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May 1993

BIOMEDICAL AND ENVIRONMENTAL
ASSESSMENT GROUP

ANALYTICAL SCIENCES DIVISION

DEPARTMENT OF APPLIED SCIENCE

BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK 11973

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GUIDELINES FOR ACCIDENT PREVENTION AND EMERGENCY PREPAREDNESS

V.M. Fthenakis, S.C. Morris and P.D. Moskowitz

1. INTRODUCTION

This chapter reviews recent developments in the guidelines on chemical accident prevention, risk assessment, and management of chemical emergencies, principally in the United States and Europe, and discusses aspects of their application to developing countries. Such guidelines are either in the form of laws or regulations promulgated by governments, or of recommendations from international, professional, or non governmental organizations. In many cases, these guidelines specify lists of materials of concern; methods for evaluating safe usage of these materials; recommend areas of responsibility for different organizations; procedures to be included in planning, evaluation, and response; and appropriate levels of training for different classes of workers. Guidelines frequently address the right of communities to be informed of potential hazards and address ways for them to participate in planning and decision making.

2. UNITED STATES

2.1 Chemical Accident Prevention

2.1.1 Federal Regulations

Shortly after the tragedy in Bhopal, the EPA established a chemical emergency preparedness and prevention program to address the concerns about the possibility of such a major accident happening in the United States. About the same time, the Chemical

Manufacturers Association (CMA) began implementing its Community Awareness and Emergency Response (CAER) program.

To this end, the Emergency Planning and Community Right-to-Know Act of 1986, ["Title III" of the Superfund Amendments and Reauthorization Act (SARA)], was also enacted. Although SARA Title III, does not address prevention directly, it paves the way for the exchange of information and communication between the facility and the community. According to the EPA, effective chemical accident prevention, along with effective emergency planning and response, occurs when information about risk, prevention, past accidents, "near-misses," and response is shared across the industry, labor, the community, environmental groups, and other stakeholders (Matthiessen, 1992). Accidents are prevented when there are comprehensive management "systems" in place specifically designed to ensure that any error, whether it be by a design engineer, mechanic, operator, or manager, does not lead to a catastrophe: in other words, process safety management (PSM) programs.

Several organizations have been trying to make PSM successful and to keep management committed to its implementation. The American Institute of Chemical Engineers (AIChE) Center for Chemical Process Safety (CCPS), along with many chemical corporations, recognized the need for a comprehensive management system and began implementing process safety management programs and publishing guidelines on such programs. The CMA prepared the Responsible Care program to emphasize process safety. The American Petroleum Institute (API) adopted a process safety management approach in "API Recommended Practices 750". The Occupational Safety and Health Administration (OSHA) believed there was a need for minimum standards to protect workers from chemical accidents and prepared its "Process Safety Management of Highly Hazardous Substances" rule. Recently, Congress ensured a federal role for EPA and OSHA in chemical accident prevention under the Clean Air Act Amendments of 1990 (CAAA). The

CAAA contain provisions for preventing chemical accidents under Title III-Hazardous Air Pollutants.

The provisions for chemical accident prevention relevant to the EPA are in Title III Section 301(r), while the requirements for OSHA are under Title III Section 304.

OSHA - CHEMICAL PROCESS SAFETY MANAGEMENT

The CAAA mandated that OSHA, under the OSHA Act of 1970, promulgates a chemical process safety standard to prevent accidental releases of chemicals that pose a threat to employees. In response to this requirement, OSHA issued the "Process Safety Management of Highly Hazardous Substances", 29 CFR Part 1910.119 (1992). This rule covers more than three million U.S. workers at nearly 25,000 worksites; it primarily affects manufacturing industries, particularly chemicals, transportation, equipment, and fabricated metal products. Other effected sectors include natural gas liquids, gas and sanitary services, and wholesale trade. This rule requires facilities that are handling substances on the OSHA list of highly hazardous chemicals (Table 18.1), in quantities greater than the listed thresholds, to establish all the elements of a process safety management program. Facilities with 10,000 pounds or more of flammable materials that are used above their boiling points, also are affected by OSHA's rule. A process safety management program is comprised of the following fourteen elements:

