an ignition source. Similarly, an open solvent bottle in the vicinity of a flame represents a fire hazard. The primary and secondary causes are inter-related. Don't equate injury or property damage with the accident. They are the results of the accident. By discovering and removing the causes of one accident, you may perhaps prevent another of the same type.

6.1.3 Accident Prediction

Statistics cannot predict which specific accident will result in a serious injury. There is, however, a relationship between the number of accidents and the number of serious injuries. Accidents are often symptomatic of a situation that will eventually result in a serious injury.

6.2 RATIONALE

6.2.1 Why Investigate Accidents?

Accidents should be investigated for two principal reasons:

1. To prevent or reduce the possibility of re-occurring accidents of the same type, the investigation should determine the causes, so that the unsafe condition may be eliminated.

2. To furnish the information required by law for the compensation of the injured.

6.2.2 Who Investigate Accidents?

You, the supervisor:
You know your area, the people, the conditions.

Especially the people: their jobs, attitudes, and behaviour. You don't have to do it alone, of course. Your boss, the unit safety officer, or the safety committee could be part of the investigating team if required.

6.2.3 When?

As soon as possible, before, physical evidence is cleared away, and before witnesses have disappeared or have had their judgement coloured. If necessary, get photographs of the accident area. Investigate while the facts are available.

6.3 HOW TO INVESTIGATE ACCIDENTS

6.3.1 Information Sources

There ar two primary sources of informtion:

1. People.

2. Physical evidence.

People are witnesses, however, the amount of information you will receive is dependent on the extent of their involvement and their attitudes. When investigating, one should be informal, impersonal and impartial. Don't attempt to assign responsibility for the accident. Assure all witnesses that the investigation is for the purpose of preventing future accidents.

KEEP IN MIND THAT YOU ARE GATHERING FACTS NOT OPINIONS.

THE EMPHASIS MUST BE ON WHAT HAPPENED AND NOT WHO DID IT.

6.3.2 Physical Evidence

Physical evidence is not affected by memory or attitude. There are four (4) important steps to follow when investigating accidents involving objects and conditions.

1. Allow nothing to be moved until the investigation is completed. If something must be removed, note its position in the accident area.

2. If the gravity of the accident warrants it, photograph the scene if possible. This allows a permanent record to be secured. It also may prove valuable in safety training.

3. Observe details -- know what to look for: you know your area.

4. If you think it might be important, write it down. Avoid confusion at a later date.

6.3.3 Value of Information

All information is potentially valuable. Details and "little things" both may resolve the issue, record as many facts as possible, even the apparently insignificant ones. When the details are available, ask why? The answer might point to hidden causes of the accident such as:

1. Poor safety attitude,
2. Unwillingness to change,
3. Cost of a safer way.

6.3.4 Investigate Thoroughly

An incomplete investigation is a waste of time and may allow the real cause to go unnoticed, allowing a recurrence of the same accident.

6.3.5 Accident Causes

In most cases there are two types of accident causes:

1. Unsafe acts,

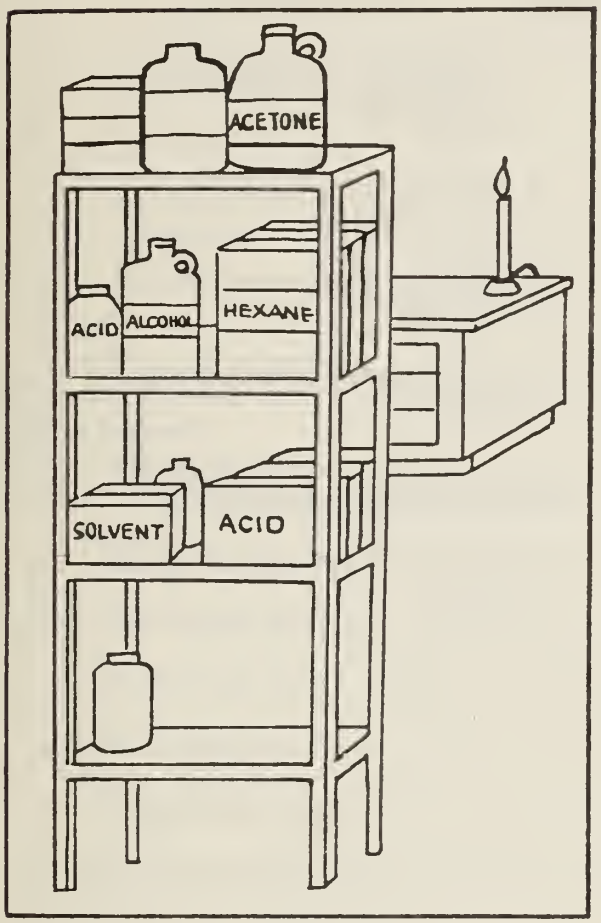
2. Unsafe conditions.

The investigation should distinguish between unsafe acts and unsafe conditions. It has been estimated that 90% of all accidents are a result of unsafe acts. For each accident, both the actions of the associated personnel and the conditions should be studied. Keep in mind that the two types of causes may be inter-related. In order to better understand the investigative process I am going to present you with the scenario of an accident. I would like you to study the events as outlined, and note the unsafe acts and unsafe conditions. (See attached).

