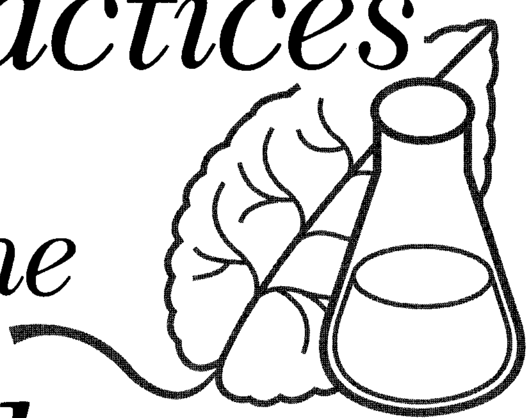
EXECUTIVE SUMMARY

Prudent Practices in the Laboratory



Handling and Disposal of Chemicals

Committee on Prudent Practices for Handling, Storage,
and Disposal of Chemicals in Laboratories

Board on Chemical Sciences and Technology
Commission on Physical Sciences, Mathematics, and Applications
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

In the early 1980s, the National Research Council (NRC) produced two major reports on laboratory safety and laboratory waste disposal: *Prudent Practices for Handling Hazardous Chemicals in Laboratories* (1981) and *Prudent Practices for Disposal of Chemicals from Laboratories* (1983). To provide safety and waste management guidance to laboratory workers, managers, and policymakers that would be responsive to knowledge and regulations in the 1990s, the NRC's Board on Chemical Sciences and Technology initiated an update and revision of the earlier studies.

After extensive consultation with members of the broad chemistry and laboratory communities, the full committee was appointed in September 1992. It first convened in November 1992 and held five additional meetings during the next two years. Several highly specialized areas were addressed by the appointment of several subcommittees, which met in conjunction with the full committee or independently as appropriate.

The Committee on Prudent Practices for Handling, Storage, and Disposal of Chemicals in Laboratories and its subcommittees were charged to:

- establish the scope of changes and new material required to update *Prudent Practices 1981* and *Prudent Practices 1983,*
- evaluate recent developments and trends in the scientific communities and regulatory areas,
- develop strategies for implementing safety programs, which include risk assessment methods in planning laboratory work with hazardous chemicals,
- develop a follow-up plan for training aids by obtaining consensus on the report and reviewing suggestions, and
- address such topics as procurement, storage, and disposal of chemicals; hazards of known chemicals; handling of chemicals; work practices; generation and classification of chemical waste; off-site transportation and landfills; and incinerators and small-scale combusters.

Prudent Practices 1981 and *Prudent Practices 1983* were conceived during the late 1970s in recognition of growing public expectations for health and safety in the workplace, protection of the environment, and the responsible use of hazardous chemicals. Since their original publication in the early 1980s, these reports have been distributed widely both nationally and internationally. In 1992, the International Union of Pure and Applied Chemistry and the World Health Organization published *Chemical Safety Matters,* a document based on *Prudent Practices 1981* and *Prudent Practices 1983,* for wide international use.

The original motivation for drafting *Prudent Practices 1981* and *Prudent Practices 1983* was to provide an authoritative reference on the handling and disposal of chemicals at the laboratory level. These volumes not only served as a guide to laboratory workers, but also offered prudent guidelines for the development of regulatory policy by government agencies concerned with safety in the workplace and protection of the environment. Pertinent health-related parts of *Prudent Practices 1981* are incorporated in a nonmandatory section of the OSHA Laboratory Standard (29 CFR 1910.1450; reprinted as Appendix A). OSHA's purpose was to provide guidance for developing and implementing its required Chemical Hygiene Plan.

Now, after nearly a decade and a half, the present volume (*Prudent Practices 1995*) responds to societal and technical developments that are driving significant change in the laboratory culture and laboratory operations relative to safety, health, and environmental protection. The major drivers for this new culture of laboratory safety include the following:

- The increasing regulatory compliance burden and associated time and financial penalties for noncompliance;
- The OSHA performance-based Laboratory Standard that places responsibility on individual laboratories to develop site-specific laboratory health programs, including certain elements such as written procedures, a designated coordinator for the written procedures, employee information and training, and compliance with OSHA-specified exposure limits;
- An increasingly litigious society and the growth of tort law;
- The increase in "public interest" groups and the realization by laboratory operators that operation of a laboratory is a privilege that carries a responsibility to go beyond mere compliance to "doing what is right" in the eyes of fellow workers and society;
- The myriad technical advances in our understanding of hazards and risk evaluation, improvements in chemical analysis, improvements in miniaturization and automation of laboratory operations, and the availability of vastly improved safety equipment, atmosphere-monitoring devices, and personal protective equipment; and
- A greater understanding and acceptance of the critical elements necessary for an effective culture of safety.

After careful consideration of these technical, regulatory, and societal changes, the committee chose to rewrite, rather than simply revise, much of the material in the previous two volumes and to condense them into a single one. In this 1995 revision, the committee has sought primarily to describe this new laboratory culture, identify its key elements, and provide certain information and procedures that have been developed within that culture. To ensure prudent handling in a coordinated manner from "cradle to grave," this new volume incorporates much material from the *Prudent Practices 1981* and *Prudent Practices 1983* volumes.

In addition, in response to users of *Prudent Practices 1981* who have emphasized the value of the information on how to handle compounds that pose special hazards, the committee has compiled Laboratory Chemical Safety Summaries (Appendix B) that provide chemical and toxicological information for 88 substances commonly found in laboratories. Although most of the information provided for these compounds will maintain its value, data on some properties, especially toxicological ones, should be updated frequently. Accordingly, the most recent Material Safety Data Sheets provided by the manufacturer or other updated sources should be consulted before work is done with hazardous compounds.

At every stage in the development of this book, the committee has maintained a close dialogue with the community of expected users through discussions with experts, participation of observers at committee meetings, and presentations to various professional organizations. In addition, subcommittees of experts were appointed to provide advice in several specialized areas. The goal in these discussions with authorities and with the general community of industrial and academic researchers and teachers has been to determine what are considered *prudent practices* for laboratory operations.

"Laboratory" means (following the OSHA Laboratory Standard) "a workplace where relatively small quantities of hazardous chemicals are used on a nonproduction basis." Through definition of the corollary terms "laboratory scale" and "laboratory use," OSHA expanded on this definition to encompass additional criteria: a laboratory is a place in which (1) "containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person," (2) "multiple chemicals or chemical procedures are used," and (3) "protective laboratory practices and equipment are available and in common use to minimize the potential for employee exposure to hazardous chemicals." The definition excludes operations (1) in which the procedures involved are part of or in any way simulate a production process or (2) whose function is to produce commercial quantities of materials.