- 1) Introduction to Process Safety Management
- 2) Employee Involvement
- 3) Process Safety Information
- 4) Process Hazards Analysis
- 5) Operating Procedures

- 6) Employee Training
- 7) Contractors
- 8) Pre-start Safety
- 9) Mechanical Integrity
- 10) Non-routine Work Permits
- 11) Managing Change
- 12) Incident Investigation
- 13) Emergency Preparedness, and
- 14) Compliance Audits

The following are highlights of compliance requirements and recommendations from Appendix C of the OSHA rule (29 CFR Part 1910, 1992; Auger, 1992):

Introduction to Process Safety Management

An effective process safety requires a systematic approach to evaluating various levels of defense to prevent or mitigate the release of hazardous chemicals. OSHA believes that process safety management in the form of proactive hazard identification, evaluation and mitigation or prevention of chemical releases will have a positive effect on the safety of employees and also offer other potential benefits (e.g., increased productivity). For small business which may have limited resources to implement process safety management options, OSHA suggests alternative ways of decreasing the risks associated with highly hazardous chemicals at their workplaces, such as reducing the inventory of the chemical or distributing storage to several isolated locations.

Employee Involvement Participation in Process Safety-

Section 304 of the CAAA states that employers are to consult with their employees regarding the employers effort in the development and implementation of the process safety management and hazard assessment. Employers are also required to train and educate their employees and to inform affected employees of the findings from incident investigations.

Process Safety Information - Employers must provide written information regarding process technology, equipment used, and hazards posed processes utilizing hazardous chemicals. Required information includes, but is not limited to: material safety data sheets, permissible exposure limits; potential risks from inadvertent mixing of materials; process flow diagrams; safe temperature and pressure limits; and equipment design codes.

Process Hazard Analysis - A process hazard analysis (PHA) is one of the most important elements of the process safety management program. The PHA focuses on equipment, instrumentation, utilities, human actions and external factors that might impact the process. OSHA prescribes a team approach, preferably with members from various disciplines. Team must include members expert in the scientific process and methodology in use, whether or not this expertise is available on site. The team's findings must be addressed formally and resolved in a timely manner. The analyses must be performed in priority order, with 25 percent of them completed by May 26, 1994, and an additional 24 percent completed each year until all are completed no later than May 26, 1997. Analyses must be updated every five years.

Operating Procedures - Operating procedures describe tasks to be performed, data to be recorded, operating conditions samples to be collected, and safety and health precautions. Operating procedures should be reviewed by engineering and operating personnel. Such procedures must be complete and comprehensive; if workers are not fluent in English, procedures need to be written in a second language understood by the workers.

Employee Training -All employees involved with highly hazardous chemicals, including maintenance and contractor employees, must be formally trained in the appropriate operating procedures. Refresher training will be required (e.g., at least every 3 years) and detailed documentation of each employee's training experience is required. Careful consideration must be given to provide current and updated training. For example, if changes are made to a process, impacted employees must be re-trained and understand the effect of the changes on their job tasks.

Contractors - This provision is basically designed to emphasize that standards are to cover all, including contract employees. Employers who use contractors to perform work in and around processes that involve highly hazardous chemicals, will need to establish a screening process for hiring contractors who accomplish their tasks without compromising safety.

Pre-Startup Safety - For new processes, a PHA is helpful in improving the reliability of design and construction of the process. The recommendations of the PHA must be addressed, and procedures and training must be completed before startup.

Mechanical Integrity - This provision sets the requirement for periodic inspection, testing and quality assurance standards for equipment used in storage, processing or handling of highly hazardous chemicals. A mechanical integrity program must be in place to assure the continued integrity of such equipment. The rule refers to primary line of defense (e.g. containment, controlled release through scrubbers or flares), and secondary systems (e.g., fire protection, water spray, dikes), systems which are discussed throughout this book. The integrity of these systems should be assured through preventive maintenance and testing.