6.4 ACCIDENT CASE STUDY

6.4.1 The Scenario of an Accident

An account of an accident will help you understand the investigative process.



The Scenario of an Accident

1. A worker reaches to the top shelf of a storage rack five feet high to remove an 8-pint bottle of acetone.

2. The storage rack is metal-frame, unattached to the wall, and contains a variety of chemicals, including acids, solvents, and reactive substances, some in cardboard boxes.

3. On a lab bench 10-feet away, there is a lit Bunsen burner.

4. The bottle is lifted, then dropped, covering the rack, its contents, and the worker with solvent.

5. No provision for solvent spill cleanup is available. The operator attempts to clean up the spill with a rag.

6. After soaking up a small portion of the solvent with the rag, the operator attempts to wring out the absorbed solvent at the lab bench sink. The rag catches fire.

7. The operator drops the burning rag on the floor.

8. Acetone vapors in the area ignite and flash back to the spill. The area surrounding the storage rack is in flames.

9. The worker escapes with minor burns.

10. Within one minute, the entire laboratory is engulfed in flames.

As previously stated, the causes of an accident can be divided into two interrelated categories:

6.4.2 Unsafe Acts

1. Reaching to the top shelf for a heavy bottle.
2. Inadequate care in removing a bottle from the shelf.
3. Attempting solvent spill cleanup with a rag.
4. Lighting a Bunsen burner in a solvent area.
5. Wringing out solvent on rag in vicinity of ignition source (Bunsen burner).
6. Dropping the rag on the floor rather than in the sink.
7. Poor supervision in allowing unsafe conditions to continue, and in improper training of personnel in hazard area.

6.4.3 Unsafe Conditions

1. Solvents not stored in safe containers in a solvent cabinet.
2. Solvents not isolated from other chemicals.
3. Liquid reagents stored above eye-level.
4. Storage rack not fastened to the wall.
5. No adequate means of solvent spill cleanup available.
6. Bunsen burner alight in solvent area.

6.4.4 Accidents and Causes

In evaluating the causes of this incident, we find that in actual fact there were four (4) inter-related accidents:

1. Accident "A" - the dropped bottle
   Causes: - Nos. 1 & 2 under unsafe acts
   No. 3 under unsafe conditions

2. Accident "B" - the rag caught fire
   Causes: - Nos. 3-4 & 5 under unsafe acts
   Nos. 5 & 6 under unsafe conditions
3. Accident "C" - flash-back of solvent vapors and ignition of acetone spill.
   Causes: - No. 6 under unsafe acts

4. Accident "D" - the final conflagration
   Causes: - The fire heat of accident "C" was the cause but nos. 1 & 2 under unsafe conditions, were certainly inter-related causes.

Finally, it might be fair to say that no. 7 under unsafe acts - poor supervision - was an integral part, if not the single primary cause of all four accidents.

6.4.5 Preventive Action Recommended

1. All solvents must be stored in approved cabinets.

2. Employees must be trained in the safe handling of solvents.

3. Provision to be made for solvent spill clean-up absorbent.

4. All ignition sources must be removed when working with solvents.

5. Liquid reagents to be stored below eye level.

6. Storage rack to be secured to wall.

7.0 BIBLIOGRAPHY OF BOOKS ON CHEMICAL & LABORATORY SAFETY

ACCIDENT PREVENTION MANUAL FOR INDUSTRIAL OPERATIONS
McElroy, F.E., ed. National Safety Council, 444 North Michigan Avenue, Chicago, IL 60611. 1980. (A good general safety manual).

*BDH LABORATORY PRODUCTS
BDH Chemicals Canada Ltd. 1985. (The BDH Catalog has 45 pages of safety information on 21 hazardous chemical groups, incompatable chemicals listings, storage recommend a taste disposal procedures; and it's Free).

BEST'S SAFETY DIRECTORY
A.M. Best Company. Oldwick, N.J. 1982. (Gives detailed OSHA regulations and sources of safety products).

BETTER SCIENCE THROUGH SAFETY
Gerlovich, J.A. ed. Iowa State University Press, 1981. (Designed for teachers of science).

BIOSAFETY IN MICROBIOLOGICAL AND BIOMEDICAL LABORATORIES
US Dept. Health and Human Services; Public Health Service; Centers for Disease Control; and National Institutes of Health. 1984.

CANCER CAUSING CHEMICALS
Sax, N.I. Van Nostrand Reinhold Company, 135 West 50th Street, New York, NY., 1981 (2400 Carcinogens are listed with citations to all animal studies). ISBN 0 442 21919 9

CARCINOGENS - REGULATIONS AND CONTROL
National Institute of Occupational Safety and Health. NIOSH, Division of Technical Services, 4676 Columbia Parkway, Cincinnati, OH 45226.

CASSARETT AND DOULL'S TOXICOLOGY - THE BASIC SCIENCE OF POISONS, 2nd edition
Doull, J.V., Klassen, C. and Amdur, M., eds. 1980. (Fundamental text covering all aspects of toxicology).

CATALOG OF TERATOGENIC AGENTS, 4th edition
Shepard, T.H. 1980. (References to original literature for over 1000 chemicals).