Dialogue with the chemical community has shown that there are many effective ways in which institutions can organize for safety in the laboratory when there is a sincere commitment to safe practice and institutional support. Accordingly, a single organizational model of institutional safety cannot be proposed as being typical. The aim throughout has been to offer generally useful guidelines rather than specific blueprints.

Public support for the laboratory use of chemicals depends on compliance with regulatory laws as a joint responsibility of everyone who handles or makes decisions about chemicals, from shipping and receiving clerks to laboratory workers and managers, environmental health and safety staff, and institutional administrators. This shared responsibility is now a fact of laboratory work as inexorable as the properties of the chemicals that are being handled. The use of chemicals, like the use of automobiles or electricity, involves some irreducible risks. However, all three of these servants to humankind have demonstrated benefits that enormously outweigh their costs if they are handled sensibly. The passage of time has demonstrated the value of *Prudent Practices 1981* and *Prudent Practices 1983* not only as guides to safe laboratory practice but also through their influence on the drafting of reasonable regulations. The committee hopes that its efforts will have a comparable beneficial impact as chemistry continues its central role in society.

Acknowledgments

Many technical experts, representing a wide variety of laboratories that use chemicals, provided input to this book. Their involvement through participation at workshops and committee meetings, submission of written materials, and review of technical material prepared by the committee has enhanced the book, and their efforts are greatly appreciated. The Committee on Prudent Practices for Handling, Storage, and Disposal of Chemicals in Laboratories thanks the following people both for their participation in the workshops and for contributions to the revision of *Prudent Practices 1995*.

Robert Alaimo, Proctor & Gamble; Bruce Backus, University of Minnesota; David Bammerlin, BP Warrensville; John Bartmess, University of Tennessee; John Beltz, Purdue University; Charles E. Billings, Massachusetts Institute of Technology; Daniel Brannegan, Pfizer; William H. Breazeale, Jr., Francis Marion University; Ronald Bresell, University of Wisconsin; Don G. Brown, University of Washington; Elise Ann B. Brown, USDA; Holmes C. Brown, Afton Associates, Inc.; Judy Brown, Edison Career Center; Rebecca Byrne, University of Illinois; Elna Clevenger, National Cathedral School; Robert G. Costello, W.R. Grace & Co.; Elizabeth Cotsworth, Environmental Protection Agency; Jeffrey L. Davidson, Environmental Protection Agency; Hugh Davis, Environmental Protection Agency; M. Sue Davis, Brookhaven National Laboratory; Gary Diamond, Syracuse Research Corporation; Howard Dobres, Drug Enforcement Administration; Laurence J. Doemeny, National Institute for Occupational Safety and Health; Greg L. Engstrom, 3M; Sandra A. Filippi, Prince George's Community College; Edward Gershey, Rockefeller University; Renae Goldman, 3M; Judith Gordon, Environmental Protection Agency; Carl Gottschall, E.G.&G.; Frederick D. Greene, Massachusetts Institute of Technology; Rolf Hahne, Dow Chemical Co.; Clayton E. Hathaway, Chesterfield, Missouri; Donna Heidel, R. W. Johnson; Jennifer Hernandez, Graham & James; Joseph Kanabrocki, University of Wisconsin; Glenn Ketcham, University of California; Robert Kohler, Monsanto; Po Yung Lu, Oak Ridge National Laboratory; Maureen Matkovich, American Chemical Society; Greg McCarney, 3M; Anne McCollister, Risk Communication International; Robert Meister, Eli Lilly; William G. Mikell, E.I. du Pont de Nemours & Co. (ret.); L. Jewel Nicholls, Sauk Rapids, Minnesota; Dan Pilipauskas, G. D. Searle; John E. Pingel, University of Illinois; Frank Priznar, Weston Inc.; Edward H. Rau, National Institutes of Health; Cynthia L. Salisbury, Compliance Solutions Inc.; David Schleicher, American Chemical Society; Eileen B. Segal, *Chemical Health and Safety*; William E. Shewbart, Dow Chemical Co.; Richard Shuman, Merck & Company; Reinhard Sidor, General Electric Co.; John Softy, Environmental Safety Office; Mary Ann Solstad, SOLSTAD Health and Safety Evaluations; Christine Springer, Scripps Research Institute; Ralph Stuart, University of Vermont; Martin J. Steindler, Argonne National Laboratory; Stephen A. Szabo, Conoco Inc./DuPont; Linda J. Tanner, 3M; David Vandenberg, University of California at Santa Barbara; George H. Wahl, North Carolina State University; Kenneth Williamson, Mount Holyoke College; Howard Wilson, Environmental Protection Agency; and Nola Woessner, University of Illinois.

Although the above list is extensive, it does not include all the individuals who have contributed their time, energy, and knowledge to this project. In full recognition that this report would not have been produced without the involvement of individuals not specifically mentioned here, the committee acknowledges their efforts by thanking the community at large.

Contents

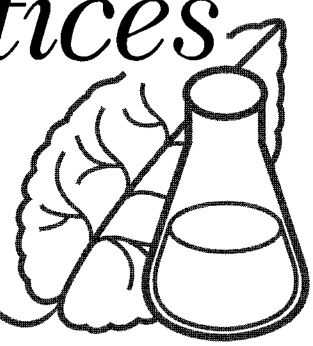
The contents of the entire report, from which this Executive Summary is extracted, are listed below.

Figures and Tables

FIGURES

TABLES

Prudent Practices in the Laboratory



Handling and Disposal of Chemicals

Overview and Recommendations

This book has been prepared by a National Research Council (NRC) committee in response to the growing recognition of the central place of chemistry in society, the special risks that are encountered by people who work with chemicals in the laboratory, and the potential hazards that are presented to the public by their use, transport, and disposal. Increased appreciation of the hazards related to certain chemicals has fostered a new "culture of safety" in many laboratories where chemicals are handled and chemical waste is generated and disposed of. Due in part to the publication of the NRC's *Prudent Practices for Handling Hazardous Chemicals in Laboratories* (hereinafter *Prudent Practices 1981*), and *Prudent Practices for Disposal of Chemicals from Laboratories* (hereinafter *Prudent Practices 1983*), there have been dramatic changes in attitudes toward shared responsibility by laboratory practitioners, management, and government at the federal, state, and local levels. These have been reflected in the OSHA Laboratory Standard (29 CFR 1910.1450; reprinted as Appendix A), which provides a legal, institutionalized, performance-based framework for safe, responsible laboratory work. There have also been important technical improvements that reduce the risks of handling chemicals in the laboratory and the cost of handling chemical waste.