Hot Work Permit - Non routine work which is conducted in the vicinity of covered by the standard process, has to be formally approved. The employer must issue a permit for such work and ensure that certain prevention and protection measures are satisfied.

Management of Change - Temporary changes have caused a number of accidents over the years, mainly because personnel was not fully aware of the impact such changes made to an operation. Management of change covers changes in process technology and changes to equipment and instrumentation. Employers are required to establish means and methods to detect both technical and mechanical changes and to provide written documentation and authorization of the changes.

Incident Investigation - Any incident which resulted or could have been resulted in a hazardous chemical release must be investigated within 48 hours by a team assembled by the employer. A multi-disciplinary team is better able to gather the

facts of the event. A report including contributing factors and suggestions for corrective actions must be submitted. The report, its findings and recommendations are to be shared with those who can benefit from the information.

Emergency Preparedness - Employers must address what actions employees are to take when there is an accidental release of highly hazardous chemical. Employers at the minimum must have an emergency action plan which will facilitate the prompt evacuation of employees during an accident. This means that they should have an emergency action plan, including escape route, procedures and assignment. This plan will be activated by an alarm system, to alert employees when to evacuate. Employees who are physically impaired must have the necessary support and assistance to get them to a safe zone as well.

Compliance Audits - Employers must audit their operations to ensure compliance with the provisions of the rule. This self-evaluation can help employers measure the continuing effectiveness of their safety management systems. Reporting procedures must be established, the findings of the audit must be followed and deficiencies corrected.

The centerpiece of the new standard is process hazard analysis. It offers an integrated approach to chemical safety by putting the focus on a comprehensive management program. The standard details the elements and performance measures so that each facility can develop the most appropriate management system to meet its particular needs. Given the large number and diversity of the industries affected by 1919.119, this new standard is necessarily performance based, giving sites some degree

of flexibility in meeting their responsibilities. OSHA will determine compliance by comparing a facility's performance with the standards set forth in the regulation in each of the thirteen interrelated areas.

EPA REQUIREMENTS

Under the CAAA, Section 112(r), the EPA has also specific duties relative to the prevention of accidental releases. In general, EPA is required to develop a list of chemicals and a Risk Management Plan. EPA believes these same elements outlined in OSHA's new standard are necessary to prevent chemical accidents that affect the general public and the environment. EPA and OSHA recognize this overlap and are working closely on the list of chemicals, thresholds and key elements to avoid confusion and duplicate rule makings (Matthiessen, 1992). EPA also believes that the OSHA standard can provide a strong foundation for EPA efforts required by Section 112(r) as described below:

General Duty

Congress recognized that industry is ultimately responsible for the prevention of chemical accidents. Consequently, the first requirement in the chemical accident prevention provisions of the statute is a general duty clause for owners and operators of fixed facilities producing, handling or storing any listed substances to:

Identify hazards that may result from accidental releases

Design, operate and maintain safe facilities

Minimize the consequences of accidental releases

List of Substances

The EPA is required to develop an initial list of at least 100 substances and corresponding threshold quantities that will be the focus of chemical accident prevention regulations. The list must be promulgated no later than November 15, 1992 and address "substances which, in an accidental release, are known to cause or may reasonably be anticipated to cause death, injury, or serious adverse effects to human health or the environment." The EPA may use the list of 402 Extremely Hazardous Substances published under SARA Title III and must also include the 16 extremely hazardous substances listed in the CAAA (Table 18-2).

Chemical Safety and Hazard Investigation Board

The Prevention of Accidental Releases plan in the CAAA, also establishes a Chemical Safety and Hazard Investigations Board with the responsibility to "investigate or cause to be investigated, accidental releases resulting in a fatality, serious injury or substantial property damages." The Board will be consisted of five-members to be nominated by the President and confirmed by the Congress. The safety board may establish reporting requirements and is required to report to Congress and to make recommendations to the EPA and OSHA on chemical accident prevention.