CHEMICAL EMERGENCY ACTION MANUAL, 2nd edition
American Lung Association of Western New York. 1982. (Specific instructions for 59 chemicals).

CHEMICAL HAZARDS IN THE WORKPLACE: MEASUREMENT AND CONTROL
Chaudhary, G. Washington, D.C., American Chemical Society, 1981.

CHEMICAL HAZARDS OF THE WORKPLACE
Proctor, N.J. Lippincott. 1978.

CHEMICAL HAZARDS TO HUMAN REPRODUCTION
Nisbet, I.C.T., Karch, N.J. Noyes Data Corporation, Park Ridge, N.J. 1983.

CHEMICAL SAFETY DATA SHEETS
Chemical Manufacturer's Association, 1825 Connecticut Avenue, N.W., Washington, DC 20009. (Sheets prepared for individual chemicals).

CHEMICAL TECHNICIANS' READY REFERENCE HANDBOOK, 2nd edition
Shugar/Shugar/Bauman, McGraw. 1981. (A text on laboratory technique).

CHEMICAL WASTE: HANDLING AND TREATMENT
Mueller, K.R. ed. Springer-Verlag. 1986.

THE CHEMIST'S COMPANION
Gordon, A., Ford, R. Wiley-Interscience. 1972. (A practical book of data and techniques).

CHEMISTRY OF HAZARDOUS MATERIALS
Meyer, E. Prentice-Hall, Inc., Englewood Cliffs, NJ. 1977. (Provides chemical basics of properties and reactions, Planned for fire fighters but very good for others).

CHEMLINE
National Library of Medicine. 8600 Rockville Pike, Bethesda, MD. (Computer-based information on over 300 000 chemicals).

CHEMTREC
Manufacturing Chemist's Association. Call 800-424-9300 for emergency handling information. This public service is available 24-hours a day and established by MCA, which is now called Chemical Manufacturers' Association.

CLINICAL TOXICOLOGY OF COMMERCIAL PRODUCTS
Gleason, M.N. 6th ed. Williams and Wilins, Baltimore. 1984. (A ready reference to more than 18 000 commercial products containing potentially toxic ingredients).

COLLECTION AND HANDLING OF LABORATORY SPECIMENS: A PRACTICAL GUIDE
Slockbower, J.M. et al. Lippincott, Philadelphia. 1983.

THE CONDENSED CHEMICAL DICTIONARY, 10th edition
Hawley, G. Van Nostrand Reinhold. 1981. (Also includes hazard information).

CRYOGENICS SAFETY MANUAL - A GUIDE TO GOOD PRACTICE
British Cryogenics Council, London, England. 1981.

*DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS. 6th edition
Sax, N.I. Van Nostrand Reinhold. New York. 1984. (Excellent introductory chapters. Lists many hazards for over 15 000 chemicals).

DEGRADATION OF CHEMICAL CARCINOGENS
Slein, M.W., Sansone, E.B. Van Nostrand Reinhold. 1979. (An annotated bibliography to disposal and degradation techniques).

DETECTION AND MEASUREMENT OF HAZARDOUS GASES
Cullis, C.F., Firth, J.C. eds. Heinemann. 1981.

DETOXIFICATION OF HAZARDOUS WASTE
Exner, J.H. ed., Ann Arbour Science. 1982. (Gives techniques).

DISINFECTION, STERILIZATION AND PRESERVATION. 3rd edition
Block, S.S. Lea & Febiger. 1983. (Gives techniques in the health-related fields).

DISPOSITION OF TOXIC DRUGS AND CHEMICALS IN MAN, 2nd edition
Baselt, R.C. Biomed Publications. 1982. (Gives fate of over 300 drugs and chemicals frequently encountered in human poisoning).

DOCUMENTATION OF THE THRESHOLD LIMIT VALUES. 4th edition
American Conference of Governmental Industrial Hygienists. Cincinnati, Ohio. Includes yearly supplements. 1980.

DRAFT MANUAL FOR INFECTIOUS WASTE MANAGEMENT
U.S. Environmental Protection Agency, Office of Solid Waste. Washington, D.C., The Office. 1982.

EFFECTS OF EXPOSURE TO TOXIC GASES. 2nd edition
Matheson Gas Products. P.O. Box 85, East Rutherford, NJ. 1977.

ELECTRON MICROSCOPY SAFETY HANDBOOK
Barber V.C., Clayton, D.L., eds. 1st edition, San Francisco Press. 1985.

EMERGENCY RESPONSE GUIDE FOR DANGEROUS GOODS
Canada. Transport of Dangerous Goods Branch. Information and Emergency Centre. Toronto, Copp Clark Pitman. 1979.

EMERGENCY MANUAL FOR ALL USERS AND MAKERS OF INDUSTRIAL CHEMICALS
International Technical Information Institute. 1978. (Includes disposal procedures for 400 hazardous substances and toxic environmental effects for 600 substances).

EMPLOYERS' GUIDE TO PROCEDURES FOR REPORTING OCCUPATIONAL INJURIES AND DISEASES UNDER THE GOVERNMENT EMPLOYEES COMPENSATION ACT
Labour Canada. Hull, Supply and Services Canada. 1983.

ENCYCLOPEDIA OF OCCUPATIONAL HEALTH AND SAFETY
Geneva, International Labour Office. 1983.