Charged with the responsibility of evaluating the chemical, regulatory, and educational changes that have had an impact on the handling of chemicals in the laboratory since the previous reports were published, the committee has assessed the needs of all those who manage, handle, and dispose of chemicals in the laboratory workplace, where relatively small quantities of hazardous materials are used on a nonproduction basis. The committee was chosen for its breadth of expertise in chemistry, education, and environmental health and safety operations, and it has also called on a wider community of experts through the appointment of special subcommittees for assessing chemical hazards, design of laboratory space and equipment, pollution prevention, and the disposal of multihazardous waste. In addition, a number of meetings of the committee with different chemical user groups have helped to structure and clarify the committee's recommendations.

This volume was prepared primarily for those who use chemicals in laboratories, ranging from researchers and students to a broad array of technicians. Chemicals are handled not only by chemists, but also by biologists, physicists, geologists, materials engineers, and others. Accordingly, this volume is intended for general use but with the recognition that a basic familiarity with chemical nomenclature and its relation to molecular structure and chemical behavior is necessary in order to understand and use many parts of this work. A wider audience of administrative and chemical hygiene officers and environmental health and safety officers in educational, chemical, and regulatory institutions is also envisioned.

Although some readers may wish to become familiar with the entire book, others may be concerned with only one or two chapters, such as Chapter 3 (Evaluating Hazards and Assessing Risks in the Laboratory), Chapter 4 (Management of Chemicals), or Chapter 5 (Working with Chemicals). Others may be concerned with only Chapter 7 (Disposal of Waste) or Chapter 9 (Governmental Regulation of Laboratories). In deference to readers whose use of this book may be infrequent and specifically focused, or may perhaps occur under emergency conditions, the chapters are free-standing, even if this arrangement leads to repetition of some topics, albeit within different contexts.

THE CULTURE OF LABORATORY SAFETY (CHAPTER 1)

The new culture of laboratory safety implements the priority of "safety first" through a greatly increased emphasis on experiment planning, including habitual attention to risk assessment and consideration of hazards for oneself, one's fellow workers, and the public. So important is the formal framework for experiment planning that this volume has been structured around the sequence of steps described in Chapter 2. The key word "prudence" provides a middle pathway between the extremes of stultifying overregulation and a reckless rush to "get the job done" in the laboratory. A prudent attitude toward dealing with hazards in the laboratory is characterized by a determination to make every effort to be informed about risks and reduce them to a minimum while recognizing that the notion of "zero risk" in laboratory operations (or any other workplace) is an impossible ideal. However, an accident-free workplace can be approached by setting a goal of zero incidents and zero excuses. Continuous basic respect and care for the health and safety of laboratory workers and the greater society constitute the starting point for *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals.*

Education for Safety and Pollution Control

Good attitudes toward rational risk assessment and safe habits, as well as awareness of the expectations of others who might be affected by laboratory work, should be instilled in laboratory workers from their earliest experiences with observing and performing laboratory operations. Early in primary school children should be involved in thinking through possible implications of and risks in experiments that they see or do, learning that this is part of the way science is done. If good habits are inculcated from the beginning, participation in the culture of safety will be natural and painless; if these lessons are neglected until college or graduate school, or until the first industrial job, reeducation can be a difficult, expensive, and perhaps even a dangerous initiation.

At the present time, there is a wide range of safety consciousness and safety preparation among individuals entering high school, college, graduate school, and industry. Teaching laboratories at all levels are faced with the problem of young personnel with diverse backgrounds and various levels of preparation. Some who are beginning their first college laboratory course work may have had no previous hands-on training in handling chemicals or equipment and may even carry a "chemophobic" prejudice to the workbench. Others may come well prepared to assume personal responsibility for risk assessment and safety planning in their experiments if their instructors in high school have trained them to share in every stage of experiment planning, with attention to suitable waste disposal as a routine component. If the research environment in their undergraduate and graduate schools has not emphasized shared responsibility and good working relationships with environmental health and safety personnel, even professional chemists entering well-run industrial or government laboratories may find it difficult to adjust to the environment of fully accountable experiment planning.

Factors Affecting Safety Practices in Laboratories

A wide variety of factors, both internal and external, have affected the conduct of laboratory work during the past 15 years. Public concern for safety in the workplace and protection of the environment through pollution prevention has resulted in a voluminous array of regulations designed to control every stage of the transportation of chemicals to and from laboratories, their handling within the laboratory workplace, and their final disposal. Safe practice by laboratory workers requires continuing attention and education; it cannot be assumed to be optional. Accordingly, an infrastructure of professionals trained in environmental health and safety has developed who serve at the interface between federal, state, and local regulatory agencies and the educational and industrial laboratories where chemicals are handled. An increasing climate of litigation has also sharpened the awareness of everyone on the ladder of responsibility, from directors and trustees to maintenance personnel, about the price that may have to be paid if accidents occur as a result of the illegal or irresponsible handling of chemicals or chemical waste. "Down the sink" disposal, for example, is no longer routine.

Many steps have been taken to improve the safety of equipment for handling and experimenting with chemicals. An increasing trend toward miniaturizing chemical laboratory operations has reduced the volume and, therefore, the cost of acquiring chemicals and handling all aspects of waste, including the removal of toxic vapors from the laboratory. Concurrent with miniaturization has been the development of instruments with vastly increased sensitivity and speed of operation so that both the quantities of materials and the turnaround time required for obtaining answers to experimental questions have been reduced drastically. In some teaching and research programs, simulation by computer has replaced experiments that pose a particular danger. Waste minimization and pollution control techniques, such as recycling and the development of more efficient or nontoxic synthetic routes, have gained increasingly high priority as the cost of waste disposal has escalated.

Unquestionably, most laboratories are safer places to work now than they were 15 years ago. However, the ultimate key to maintaining a safe environment lies in the attitude and behavior of the individual worker.

PRUDENT PLANNING OF EXPERIMENTS (CHAPTER 2)

Preparation for running an experiment in the laboratory has always required forethought in order to assemble the necessary chemicals, purify them to an acceptable level, set up and test the required apparatus, and use precedents from the literature, or in-house reports, to consider the appropriate scale and conditions to be employed. Depending on the individual worker, the supervisors, and the requirements of the institution, the process may be formalized to different degrees. The new culture of laboratory safety recognizes that it is wise to formalize the process of experiment planning, both in the interest of safety and to ensure compliance with regulations for the handling of reactants required for the proposed processing and disposal of all waste generated. The sequence of steps for planning is so fundamental and repeatable that the committee has structured this book in accordance with the work-flow diagram, Figure 1.2, given in Chapter 1. Each chapter is organized around a key step in that protocol.