Prevention Regulations

By November 1993, the EPA must promulgate "reasonable regulations and guidance" for the prevention, detection and response to accidental releases by facility owners or operators. Facilities having substances on the list established above in quantities greater than the threshold level, will be required to comply with EPA rules for the "use, operation, repair, replacement, and maintenance of equipment to monitor, detect, inspect, and control releases." Such regulations must also require owners and operators to "prepare and implement a risk management plan to detect and prevent or minimize

accidental releases of listed substances and to provide a prompt emergency response to any such releases."

A risk management plan must include the following:

Hazard assessment - A five-year release history and an evaluation of the worst case accidental release scenarios including potential release quantities and potential exposures to populations living downwind;

A program for prevention of accidental releases; and

A response program for specific actions to be taken in the event of an accidental release, including employee training for response, emergency health care and informing the public.

Risk management plans must be registered with EPA and submitted to the state where the facility is located, local emergency planning or response agencies, the Chemical Safety and Hazard Investigation Board, and also made available to the public.

The EPA believes that the elements of good process safety management, as required by OSHA, form the basis of the prevention program part of the risk management plan (Matthiesen, 1992). The major difference between the OSHA and EPA requirements would be that process hazard analyses must assess the impact of chemical accidents on the general public and the environment.

EPA also is granted new authority to take action in the event of accidental releases. The CAA authorizes EPA, in case where there may be imminent and substantial risk due to the release of an extremely hazardous substance, to "... secure such relief as may be necessary to abate such danger or threat...".

2.1.2 State Prevention Statutes

In addition to federal regulations, the states of Delaware, New Jersey, and California, as well as several local governments, have regulations that deal with chemical accident prevention. These regulations list threshold planning quantities for specific chemicals; if the quantity of a chemical on-site exceeds the threshold quantity, the facility must notify the regulating agency, and prepare a risk management plan. These risk management plans should provide a description of management program to prevent accidents, the results of a formal hazard assessment, design safety reviews, standard operating and preventing maintenance procedures, risk assessment, and response planning. New Jersey and California require a facility to submit a complete risk management plan to both the state and local government for approval. Delaware requires that facilities develop a risk management plan and make it available to inspectors during site inspections. In New Jersey and Delaware, every facility that meets or exceeds a specified threshold quantity, must develop a plan. In California, it is up to the local implementing agency (e.g., fire department to determine whether a plan is required.

The new OSHA-Chemical Process Safety Management (CPSM) regulation will have an impact on these state CPSM programs. Implementation of the CPSM standard in New Jersey and Delaware will depend on OSHA's acceptance of the existing state level Risk Management Programs (RMP). Facilities in these two states have invested significant resources into the development and implementation of the state RMPs and would only need minor modification to comply with the federal standard. California has an existing Risk Management and Prevention program (RMPP), but is also planning to adopt a state level OSHA CPSM program. The state CPSM program will have similar requirements but different compliance deadlines than the Federal standard. For the other states which do not have CPSM programs in place, implementation of the OSHA's standard will be determined according to the state's authority to adopt and enforce the federal standard.

There are 23 states with authority to adopt and enforce the federal standard; for those an active and closely monitored implementation approach is expected. For the remaining 25 states with no authority to adopt the federal standard, implementation will be at the federal level (Edwards et al, 1992).

2.2 Minimum Reportable Amounts of Releases

Guidelines frequently address minimal amounts of each hazardous material, above which action is required. These amounts may apply to stocks or to releases. Four US laws set minimal reportable amounts for releases; these are described below.

1) CERCLA Hazardous Substances

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund) requires reporting of releases into the environment of over 700 hazardous substances in quantities higher than a designated reportable quantity (RQ). For several compounds these RQs correspond to a 24-hr release of only 1 pound. Designation of these substances and their reportable quantities may be based on aquatic or mammalian toxicity, ignitability, reactivity, and carcinogenicity. Substances and RQs are listed in 40 CFR Part 302, Table 302.4. The report must be made via a 24-hour telephone hotline operated by the National Response Center in Washington DC. Failure to do so may result in a fine of up to \$10,000 and imprisonment of up to one year.