ENCYCLOPEDIE DE MEDECINE, D'HYGIENE ET DE SECURITE DU TRAVAIL
Geneve, Bureau international du Travail. 1973-1974.

ENGINEER'S GUIDE TO CONTROL OF HAZARDOUS WASTE
Van Nostrand. 1986.

ENVIRONMENTAL HEALTH AND SAFETY IN THE HOSPITAL LABORATORY
Flury, P. CC Thomas. 1978.

EXPLOSION HAZARDS AND EVALUATION
Baker, W.E., Westine, P.S., Kulesz, J.J. and Strehlow, R.A. Elsevier. 1983.

EXPLOSIONS
Bartknecht, W. 1981. (A text on course, causes and control).

EXPLOSIVES, 2nd edition
Meyer, R. Verlag Chemie. 1981. (An encyclopedia).

FIRST AID MANUAL FOR CHEMICAL ACCIDENTS
Lefevre, M.J. Dowden, Hutchinson and Ross Inc. Stroudsburg, PA. 1980. (First aid treatment for exposure to about 500 chemicals).

FIRE LOSS CONTROL: A MANAGEMENT GUIDE
Planer, R.G. Dekker. 1979. (Good on background and types of extinguishing systems).

FIRE PROTECTION GUIDE ON HAZARDOUS MATERIALS. 7th edition
Dean, A.E.F., Tower, K., eds. National Fire Protection Association, Boston, MA. 1978. (Helpful, especially for fire and police departments when responding to emergencies).

FIRE PROTECTION HANDBOOK, 15th edition
National Fire Protection Association. 1981.

FLASH POINT INDEX OF TRADE NAME LIQUIDS. 9th edition
National Fire Protection Association. 1978. (Listing for over 8 800 trade name products).

FOOD SAFETY
Roberts, H.R. Wiley- Interscience. 1981. (Examines areas of potential hazard associated with food supply).

FUNDAMENTALS OF INDUSTRIAL HYGIENE. 2nd edition
National Safety Council, 444 North Michigan Avenue, Chicago, IL 60611. 1979. (Excellent survey).

GOOD LABORATORY PRACTICE
Paget, G.D. Lancaster, England, MTP Press. 1979.

A GUIDE TO ACCIDENT INVESTIGATION
Health and Welfare Canada. 1983.

GUIDE TO THE COLLECTION AND TRANSPORT OF VIROLOGICAL SPECIMENS (INCLUDING CHLAMYDIAL AND RICKETTSIAL SPECIMENS)
Madeley, Charles Richard. Geneva, World Health Organization. 1977.

GUIDE DE L'EMPLOYEUR METHODES A SUIVRE POUR L'ETABLISSEMENT DES RAPPORTS D'ACCIDENTS DU TRAVAIL ET DE MALADIES PROFESSIONNELLES EN VERTU DE LA LOI SUR L'INDEMNISATION DES EMPLOYES DE L'ETAT
Travail Canada. Hull, Ministre des Approvisionnements et Servives. 1983.

GUIDES DES ENQUIETES SUR LES ACCIDENTS
Santé et Bien-être social Canada. 1983.

A GUIDE TO LABORATORY DESIGN
Everett, K., Hughes, D. 1975. (Concerned with labs used for work with potentially hazardous materials and minimizing problems of contamination).

GUIDE TO SAFE HANDLING OF COMPRESSED GASES
Matheson Gas Products.

GUIDE TO SAFE PRACTICES IN CHEMICAL LABORATORIES
Royal Society of Chemistry. 1986. Provides general guidance in organization for safety, chemical and physical hazards, design, fire prevention, storage and utilities. ISBN 0 85186 479 1

*GUIDE FOR SAFETY IN THE CHEMICAL LABORATORY. 2nd edition
Manufacturing Chemists' Association. Van Nostrand Reinhold Co., 135 W. 50th St., New York, NY. 1972. (Good overall reference. In addition gives hazard chart and waste disposal procedures for 1200 chemicals).

GUIDE DE SECURITE EN LABORATOIRE. 2e édition
Ordre des Chemistes du Québec, Ste. Foy, Québec. 1985.

GUIDE DE SECURITE POUR LES OPERATIONS DE LABORATOIRE. 2e édition
Ottawa, Conseil du Trésor. 1977.

GUIDE D'URGENCE POUR LES MATIERES DANGEREUSES
Canada. Direction du transport des marchandises dangereux. Centre d'information et d'urgence. Toronto, Copp Clark Pitman. 1977.

GUIDELINES FOR HANDLING CHEMICAL CARCINOGENS AND MUTAGENS
Biological Safety Committee, Univ. Wisconsin-Madison. 1978.

GUIDELINES FOR THE HANDLING OF RECOMBINANT DNA MOLECULES AND ANIMAL VIRUSES AND CELLS
Medical Research Council of Canada. 1980.

HANDBOOK OF COMPRESSED GASES. 2nd edition
Compressed Gas Association Inc., 500 5th Avenue, New York, NY 10035. 1980.

HANDBOOK OF ENVIRONMENTAL DATA ON ORGANIC CHEMICALS. 2nd edition
Verschueren, K. Van Nostrand Reinhold. 1983.