There is great diversity in the formality and means by which the planning structure applies. For example, laboratory manuals for students provide a complete package of planned experiments and detailed technical directions. Future manuals should include questions and assignments that involve the student actively in considering the risks, regulations, and waste disposal costs for alternative approaches to the problem under discussion. In research laboratories where important steps of the planning process have, over time, become standard operating procedure, mental planning may be sufficient to enable doing the next routine experiment safely and effectively. In contrast, a completely new type of experiment involving unfamiliar materials and unprecedented hazards may require formal planning for every stage, and discussion with experts outside the immediate research group and members of the environmental health and safety office should be considered carefully.

EVALUATING HAZARDS AND ASSESSING RISKS IN THE LABORATORY (CHAPTER 3)

A first step in planning a new experiment is consideration of the types of hazards that may be posed by toxic, flammable, reactive, and/or explosive materials encountered in the proposed work. Even if the experiment is part of a series that has been repeated so many times that every step has become routine, the change in conditions or compounds that makes this a new experiment, rather than just a repetition, may introduce a new hazard, unprecedented in the series; for example, a minor molecular modification may result in a sharp increase in toxicity or likelihood of explosion.

Thus, planning for the first experiments in a new field, as well as experiment planning by inexperienced workers, requires considerable investigation of published resources and discussion with competent experts on potential technical hazards and regulatory requirements. Advice from environmental health and safety or industrial hygiene personnel may be particularly valuable in the initial stage of planning.

A wide variety of published resources describe the dangerous properties of specific compounds. All of the common types of explosive, reactive, and flammable compounds are well documented. Because the functional groups that are associated with these properties are clearly identified, and their hazards well known, it is usually possible to predict the potential for a serious accident. However, unprecedented accidents are reported occasionally, and new substances with unknown properties are continually being generated as products and by-products of chemical experiments.

At the present time, the least predictable dangerous chemical property is toxicity. In addition to discussing toxicity extensively, Chapter 3 provides general guidelines and references to specific toxicological information. Unless there is very well established evidence that a chemical is innocuous, the following warnings should always be borne in mind:

- Assume that all chemicals encountered in the laboratory are potentially toxic to some degree. Because the risk posed by a toxic chemical depends on the extent of exposure and the chemical's inherent toxicity, minimize exposure by avoiding skin contact and inhalation exposure through proper clothing and ventilation as habitual safe practice.
- Treat any mixture of chemicals as potentially more toxic than its most toxic component.
- Treat all new compounds, or those of unknown toxicity, as though they could be acutely toxic in the short run and chronically toxic in the long run. Because typical reactions produce a variety of by-products that are often unidentified or unknown, reaction products should be assumed to be toxic during work-up. Even though the likelihood is small that any given unknown chemical is very toxic, and the potential dose is usually low, laboratory researchers and workers may be exposed to thousands of chemicals during a professional lifetime, and there is a reasonable probability of eventual dangerous accidental exposure to a toxic substance. A habit of minimizing exposure should be cultivated.

The flammability, corrosiveness, and explosibility of chemicals and their combinations must also be considered along with toxicity in evaluating hazards and planning how to deal with them. In addition, wise risk management requires taking into account the amount of material to be used in an experiment.

Chapters 3, 5, and 6 are the heart of this volume because of their detailed guidelines regarding laboratory hazards and procedures. The content of these chapters inevitably overlaps because assessing the risks of a given procedure with a given chemical (Chapter 3) may also suggest the best ways to work with it (Chapters 5 and 6). Some of the most notable laboratory hazards arise from the interactions of equipment with chemicals (e.g., fires from sparking motors near flammable vapors) or from special nonchemical properties such as radioactivity or biological contamination.

Of the various resources that describe the properties of selected chemicals, two listed in Chapter 3 deserve particular comment: Material Safety Data Sheets and Laboratory Chemical Safety Summaries.

Federal law requires that Material Safety Data Sheets (MSDSs) be provided to users of chemicals by their manufacturers and distributors. MSDSs provide necessary information about precautions for protecting against known hazards associated with the subject product and often include useful information on chemical, physical, and toxicological properties, along with suggestions for storing, transporting, and disposing of chemicals. MSDSs are the best *general* source of information available, and they should be consulted as a first step in assessing the risk associated with doing an experiment. However, because there is currently no standard format for MSDSs, their quality varies widely, and the information that they contain may be inappropriate for laboratory use.

In consideration of the special problems of planning chemical experiments in the laboratory, the committee prepared Laboratory Chemical Safety Summaries (LCSSs) for 88 carefully chosen chemicals; these summaries are included as Appendix B of this book. Since many of these 88 chemicals are representative of a class of potentially hazardous compounds, the LCSSs can also be used as guides to handling many other compounds with related chemical structures. The LCSSs provide concise critical discussions, in a style readily understandable to laboratory workers, of the toxicity, flammability, reactivity, and explosibility of the subject chemicals. Directions for handling, storage, and disposal and special instructions for first aid and emergency response are given. The 88 LCSSs provide considerably greater coverage of specific and representative chemicals than was available in *Prudent Practices 1981* and *Prudent Practices 1983* and, unlike most MSDSs, are designed especially for laboratory workers.

MANAGEMENT OF CHEMICALS (CHAPTER 4)

Virtually every stage in the life cycle of a chemical has undergone dramatic change during the past 15 years as the new culture of laboratory safety has become established. Necessarily, the new ways that chemicals are acquired, tracked through an institution, stored, and delivered to the laboratory must be considered in contemporary experiment planning along with the detailed conduct of the experiment and the follow-up stages of handling all products and waste. Factors that once played at most a minor role in the handling of chemicals are now central. Almost all of these are related directly or indirectly to the legal, bureaucratic, and associated financial costs that have resulted from elevating the priority of safety in the workplace and protection of the public and the environment. The costs of documenting, handling, and disposing of all unwanted chemicals (i.e., waste) from completed experiments have increased enormously. Consequently, strategies that once were accepted as prudent, frugal, or, at worst, harmless are now no longer common practice. Fortunately, a number of technical advances, such as miniaturization and the large-scale management of information by computers, have allowed partial accommodation to the new forces affecting education and research in laboratories. Still, there is no doubt that the way science is done has changed enormously and that allowing adequate time and money for managing chemicals has become a major factor in planning experiments. Chapter 4 contains guidelines for the safe acquisition and storage of hazardous chemicals.