Section 102 of CERCLA provides the EPA administrator with authority to promulgate regulations establishing quantities of hazardous substances which must be reported. In the absence of such regulations, reportable quantities are defined as either those established based on Section 311(b) of the Federal Water Pollution Control Act, or, for other compounds, a quantity of 1 pound.

2) SARA -Title III

The Emergency Planning and Community Right-to-Know Act of 1986, often called "Title III" of the Superfund Amendments and Reauthorization Act (SARA), has four major provisions: i) Emergency planning (Sections 301-303), ii) emergency notification (Section 304), iii) community right-to-know reporting requirements (Section 311-312), and iv) toxic chemical releases reporting-emissions inventory (Section 313).

The emergency planning sections are designed to assist state and local government emergency preparedness and response capabilities through better coordination and planning. The emergency notification section requires all facilities that produce, use, or store one or more hazardous chemicals to immediately notify designated authorities in case of a release in excess of the reportable quantity for this substance. The community right-to-know (Section 311) requires any facility which must have material safety sheets (MSDS) under the OSHA hazard communication regulations, to submit either copies of the MSDSs, or a list of those chemicals to local authorities. Reporting requirements apply to chemicals in quantities above designated Threshold Planning Quantities (TPQ). The presence of EHSs in quantities above the Threshold Planning Quantity (TPQ), requires certain emergency planning activities to be conducted. These substances are listed in 40 CFR, Part 355, Appendices A and B. If a final RQ has not been assigned under CERCLA to a chemical listed under section 302, a statutory RQ of 1 pound applies for reporting.

SARA Title III requires facilities to notify State emergency Response Commissions (SERCs) when Extremely Hazardous Substances (EHSs) are present and to participate with Local Emergency Planning Committees (LEPCs) to plan and prepare for chemical emergencies. Facilities are also required to provide critical information on the identity, quantity and location on-site of EHSs to the community. Also under Title III's community

right to know, emissions or releases of chemicals listed under section 313, must be reported annually.

A consolidated list of all hazardous substances included in CERCLA, SARA Section 302, and SARA Section 313, can be found elsewhere (EPA, 1991a).

3) Hazardous Materials Transportation Act

Releases during transport of hazardous material are subject to reporting under the Hazardous Materials Transportation Act. These substances and their reportable quantities are listed in the Appendix to 49 CFR 172.101.

4) Clean Water Act

Releases of hazardous substances and oil to navigable waters of the United States (this legal term includes most substantial waters in the US, including territorial seas and rivers) must be reported under the Clean Water Act. Hazardous substances are listed in 40 CFR 117.3, and are also Superfund hazardous substances.

3. EUROPE

Guidelines for emergency preparedness and response often grow out of lessons learned from past disasters. Major accidents in 1974 in Flixborough, U.K., In Holland in 1975 the dioxin release near Seveso, Italy, in 1976, led to the European Community's first comprehensive rules, in 1982, on major-accident hazards of industrial activities, known as the Seveso directive (EEC, 1982). The directive was further strengthened in 1987 and 1988 (EEC, 1987; 1988). Although these amendments stemmed from the 1986 Sandoz

warehouse fire in Schweizerhalle, Switzerland, as Schwabach (1989) points out, they do not apply to Switzerland, since it is not an EC member.

The Seveso directive established requirements to be adopted by member states. Manufacturers are required (1) to identify major accident hazards; (2) to take measures to prevent major accidents; (3) to limit the potential consequences in the event of an accident; and (4) to notify authorities of potential hazards, preventive measures taken, and the occurrence of any major accident. The directive identified threshold quantities of dangerous substances on the basis of toxicity, flammability or explosiveness. Classes of these materials are given in Table 1. Countries are required to appoint authorities competent to (1) receive the notification from manufacturers; (2) examine information provided; (3) assure emergency plans were prepared; and (4) organize inspections or other control measures.