HANDBOOK OF HAZARDOUS MATERIALS
American Mutual Insurance Alliance, 20 North Wacker Drive, Chicago, IL. 60606.

HANDBOOK OF HAZARDOUS MATERIALS SPILLS
Bennett, G.F. et al. McGraw. 1982.

HANDBOOK OF HOSPITAL SAFETY
Stanley, P.E. CRC Press. 1981.

HANDBOOK OF IDENTIFIED CARCINOGENS AND NONCARCINOGENS: CARCINOGENICITY-MUTAGENICITY DATA BASE, Volumes I and II
Soderman, J.V. CRC Press. 1982.

HANDBOOK OF INDUSTRIAL WASTE DISPOSAL
Conway, R. and Ross, R. Van Nostrand Reinhold. 1980.

*HANDBOOK OF LABORATORY SAFETY. 2nd edition
Steere, N.V. CRC. 1971. (Excellent overall reference even though not up to date).

HANDBOOK OF OCCUPATIONAL HEALTH AND SAFETY. 3rd edition
Canada. Treasury Board. Occupational Health and Safety Group. Hull, Supply and Services Canada. 1982.

HANDBOOK OF ORGANIC INDUSTRIAL SOLVENTS. 3rd edition
American Mutual Insurance Alliance, 20 North Wacker Drive, Chicago, IL 60606. 1980. (Important data on solvent safety).

HANDBOOK OF POISONING. 11th edition
Dreisback, R.H. Lange. 1982. (A concise summary of the diagnosis and treatment of poisoning. Used by Poison Control Centres).

*HANDBOOK OF REACTIVE CHEMICAL HAZARDS: AN INDEXED GUIDE TO PUBLISHED DATA. 3rd edition
Bretherick, L. Butterworths, London. 1985. (A comprehensive discussion of the types of hazards followed on excellent chemical reactivity list with references).

HANDBOOK ON ANALYTICAL TOXICOLOGY
Sunshine, I. ed. CRC Press. 1969. (A collection of physical, chemical and toxicological data on a variety of chemicals).

HANDBOOK OF ENVIRONMENTAL DATA ON ORGANIC CHEMICALS
Van Nostrand. 1983.

HANDBOOK OF TOXIC AND HAZARDOUS CHEMICALS. 2nd edition
Sittig, M. Noyes Data Corporation, Park Ridge, N.J. 1985. (Concise chemical health, and safety information on 600 chemicals).

HANDBOOK OF VENTILATION FOR CONTAMINANT CONTROL (including OSHA requirements)
McDermott, H.J. Ann Arbor Science. 1976. (How to design and use exhaust ventilation systems).

HANDLING CHEMICAL CARCINOGENS IN THE LABORATORY: PROBLEMS OF SAFETY
Lyon, International Agency for Research on Cancer. 1979.

HANDLING CHEMICALS SAFELY
Published by Dutch Association of Safety Experts, Dutch Chemical Industry Association and the Dutch Safety Institute. English edition. 1980. (Data on 874 chemicals - hazards, storage, spillage, fire and protection).

HANDLING RADIATION EMERGENCIES
Purington, R.G., Patterson, W. eds. National Fire Protection Association. 1977.

HANDLING RADIOACTIVITY: A PRACTICAL APPROACH FOR SCIENTISTS AND ENGINEERS
Stewart, D.C. Wiley-Interscience. 1981.

HAZARD ASSESSMENT OF CHEMICALS, Volume 1, Volume 2
Saxena, J. and Fisher, F. ed. Volume 1. 1981. Volume 2, Academic Press. 1983. (A collection of reviews).

*HAZARDS IN THE CHEMICAL LABORATORY. 4th edition
Bretherick, L. ed. Royal Society of Chemistry, London. 1986. (Extensive introduction. Gives toxic properties, hazardous reactions, first aid, and spill disposal information for over 480 chemicals). ISBN 0 85186 489 9

HAZARDOUS CHEMICAL SPILL CLEANUP
Robinson, J.S. Noyes Data Corp., Park Ridge, New Jersey, U.S.A. 1979. (A practical guide for handling and control of hazardous material spills).

HAZARDOUS CHEMICALS DATA BOOK
Weiss, G. Noyes Data Corporation. Park Ridge, N.J. 1980.

HAZARDOUS CHEMICALS INFORMATION ANNUAL #1
Sax. N.I. 1986.

*HAZARDOUS CHEMICALS: INFORMATION AND DISPOSAL GUIDE. 2nd edition
Armour, M.A., Browne, L.M., Weir, G.L. Edmonton, Alta., Department of Chemistry, University of Alberta. 1984. (Reactivity, fire and health hazards in addition to spill and tested waste disposal procedures for about 250 chemicals).

HAZARDOUS MATERIALS SPILLS HANDBOOK
Bennett, G.F., Feates, F.S., Wilder, I. eds. New York, McGraw-Hill. 1982. (Covers all aspects from theoretical to practical).

HAZARDOUS AND TOXIC EFFECTS OF INDUSTRIAL CHEMICALS
Sittig, Marshall. Park Ridge, N.J., Noyes Data Corporation. 1979.