The prudent handling of chemicals now requires reducing the volume of every component to the minimum necessary to achieve the goals for which it was acquired. Any excess should be disposed of quickly and legally, unless there is a justifiable future use for it. In minimizing risks to laboratory, transport, and storeroom personnel, and to minimize the cost of waste disposal, source reduction is the first step. One should order and have on hand only what is necessary for currently planned experiments. No longer is it frugal to accept gifts of unneeded materials on the chance that they might be useful in the future or to buy the "large economy size" and store unused leftover chemicals for potential but unknown applications. The American Chemical Society booklet "Less Is Better" (1993) emphasizes the safety and financial reasons for buying chemicals in small packages: reduced risk of breakage, reduced risk of exposure following an accident, reduced storage cost, reduced waste from decomposition during prolonged storage in partially empty bottles, and reduced disposal cost for small containers of unused material. A well-planned experiment should reflect the "just in time" acquisition strategies used in modern manufacturing. If possible, the responsibility for storing and inventorying chemicals should remain with the supplier.

For chemicals likely to be used in the near future, storage is reasonable and can be a frugal component of a well-managed plan for handling chemicals. In general, though, if a chemical has not been used during the two years since it was placed in laboratory storage, the chance is small that it will ever be used again. Three years is a reasonable deadline for use, recognizing the value of shelf space, the deterioration of many chemicals, and the enormous price of disposal if the label decomposes or falls off and the compound becomes an "unknown." Unused remainders can be handled best by maintaining a comprehensive, reliably updated inventory, especially in a large institution. Maintaining a readily accessible inventory can be expedited if all chemicals are bar-coded and records of their status are continuously updated and made available through computer networking (see "Recommendations" below). Manufacturers and vendors of laboratory chemicals also can play an increasingly valuable role by responding to the needs of their customers to reduce the scale of experimentation, maintain continuously updated inventories accessible over networks, and reduce the cost of waste disposal.

The costs of acquisition, storage, and disposal can be minimized by conducting experiments on the smallest practical scale, a practice that also reduces the risk of hazards from exposure, fire, and explosion. Microscale reactions can now be run conveniently with less than 100 milligrams of solids or 100 microliters of liquids, compared with the traditional 10 to 50 grams and 100 to 500 milliliters.

Traditionally, the hazardous properties of chemicals have been regarded as a significant factor in planning experiments only if extreme toxicity or danger from explosion was apparent. The present emphasis on reducing risks and waste of all kinds may suggest the substitution of different solvents or less hazardous synthetic routes. Although it may not always be feasible to improve safety through the use of more benign materials, it is always appropriate to consider the possibility of reducing risks in this way, especially if precedents for the planned work were taken from the older literature, where safety and pollution problems were afforded less weight than is now given to them.

WORKING WITH CHEMICALS (CHAPTER 5)

Chapter 5 is a comprehensive manual for the safe handling of hazardous chemicals commonly used in laboratories. Like Chapters 3 and 6, Chapter 5 is intended to be used as a daily reference guide to appropriate standards of professional laboratory performance. In addition to discussing handling of chemicals in a variety of specific circumstances, it addresses issues such as proper protective clothing, good housekeeping, and necessary preparation for accidents and concludes with an alphabetical listing of especially hazardous materials.

WORKING WITH LABORATORY EQUIPMENT (CHAPTER 6)

Chapter 6 explains how to use the various kinds of equipment associated with handling hazardous chemicals. Although dangers such as electrical shock from bad wiring, falls on flooded floors, or cuts from broken glassware are not unique to the laboratory workplace, their consequences for laboratory personnel can be compounded because of the added hazards of toxicity, flammability, corrosiveness, and reactivity that characterize many chemicals. The accidental dropping of a glass container of a volatile poison or the fire hazard from sparking electrical equipment or switches in the presence of flammable fumes, for example, present potentially serious situations of a kind that must be kept in mind when laboratory experiments are planned and conducted.

The special hazards that accompany the use of electrical equipment (e.g., stirrers, pumps, and heating/cooling devices), the precautions necessary for handling gases in various containers and systems, and the equipment for dealing with and preventing many kinds of laboratory accidents are discussed in detail.

DISPOSAL OF WASTE (CHAPTER 7)

Concern about the fate of used or unwanted products of chemical reactions has not been a significant part of the traditional culture of laboratory workers. To emphasize the high priority that waste disposal has assumed in modern laboratory operations, the committee was charged to merge the subject matter of *Prudent Practices 1983* on the disposal of waste from laboratories with that of *Prudent Practices 1981* on the handling of hazardous chemicals in laboratories. Furthermore, it was asked to investigate the especially vexing problems of handling multihazardous chemical, biological, and radioactive waste and to propose recommendations for dealing with it. These are offered in Chapter 7. In view of the crucial role of regulations in dealing with laboratory waste, Chapter 9 on governmental regulation of laboratories should be referred to frequently as background for Chapter 7.

Waste is generally defined as excess, unneeded, or unwanted material. Because these terms are fairly subjective, regulatory agencies have attempted to provide more objective and specific definitions. However, the regulatory viewpoint that a material is waste if it is abandoned or "inherently wastelike" remains inescapably subjective. Although the residues from cleaned-up spills are obviously waste, the point at which a laboratory worker decides that a given chemical is no longer potentially useful may be difficult to define. Once the determination has been made, the waste must be handled within the constraints of legal guidelines that are usually defined according to the nature of the waste (chemical, radioactive, biological), the type and degree of hazard that it presents, and its quantity. Enlightened risk management also dictates that the amount of material be one factor in decisions on handling and disposal of waste.

The Environmental Protection Agency (EPA) has formulated most of the regulations for assessing risks from chemical waste and for dealing with them. Waste chemicals are characterized as ignitable, corrosive, reactive, and toxic. The responsibility for determining whether a waste is hazardous, and for characterizing the hazard, rests with the waste's generator, who may consult the appropriate LCSS, MSDS, or other published listing when dealing with a fairly common chemical. For other kinds of waste, workers who are well versed in reasoning by analogy from structural formulas should be able to make an educated guess by referring to related compounds whose molecules contain common structural units. If there is serious doubt, questions can be forwarded to an institution's environmental health and safety office or to the regional EPA office.

Hazardous Chemical Waste

Hazardous waste should be identified clearly so that its origin can be traced. Waste management facilities are prohibited from handling materials that are not identified and classified by hazard. Unidentified materials must be analyzed according to the following criteria before they will be accepted by most waste disposal firms: physical description; water reactivity; water solubility; pH; ignitability; and the presence of an oxidizer, sulfides or cyanides, halogens, radioactive materials, biohazardous materials, or toxic constituents. Chapter 7 provides detailed procedures for testing unknown materials.