The World Health Organization Regional Office for Europe developed a manual of guidelines for disaster preparedness. The manual covers preparation, implementation, and rehabilitation phases and includes information needed, procedures, administrative action, organization, management, and allocation of resources. Continuity is provided by an in-house task force and an outside group of assessors made up of experts from Member States and from the WHO Regional Office (Jones, 1989).

Non-EEC countries have their own safety regulations. Sweden, for example, regulates the control of several chemicals according to the Swedish Act on Chemical Products. Under this Act, manufacturers and importers of chemical products are responsible for providing hazard information and safety advice for those using the chemicals. In addition, there is a general obligation to take precautions to prevent or minimize harm to human beings or the environment; such precautions include substitution of chemicals with less hazardous substitutes.

4. LESS DEVELOPED COUNTRIES

Less developed countries face special problems preparing for and responding to industrial accidents. Existing industrial plants may be technologically obsolete, not incorporating modern safety features. Population density and proximity of settlements to industrial sites often complicates planning. Transportation, communication, and other physical infrastructure are often weak. Regulatory bodies may not be up-to-date with technological advances, are often underfunded, and lack needed equipment and resources. Even scientific knowledge of the effect of hazardous chemicals may not extend to some less developed countries. Environmental health criteria derived from experience in temperate regions may not be completely applicable in tropical or semi-tropical countries. Guidelines for industrial accidents in less developed countries have been developed by the World Bank and the World Health Organization. These are described below.

5. INTERNATIONAL ORGANIZATIONS

International Labor Organization. Guidelines of the ILO were given in a working paper produced by a tripartite (employers, labor, government) meeting (ILO, 1985). They include methods of hazard identification, characterization, and management, and emergency planning for workers and the public. They encourage nations to establish a regulatory program and provide a framework for such programs. Much of the approach drew on the earlier EEC guidelines, which listed hazardous substances with threshold quantities above which facilities must notify regulatory authorities. Guidelines are also provided for identification of very toxic, flammable, and explosive substance for this purpose. Although specific for toxicity and flammability, they allow considerable interpretation on the chemical and physical conditions that might increase the risk of a major accident.

The ILO guidelines place the fundamental responsibility for ensuring safe operation on manufacturers, and indicate that they conduct their own hazard surveys in addition to those by the regulatory authority. Manufacturers must take all necessary measures to prevent major accidents and to limit their consequences. The manufacturers' responsibility is twofold: (1) to identify hazards, inform and train personnel, prevent accidents, minimize their consequences and prove compliance to the competent authority at anytime; and (2) to notify competent authorities if specific chemicals from among those identified as hazardous are present in storage, processing, manufacture, or produced as residues or by-products in amounts over the threshold. Hazard management is achieved through design standards, protective devices, maintenance, inspecting and testing, emergency planning and training. Considerable administrative guidance is provided, but not technical guidance. For example, guidelines for the integrity of pressurized systems include recommendations that inspection, preventive maintenance and standby equipment for pumps are necessary only if failure could create a hazardous situation. This determination is made by professionals on the staff of the manufacturer with oversight by the regulatory agency.

World Bank. In financing industrial programs in developing countries, the World Bank evaluates the adequacy and effectiveness of measures to control major hazards affecting public health and the environment outside the plant boundary. The World Bank guidelines (World Bank, 1985a) were based heavily on the earlier EEC and UK guidelines (H&SE, 1984), but are supplemented with a technical manual (World Bank, 1985b) and microcomputer software that includes computer codes of recommended consequence models (Technica, 1986). Guidelines and manual aim at developers of industrial projects in developing countries. The accompanying Manual of Industrial Hazard Assessment Techniques (World Bank, 1985b) provides a framework for the structured identification of such hazards. The basic procedures included in this manual guide engineers and safety analysts through a series of steps to identify basic failure modes, estimate the quantities of

material released, and calculate the impacts of these materials on plant equipment and personnel or the surrounding population and the environment. Attention is also focused on approaches for estimating event frequencies and for examining the need for remedial measures. Methods are available for relating event frequencies to consequences, but are not covered in this manual.