HAZARDOUS AND TOXIC MATERIALS: SAFE HANDLING AND DISPOSAL
Fawcett, H.H. John Wiley and Sons, New York. 1984.

HAZARDOUS WASTES HANDBOOK. 4th edition
Code of Federal Regulations. 1982. (EPA regulation analysis).

HAZARDOUS WASTE MANAGEMENT
Pierce, J.J. and Vesilind, P.A. Ann Arbor Science Publishers. Ann Arbor, Mich. 1981.

HAZARDOUS WASTE MANAGEMENT FOR THE 80's
Sweeney, T.L., Bhatt, H.G., Sykes, R.M., Sproul, O.J., eds. Ann Arbor Science. 1982.

HAZARDOUS WASTE MANAGEMENT HANDBOOK 1982
Orchard, R.V. Corpus, Don Mills, Ont. 1981.

HEALTH AND SAFETY IN THE CHEMICAL LABORATORY-HWERE DO WE GO FROM HERE?
Royal Society of Chemistry, London. 1984. Special Publication No. 51. An overview of recent developments. ISBN 0 85186 945 9

HEALTH AND SAFETY OF LABORATORY WORKERS IN CANADA: A REVIEW OF THE LITERATURE
Canada. Environmental Health Directorate. Ottawa, Health and Welfare Canada. 1982.

HEALTH AND SAFETY MANUAL
Lawrence Berkeley Laboratory. Springfield, Va., National Technical Information Service. 1980.

HIGH RISK SAFETY TECHNOLOGY
Green, A.E. 1982. (Techniques for evaluating the safety of technological systems).

HIGHLY HAZARDOUS MATERIAL SPILLS AND EMERGENCY PLANNING
Zajic and Himmelman. Marcel Dekker. 1978. (Planning manual. Gives classification list of highly hazardous materials and a rating system).

IF YOU HAVE AN ACCIDENT: WHAT TO DO AND HOW TO DO IT
Labour Canada. Hull, Supply and Services Canada. 1982.

INDUSTRIAL FIRE HAZARDS HANDBOOK
McKinnon, G., Tasner, P., Hill, M. eds. National Fire Protection Association. 1979.

INDUSTRIAL RESPIRATORY PROTECTION
Teresinski, M.F., Cheremisinoff, P.N. Ann Arbor Science. 1983. (Comprehensive overview of technical data for efficient respiratory protection in hazardous atmospheres).

INDUSTRIAL SOLVENTS HANDBOOK
Mellan, I. Noyes Data Corp. (Engineering and Safety detail).

INFORMATION RESOURCES IN TOXICOLOGY
Wexler, P. Elsevier. 1982. (A selective and annotated listing).

INITIAL EMERGENCY RESPONSE
Transport Canada. 1986. (Gives practical information on how to deal with large chemical spills).

INSTRUMENTATION FOR ENVIRONMENTAL MONITORING. 2nd edition
Lawrence Berkeley Laboratories. 1983. (A survey of radiation monitoring).

INTRODUCTION TO SAFETY IN THE CHEMICAL LABORATORY
Freeman, N.T. and Whitehead, J. London, Academic Press. 1982.

LABORATORY-ACQUIRED INFECTIONS: HISTORY, INCIDENCE, CAUSES AND PREVENTION
Collins, C.H. Butterworths, London. 1983.

LABORATORY BIOSAFETY MANUAL
Geneva, World Health Organization. 1983.

LABORATORY DECONTAMINATION AND DESTRUCTION OF AFLATOXINS B_1, B_2, G_1, B_2 IN LABORATORY WASTES
International Agency for Research on Cancer. Lyon, France. 1980.

LABORATORY DECONTAMINATION AND DESTRUCTION OF CARCINOGENS IN LABORATORY WASTES: SOME N-NITROSAMINES
International Agency for Research on Cancer. Lyon, France. 1982.

LABORATORY DECONTAMINATION AND DESTRUCTION OF CARCINOGENS IN LABORATORY WASTES: SOME POLYCYCLIC AROMATIC HYDROCARBONS
International Agency for Research on Cancer. Lyon, France. 1983.

LABORATORY HAZARDS BULLETIN
The Royal Society of Chemistry. The University; Nottingham, England.

LABORATORY SAFETY & HANDLING PROCEDURE FOR CHEMICAL MUTAGENS
Environ. Mutagen. USA. 1980.

LABORATORY SAFETY: THEORY AND PRACTICE
Fuscaldo, Anthony A., Erlick, B., Hindman, B. eds. Academic Press. New York. 1980. (Provides information on microbiological hazards).

LABORATORY WASTE DISPOSAL MANUAL
Manufacturing Chemist's Association. Washington, D.C. 1973.

LASER SAFETY HANDBOOK
Mallow, A. and Chabot, L. Van Nostrand Reinhold. 1978.

MANAGING HAZARDOUS SUBSTANCES ACCIDENTS
Smith, Al. J. Jr. 1981. (Book shows how to develop management system to best coordinate activities at a spill site).

MANUAL OF HAZARDOUS CHEMICAL REACTIONS. 5th edition
National Fire Protection Association, Boston, MA. 1975.

MANUEL DE L'HYGIENE ET DE LA SECURITE PROFESSIONNELLES
Canada. Conseil du Trésor. Group de l'hygiène et de la sécurité professionnelles. 3e édition. Hull, Approvsionnements et Services Canada. 1982.