Chemical waste should be accumulated at a central site where it can be sorted, stored temporarily, and prepared for disposal by commingling (according to regulation) or allowable on-site treatment for hazard reduction or, perhaps, recycling. During any waste-handling processes at a central site, or on the way to or from it, personnel should be protected: in particular, removal of toxic vapors, fire suppression, and spill control should be provided for. All personnel responsible for handling chemical waste must be trained.

Typically, chemical waste is sent for ultimate disposal to a landfill or incinerator in a 55-gallon Lab Pack or bulk solvent drum. Records must be maintained of the quantity, identity, and analyses (if necessary) of waste and of shipping and verification of disposal.

In many cases, the cost of waste handling and removal may be lowered sharply by using appropriate deactivation procedures for hazard reduction. Resource Conservation and Recovery Act (RCRA) regulations define the term "treatment" broadly, but the cost of being an EPA-permitted treatment facility is too high for most laboratories. However, small-scale treatments such as acid-base neutralization can be carried out as part of an experiment plan. Because illegal treatment can lead to fines of up to $25,000 per day of violation, it is important to check with an institution's environmental health and safety office or EPA before engaging in treatment procedures of any scale. Chapter 7 provides hazard reduction procedures for dealing with some common classes of chemicals. For disposal of small quantities of waste, approved procedures for identification, pickup, and delivery to a central site should be used to avoid risking citation for illegal treatment without a permit.

Incineration, addition to a landfill, release to the atmosphere, and discarding in the normal trash or the sanitary sewer are all options for disposal, depending on whether or not a waste is hazardous and on how it is regulated. Nonhazardous materials such as potassium chloride, sugars, amino acids, and noncontaminated chromatography resins or gels can usually be disposed of in the regular trash. Broken glass, needles, and sharp objects should be disposed of in special containers for the protection of custodial personnel, whose welfare must always be considered when dealing with laboratory waste. Spills present a wide range of hazards, depending on the nature and volume of the material, and should normally be dealt with by an institution's environmental health and safety office.

Multihazardous Waste

Multihazardous waste is a by-product of various kinds of critically important work in, for example, clinical and environmental laboratories. With the help of several experts as part of a special subcommittee, the committee studied the disposal of various combinations of chemical, radioactive, and biological waste. Few disposal facilities exist for multihazardous waste, and some waste materials are so unique and occur in such small quantities that there is no commercial incentive for developing special legal means for handling them.

Although there are no general federal regulations covering disposal of biohazardous or infectious waste, OSHA regulates the handling of some kinds of laboratory waste containing human body fluids, and local ordinances may apply to other types. Generally, biological waste may be disinfected, autoclaved, incinerated, or sent to the sanitary sewer.

For disposal of a multihazardous waste, the goal may be reduction to a waste that presents a single hazard, which can then be managed as a chemical, biological, or radioactive waste. Each option should be ranked, ordered, and prioritized according to the degree of risk posed. Any combination of methods that poses unacceptable risk to waste handlers should be rejected.

Chemical-Radioactive Waste

The management of mixed waste (chemical-radioactive) is often complicated by regulations whose application to a particular case is inconsistent with the relative risk posed by each component hazard. For example, chemical waste containing short-half-life radionuclides is managed best by being held for a period long enough to allow safe decay (e.g., 10 half-lives, but not to exceed 2 years). However, EPA regulations and state laws may limit storage of hazardous chemical waste to 90 days. Chemical-radioactive (mixed) waste is difficult to deal with, primarily because of EPA regulations that prevent on-site storage until *de minimis* levels of radioactivity can be reached and stringent U.S. NRC regulations for the management of low-activity radioactive waste that poses no significant risk to the public or the environment. Used flammable liquid scintillation cocktails, phenol/chloroform nucleic acid extractants from radioactive cells, neutralized radioactive trichloroacetic acid solutions, and some gel electrophoresis waste are examples of chemical-radioactive waste. Techniques for minimizing these types of waste include the use of nonhazardous chemical substitutes so that the waste can be handled simply as radioactive and treated by U.S. NRC "decay-in-storage" regulations. In some cases, EPA-approved chemical hazard reduction methods may be applied and the waste treated as radioactive.

Chemical-Biological Waste

Most, but not all, chemical-biological waste is best dealt with as chemical waste after due consideration is taken of special restrictions that may apply to the biological component if it is putrescible, infectious, or biohazardous. Incineration as a hazardous chemical is usually preferable because animal and medical waste incinerators are not licensed to burn regulated chemical waste. Many types of biological fluid waste containing chemical components can be disposed of in the sanitary sewer, but local approval may be required. Autoclaving can sterilize infectious waste, which then can be treated as chemical waste. However, autoclaving may volatilize chemicals, which could then pose hazards to personnel or could damage the autoclave. Waste and "sharps" of all kinds from laboratories working with hepatitis B or human immunodeficiency viruses must be handled with special care under the OSHA Bloodborne Pathogen Standard.

Radioactive-Biological Waste

If short-half-life radionuclides are present, decay-in-storage until U.S. NRC regulations allow disposal as biological waste is the appropriate strategy for radioactive-biological waste. Preliminary disinfection or freezing should be used to protect personnel who handle putrescible waste during radionuclide decay. Appropriate options for ultimate disposal are incineration after the waste has reached U.S. NRC-approved levels of radioactivity or alkaline digestion and submission to the sanitary sewer in accordance with local regulations. Particular attention must be given to the handling or cleaning of radioactive laboratory ware, and to the proper disposal of needles, broken glassware, or sharps from biological or medical laboratories.

Chemical-Radioactive-Biological Waste

As indicated above, a combination of waste types may be very difficult to deal with and should always be considered case by case. Decay-in-storage to acceptable levels of radioactivity can reduce the problem to that of handling chemical-biological waste. Autoclaving or use of a disinfectant may be needed to reduce the hazard of biological waste during storage. Unlike the radioactive and biological component of a multihazardous waste, the chemical content does not usually vary significantly with time, although the possibility of treatment to convert hazardous chemical content to nonhazardous should be considered as part of the overall approach to waste management. Before initiating any experiment that might lead to chemical-biological-radioactive waste, researchers are advised to consult with their environmental health and safety office and/or waste removal contractor to avoid an intractable disposal situation. Growing recognition by regulatory agencies of the special problems of multihazardous waste management offers hope that disposal will become increasingly manageable.

LABORATORY FACILITIES (CHAPTER 8)

Chemical laboratories are the most common type of workplace where a wide variety of chemicals are handled on a routine basis. They have evolved into unique facilities designed to deal with many of the hazards described in this book. Chapter 8 discusses the modern laboratory environment as an essential component of the culture of safety and outlines the important role of safety inspection programs. Laboratory ventilation systems are described in considerable detail.

Although many other types of buildings in a large institution can be converted fairly readily from one use to another, the special demands of chemical laboratories require that they be dedicated to their unique purpose. Because of the great expense for a laboratory's construction and operation, the intricacy of its facilities, and its important role in protecting the public and the workers who use it, laboratory personnel should have a thorough understanding of specialized facilities designed for their safety. For the full value of a modern laboratory to be realized, it is important to maintain good working relationships between laboratory personnel and the facility engineering and maintenance staff as well as with environmental health and safety workers.

Perhaps the single most important safety system in chemical laboratories, and certainly the one most responsible for their unique design and cost, is the ventilation system, especially the fume hoods that remove toxic vapors from the workplace. During the past 15 years, virtually every aspect of air handling in the laboratory has been refined, and the issue of acceptable emissions to the outside environment has come under increasing scrutiny. As demands for "zero emissions" become more frequent, the hood is viewed increasingly as a necessary safety device that should be used for removing toxic vapors in case of an accident. Although this viewpoint may be unrealistic if carried to the extreme, it requires special consideration in the planning and execution of laboratory chemistry.

Many of the regulations that now impinge on the handling and disposal of hazardous chemicals in laboratories attempt to formalize their safe operation and to penalize noncompliance. Laboratory inspections are an important means for ensuring not only that laboratories are maintaining a safe operating standard, but also that they are being operated in an efficient manner that justifies their expense. Suitable laboratory inspections cover a wide range of formality and detail. At one end is the informal peer review by fellow workers or the laboratory supervisor giving collegial advice on safe procedures or identifying deteriorating equipment that needs maintenance or lapses in good housekeeping. At the other end are formal inspections by regulatory officers looking for noncompliance with local, state, or federal laws. Chapter 8 provides a variety of options and advice on conducting inspections, along with a basic checklist of common hazards that should be considered.

GOVERNMENTAL REGULATION OF LABORATORIES (CHAPTER 9)

In recognition of the enormous impact of federal, state, and local regulations on the planning and performance of every stage of the handling of chemicals as they move to, in, and from laboratories, Chapter 9 outlines the vast and intricate legal framework by which organizations, laboratory workers, and supervisors are held accountable for compliance. Most institutions that deal with chemicals in laboratories, and dispose of them, have organized professional infrastructures to give advice and help implement the laws. The most essential regulations are promulgated under the OSHA Laboratory Standard and the Resource Conservation and Recovery Act, which were conceived to protect the public, the environment, and the individual laboratory worker. Noncompliance may expose workers to unnecessary risks, undermine the public's confidence in its institutions, and lead to fines of up to $25,000 per day of violation and severe criminal penalties. Prudent practice in the laboratory is mandated by law and enforceable through citations.

Although some regulations have not recognized the laboratory as a special environment for using chemicals, the OSHA Laboratory Standard specifies that each institution accountable for handling and disposal of chemicals must develop its own Chemical Hygiene Plan for implementing the requirements of the Laboratory Standard. Each employer is required to "furnish to each of his employees . . . a place of employment . . . free from recognized hazards that are likely to cause death or serious physical harm . . . ." The individual employee is required to "comply with occupational safety and health standards and all rules . . . which are applicable to his own actions and conduct." Although the position of students, in contrast to that of employees, is not covered explicitly, custodial and maintenance personnel who work in laboratories or handle chemicals or chemical waste are clearly protected by requirements for training and other safeguards. Provision is made for the development and enforcement of state OSHA regulations.

In addition to the Laboratory Standard, the Hazard Communication Standard (29 CFR 1910.1200) applies to all nonlaboratory businesses or operations "where chemicals are either used, distributed, or produced" and is more stringent than the Laboratory Standard in some respects. Other OSHA standards concerning level of exposure apply to hundreds of chemicals and are included in the LCSSs prepared for this report and in many MSDSs.

The Resource Conservation and Recovery Act (RCRA; 42 USC 6901 et seq.) applies to waste reduction and disposal of laboratory chemicals from "cradle to grave." Laboratory workers should be aware of RCRA definitions of "generators" of different amounts and types of hazardous waste as described in Chapter 7, and of the legal limitations on moving and disposing of hazardous chemical waste as defined by RCRA.

Although the sewer was the traditional dumping ground for many liquid laboratory wastes, such disposal is now out of the question for most waste chemicals and carries heavy penalties. Nevertheless, not all chemical waste is hazardous, and some may be disposed of in the sanitary sewer under carefully defined conditions. RCRA also controls and defines the in-laboratory treatment of hazardous wastes. Some methods for treatment, most of which may require a permit, are discussed in Chapter 7.

Several sets of wide-reaching regulations also directly affect laboratory operations. The Clean Air Act (42 USC 7401 et seq.) regulates emissions into the air and sets specific limits on the disposal of volatiles through the fume hood system. To protect both the community and the emergency response personnel that may be put at risk by a laboratory accident, the Superfund Amendments and Reauthorization Act (SARA; 42 USC 9601 et seq., 11000 et seq.) requires that inventories of hazardous chemicals be maintained and made available to the public. The Toxic Substances Control Act (TSCA; 15 USC 4601 et seq.) is concerned with the manufacture, distribution, and processing of new chemicals that are unusually dangerous to health and/or the environment.

Of necessity, the legislation and the activities of regulatory agencies referred to in this book represent only the most important and relevant of those concerned with chemicals in laboratories. It is essential that good communication be maintained among all laboratory workers and their colleagues in the institutional offices that are responsible for interfacing with regulatory agencies and keeping abreast of new laws.

RECOMMENDATIONS

In its entirety, this book constitutes a strong recommendation to workers in laboratories to exercise prudence in designing and carrying out their studies so as to maintain a safe workplace and safe operational procedures. In addition, the committee has identified a number of specific areas that need improvement, not only by laboratory workers themselves, but also by regulators at all levels and by chemical suppliers, in order to enhance the climate for laboratory safety. Summarized below are the committee's findings and specific recommendations for action.

Recommendations to the Environmental Protection Agency and Other Regulatory Agencies

In contrast to manufacturing facilities, laboratories generally use small amounts of a large variety of chemicals, often in frequently changing procedures; in addition, they are staffed by highly trained technical workers. As a consequence, overly prescriptive regulations for laboratories may not efficiently protect personnel and the environment. The OSHA Laboratory Standard, promulgated in 1990, formally recognized several unique aspects of laboratories and laboratory operations and established a performance-based system for regulating them. Such a performance-based system is often more effective, both for the laboratories being regulated and for those regulatory agencies concerned with health, safety, and the environment.