MATHESON GAS DATA BOOK. 6th edition
Matheson Gas Products, P.O. Box 85, East Rutherford, NJ.

*THE MERCK INDEX. 10th edition
Windholz, M. ed. Merck & Co. 1983. (An encyclopedia of over 10 000 chemicals, drugs and biologicals).

THE MERCK MANUAL OF DIAGNOSIS-THERAPY. 14th edition
(A virtual medical Library).

MODELING REMEDIAL ACTIONS AT UNCONTROLLED HAZARDOUS WASTE SITES
Boutwell, S.H. et al. Noyes Publications Park Ridge, N.J. 1986.

NATIONAL FIRE CODES
National Fire Protection Association, NFPA, 470 Atlantic Avenue, Boston, MA. Updated annually.

*NIOSH-OSHA POCKET GUIDE TO CHEMICAL HAZARDS
National Institute for Occupational Safety and Health. Washington, D.C., U.S. Government Printing Office. 1978. (Valuable information on toxicity, reactivity and personal protection on 380 regulated chemicals).

OCCUPATIONAL DISEASES: A GUIDE TO THEIR RECOGNITION
Key, M. et al., eds. U.S. Department to Health, Education and Welfare, Washington, D.C. Revised June 1977.

OCCUPATIONAL HEALTH GUIDELINES FOR CHEMICAL HAZARDS
National Institute for Occupational Safety and Health. Washington, D.C., U.S. Government Printing Office. 1981.

OCCUPATIONAL HEALTH AND SAFETY: A TRAINING MANUAL
Ontario Federation of Labour. Toronto, Copp Clark Pitman. 1982.

ORGANIC CHEMICALS MANUFACTURING HAZARDS
Goldfarb, A.S. et al. Ann Arbor Science. 1981.

ORGANO-CHLORINE SOLVENTS-HEALTH RISKS TO WORKERS
Royal Society of Chemistry, London. 1986. Discusses 10 common solvents. ISBN 0 85186 078 8

PATTY'S INDUSTRIAL HYGIENE AND TOXICOLOGY. 3rd edition
Volume I. General Principles, Clayton, G.D. and Clayton, F.E. eds. 1978. Volume IIA-Toxicology, 1980; Volume IIB-Toxicology, 1981; Volume IIC-Toxicology, 1982; Volume III-Theory and Rationale of Industrial Hygiene Practice - Cralley, L.V. and Crally, L.J. eds. 1979. Wiley-Interscience. (Comprehensive coverage).

PESTICIDE DISPOSAL AND DETOXIFICATION: PROCESSES AND TECHNIQUES
Dillon, A.P. Noyes Data Corporation, Park Ridge, N.J. 1981.

POISONING, TOXICOLOGY, SYMPTOMS, TREATMENT. 2nd edition
Arena, J.M. Charles C. Thomas, Springfield, Illinois. 1970.

POTENTIAL INDUSTRIAL CARCINOGENS AND MUTAGENS
Fishbein, L. Elsevier. 1979. (Organized by structural categories).

PRECAUTIONS FOR THE PROPER USAGE OF POLYURETHANES, POLYISOCYANURATES, AND RELATED MATERIALS. 2nd edition
Upjohn Company. Kalamazoo, Mich. 1980.

*PRUDENT PRACTICES FOR DISPOSAL OF CHEMICALS FROM LABORATORIES
National Academy Press. Washington, D.C. 1983. (Gives disposal procedures).

*PRUDENT PRACTICES FOR HANDLING HAZARDOUS CHEMICALS IN LABORATORIES
National Research Council. Committee on Hazardous Substances in the Laboratory. National Academy Press. Washington, D.C. 1981. (Gives procedures for working with substances that pose hazards because of reactivity, flammability, corrosiveness, toxicity, and other properties, and for storage and disposal of such substances). ISBN 0 309 03128 1

QUANTITATIVE RISK ASSESSMENT FOR ENVIRONMENTAL AND OCCUPATIONAL HEALTH
Hallenbeck, W.H., Cunningham, K.M. Lewis Publishers, Chelsea Mich. 1986.

RADIATION PROTECTION. A GUIDE FOR SCIENTISTS AND PHYSICIANS. 2nd edition
Shapiro, J. Harvard Univ. Press. 1981.

RADIOISOTOPE LABORATORY TECHNIQUES. 4th edition
Faires, R.A., Boswell, G.G.J. Butterworth. 1981.

RAPID GUIDE TO HAZARDOUS CHEMICALS IN THE WORKPLACE
Sax, N.I., Lewis, R.J., Sr. Van Nostrand. 1986. (700 common chemicals, cross ref. indieces by CAS, RTECS, DOT 7 aliphatical).

RECOMMENDATIONS POUS L'USAGE DES PRODUITS CHIMIQUES TOXIQUES ET DANGEREUX DANS LES ETABLISSEMENTS D'ENSEIGNMENT
Canada. Direction de l'hygiène du milieu. Ottawa, Santé et bien-être social Canada. 1980.

REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES
National Institute for Occupational Safety and Health. Superintendent of documents, U.S. Government Printing Office, Washington, D.C. 20402. 1980. Continually updated. Over 40 000 chemicals listed.