- The committee recommends that regulations directed to laboratories be *performance based* and be structured to take into account the unique aspects and professional expertise within the laboratory.
- The committee recommends that each federal regulatory agency establish a formal channel (e.g., through its science advisor or through a formal advisory committee) to ensure incorporation of research laboratory scientists' viewpoints in the preparation and implementation of regulations affecting research laboratories.

Pollution prevention and waste minimization have become major goals of U.S. industry and regulatory bodies. The technical expertise of well-trained laboratory workers offers opportunities for waste minimization through recycling, treatment of waste, and collection of laboratory quantities of waste. Such treatment of laboratory waste offers the possibility of substantially reducing the risks associated with certain hazardous waste before sending it off-site.

- The committee recommends that the Environmental Protection Agency extend its permit-by-rule provisions to allow scientifically sound treatment of small quantities of waste generated in laboratories.
- The committee recommends that the Environmental Protection Agency allow storage of small quantities of waste in laboratory facilities for periods longer than the current time limitation on storage of hazardous waste.

The laboratory community is trained to adhere to standard methods and protocols. But as students and career laboratory personnel advance from one stage to another, or change professional laboratory positions, relocation among geographical regions is frequent. Often, such job relocations require costly and time-consuming relearning of previously acquired safety and waste management habits and retraining in alternative methods because of the absence of a uniform regulatory environment. Worker safety and waste disposal procedures are seriously impeded when regulatory requirements vary among regions.

• The committee recommends that federal, state, and local lawmakers and regulators strive for conformity and consistency in the regulations that affect laboratories.

If disposal of multihazardous waste is to be accomplished safely and cost effectively, regulations affecting its individual components should not conflict, and the regulatory framework should be based on risk priority. For example, health and safety considerations may sometimes demand that greater emphasis be given to one component of the total chemical, biological, and radiological toxicity, while existing regulations would require equal emphasis for all components. This situation arises, for example, with mixtures containing trace amounts of radioactive material in which the major health and safety risk is associated with a chemical or biological component.

• The committee recommends that the U.S. Nuclear Regulatory Commission and the Environmental Protection Agency establish *de minimis* levels for radionuclides, below which laboratory waste can be disposed of without regard to radioactivity.

• The committee recommends that the Environmental Protection Agency encourage safe disposal of chemical-radioactive (mixed) waste materials with short half-lives by excluding the decay-in-storage period from the current 90-day limitation on storage of hazardous waste.

Requirements for multiple EPA identification numbers for a single campus create an unnecessary administrative burden.

• The committee recommends that the Environmental Protection Agency allow the use of one EPA identification number for all chemical waste generated on a single campus of an educational institution.

Complete safety procedures for an institution must incorporate emergency planning and must recognize the role of external agencies. It is essential that emergency procedures be developed that will minimize risk to personnel and allow emergency response workers to function effectively. Clear lines of communication must be maintained. In addition, local regulations affecting laboratories should be oriented toward reduction of risk. Federal law, for example, specifically exempts laboratories from detailed reporting of every chemical stored in a facility, enabling a reporting system focused on those chemicals that would pose the greatest risks in an emergency.

• The committee recommends that laboratory personnel, in cooperation with the institutional health and safety structure, establish ongoing relationships and clear lines of communication with emergency response teams.

• The committee recommends that emergency response regulations require inventory information only on those containers with chemicals in quantities large enough to pose a significant risk to personnel or the environment in the case of an emergency release or fire.

Small colleges and high schools often do not have an environmental health and safety office or the resources to manage laboratory waste. Teachers are thus left to shoulder the burden of waste disposal, and their attention can be diverted from core science teaching as a result.

• In order to support the teaching of laboratory courses in small colleges and high schools, the committee recommends a careful review of current record-keeping requirements to avoid excessive burdens on teachers at small institutions.

Recommendations to the Industrial Sector

Prudent management of chemicals is important for a variety of environmental, social, and economic reasons. Manufacturers and suppliers of chemicals play a central role in these efforts because they manage the commercial flow of chemicals and have responsibility for the procedures by which chemicals are packaged and shipped. Uniform identification of chemicals by manufacturers and suppliers could help to reduce risks in the storage, use, and disposal of chemicals, improve the management of chemicals in the laboratory, and enhance emergency response preparedness.

• The committee recommends that chemical suppliers adopt a uniform bar code identification system that would facilitate establishment and maintenance of laboratory chemical inventory and tracking systems.

• The committee recommends that all laboratory chemicals be labeled with the date of manufacture.

• The committee recommends that chemical suppliers adopt uniform color coding and bar coding for compressed gas cylinders.

The policies and practices of commercial manufacturers and suppliers of laboratory chemicals directly affect the management of chemicals in the laboratory, especially the ability to practice effective pollution-prevention techniques such as source reduction and recycling-reuse-recovery. The costs and risks associated with disposal of waste can be reduced greatly if materials never enter the waste stream.

- The committee recommends that chemical suppliers provide and promote to their customers the option of purchasing small quantities of chemicals.
- The committee recommends that chemical suppliers develop a mechanism whereby laboratories can return unopened containers of chemicals.

Recommendations to Chemical Laboratories

Academic departments and industrial laboratories that use chemicals are advised to develop internal safety groups that are complementary to their institution's environmental health and safety organization and include representation from all segments of the laboratory work force. Such internal safety groups should meet regularly to discuss departmental safety and waste disposal issues and to analyze any incidents that may have occurred. To achieve maximum effectiveness in working with an institution's environmental health and safety organization to minimize risks, a departmental safety group must have the full support of the institution's administration.

- The committee recommends that chemical laboratories establish their own safety groups or committees at the department level, composed of a cross section of laboratory workers, including students and support staff as well as faculty in academic laboratories.

The ability of any laboratory to operate in a manner that minimizes risks to personnel and the environment is dependent on laboratory workers who understand and carry out prudent practices for handling, storage, and disposal of chemicals. Training of laboratory personnel in safety and waste management is essential and must be followed up with an appropriate inspection system to ensure that safe practices are followed. Safety training must include discussion of chemical hazards, equipment hazards, laboratory safety and environmental systems, and the potential impact of laboratory work on these systems.

- The committee recommends that any laboratory using hazardous chemicals should provide appropriate training in safety and waste management for all laboratory workers, including students in laboratory classes.
- The committee recommends that laboratories using hazardous chemicals should incorporate institutionally supported laboratory and equipment inspection programs into their overall health and safety programs.