REPRODUCTIVE HAZARDS OF INDUSTRIAL CHEMICALS
Barlow, S.M., Sullivan, F.M. Academic Press. 1982. (Detailed review of 50 most commonly used industrial chemicals).

SAFE AND EFFICIENT PLANT OPERATION AND MAINTENANCE
Greene, R. ed. McGraw. 1980. (Guide on chemical plants).

SAFE HANDLING OF CHEMICAL CARCINOGENS, MUTAGENS, TERATOGENS AND HIGHLY TOXIC SUBSTANCES
Walters, D.B. Ann Arbor, Mich., Ann Arbor Science Publishers. 2 volumes. 1980. (Very useful. Discusses facility design, handling, monitoring, disposal, control and more).

SAFE STORAGE OF LABORATORY CHEMICALS
Pipitone, D.A. John Wiley and Sons. New York. 1984.

SAFETY IN ACADEMIC CHEMICAL LABORATORIES. 4th edition
American Chemical Society, Washington, D.C. 1985.

SAFE USE OF SOLVENTS
Collings, A.J., Luxan, S.G. ed. Academic Press. 1982.

SAFETY AND ACCIDENT PREVENTION IN CHEMICAL OPERATIONS. 2nd edition
Fawcett, H.H., Wood, W.S. John Wiley and Sons. New York. 1982.

SAFETY IN BIOLOGICAL LABORATORIES
Hartree, Edwards and Booth, Vernon. Biochemical Society, London. 1977.

SAFETY GUIDE FOR LABORATORY OPERATIONS. 2nd edition
Treasury Board, Ottawa. 1977.

SAFETY AND LABORATORY PRACTICE: LEVEL I
Clarke, B.P. Van Nostrand Reinhold, New York. 1981.

SAFETY WITH LASERS AND OTHER OPTICAL SOURCES: A COMPREHENSIVE HANDBOOK
Sliney, D. and Wolbarsht, M. Plenum, New York. 1980.

SAFETY IN MICROBIOLOGY
Shapton, D.A. and Board, R.G. Academic Press, London. 1972.

SAFETY TRAINING METHODS
ReVelle, Jack B. Wiley-Interscience. 1980.

SAFETY IN WORKING WITH CHEMICALS
Green, M. and Turk, A. Macmillan Publishing Co., Inc., 866 3rd Avenue, New York, NY 10022. 1978. (Oriented toward the academic laboratory).

LA SANTE ET LA SECURITE DANS LES LABORATOIRES: UNE ETUDE DE LA DOCUMENTATION
Canada. Direction de l'hygiène du milieu. Ottawa, Santé et bien-être social Canada. 1982.

SI VOUS AVEZ UN ACCIDENT CE QU'IL FAUT FAIRE ET COMMENT LE FAIRE
Travail Canada. Hull, Ministre des Approvisionnements et Services Canada. 1982.

**THE SIGMA-ALDRICH LIBRARY OF CHEMICAL SAFETY DATA
Lenga, R.E. ed. Alrich Chemical Co., Milwaukee, WI. 1986. (An extensive collection of up-to-date safety information on over 7000 chemicals. Very expensive, but worth it).

THE SIGNS AND SYMPTOMS OF CHEMICAL EXPOSURE
Block, J.B. Thomas, Springfield, Ill. 1980.

SYSTEM SAFETY ENGINEERING AND MANAGEMENT
Roland, H.E. and Moriarty, B. Wiley-Interscience. 1983.

TECHNICAL MANUAL FOR THE MANAGEMENT OF CHEMICAL WASTE IN LABORATORIES
Environment Canada. 1986.

THRESHOLD LIMIT VALUES FOR CHEMICAL SUBSTANCES AND PHYSICAL AGENTS IN THE WORK ENVIRONMENT
American Conference of Governmental Industrial Hygienists. P.O. Box 1937, Cincinnati, Ohio. 1983. Updated annually.

TOXIC HAZARD ASSESSMENT OF CHEMICALS
Richardson, M. ed. Royal Society of Chemistry, London. 1986. (Provides basic guidance for retrieving, validating, and interpreting data in order to make a toxicological hazards assessment upon a chemical).
ISBN 0 85186 897 5

TOXIC AND HAZARDOUS INDUSTRIAL CHEMICALS SAFETY MANUAL. Revised edition
International Technical Information Institute, Tokyo. 1982. (Toxicity and hazard data for 700 chemicals; procedures for handling and disposal).

TOXIC ORGANIC CHEMICALS DESTRUCTION AND WASTE TREATMENT
Hackman, E. III. Noyes Data Corp. 1978. (For manufacturing personnel).

TOXLINE
National Library of Medicine, 8600 Rockville Pike, Bethesda, MD 20014. (Computer-based information on original references to animal and human data).

TREATMENT RECOVERY AND DISPOSAL PROCESSES FOR RADIOACTIVE WASTE
Duffy, J.I. ed. Noyes Data Corp. 1983. (Reviews patent literature).

WORKING WITH COMPRESSED GASES
Matheson Gas Products, P.O. Box 85, East Rutherford, NJ.

8.0 SUBJECT INDEX

9.0

CHEMICAL INDEX