The guidelines specify that a major hazard assessment be conducted if threshold quantities are exceeded. These thresholds refer to (1) very acutely toxic substances; (2) other toxic substances; (3) highly reactive substances and explosives; and (4) flammable substances. These classes are generally defined according to EEC criteria. A major hazard assessment is required irrespective of the quantity involved for three categories considered particularly dangerous: (1) very acutely toxic substances; (2) highly reactive substances (except for specifically named compounds); and (3) flammable liquids at high temperature and pressure. Other toxic substances require a major hazard assessment when quantities exceed 1 tone (except for specifically named substances with higher threshold quantities). Flammable gases and highly flammable liquids have threshold quantities of 15 and 10,000 tones respectively. The World Bank manual provides the framework for the assessment. It focuses on possible causes of a release and on analysis of the resulting consequences. Representative failures and associated releases for components (i.e., pipes, flexible connections, filters, valves, pressure/process vessels, pumps, compressors, storage tanks, storage vessels, and flare vents) are given. Tree diagrams guide the analyst to a selected set of transport and effects models that are based on properties of the discharged material (i.e., phase, pressure, temperature, flammability, and toxicity). The full structure and models are included in the WHAZAN computer software (Technica, 1986).

World Health Organization

The WHO was instrumental in recommending guidelines for less developed countries (Krishna et al., 1990). Table 3 summarizes these guidelines.

6. COMPARISON OF EPA, ILO AND WORLD BANK GUIDELINES

Guidelines may vary in technical detail or specific focus depending on intended users. Guidelines aimed at community groups, for example, will be much different in content than those aimed at consulting engineers.

A comparison of EPA, International Labor Organization (ILO), and World Bank guidelines for risk identification, assessment and management of chemical emergencies (Morris et al., 1987) found that they differed principally in the audience addressed, the types of contaminants considered, the sophistication of the release scenario and environmental transport models considered, and the end-point evaluated. Parts of the descriptions of these guidelines given below are taken from this comparison report. EPA guidelines (EPA, 1985) were aimed at community groups, providing approaches that could be used without professional expertise, but which thus lacked sophistication and could not take into account many factors affecting release. The result was likely to be a burdensome number of cases were likely to be identified as potential hazards that would turn out, upon more detailed investigation, not to pose significant risk. More recent EPA actions, based on the 1990 Amendments to the Clean Air Act, are discussed below.

The ILO (1985) approach was based on the European Community approach, discussed in more detail and updated below. It aimed at government regulatory agencies and industrial firms that are presumed to have professional expertise to conduct detailed analyses, but did not give detailed guidance on how to conduct the analysis. These guidelines contain a

list of hazardous chemicals with threshold quantities for action, a description of responsibilities for each organization, and what is essentially a check list of what must be done in an assessment and analysis of potential major hazards.

The World Bank guidelines are aimed at project developers, who also would have access to professional expertise. It provides essentially an engineering handbook, proscribing detailed methods for analysis of hazards.

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Table 1. OSHA List of Highly Hazardous Chemicals

CHEMICAL name	CAS*	TQ**
Acetaldehyde	75-07-0	2500
Acrolein (2-Propenal)	107-02-8	150
Acrylyl Chloride	814-68-6	250
Allylamine	107-11-9	1000
Alkylaluminums	varies	5000
Ammonia, Anhydrous	7664-41-7	10000
Ammonia solutions (> 44% ammonia by weight)	7664-41-7	15000
Ammonium Perchlorate	7790-98-9	7500
Ammonium Permanganate	7787-36-2	7500
Arsine (also called Arsenic Hydride)	7784-42-1	100
Bis(Chloromethyl) Ether	542-34-5	100
Boron Trichloride	10294-34-5	2500
Boron Trifluoride	7637-07-2	250
Bromine	7726-95-6	1500
Bromine Chloride	13863-41-7	1500
Bromine Pentafluoride	7789-30-2	2500
Bromine Trifluoride	7787-71-5	15000
3-Bromopropyne (also called Propargyl Bromide)	106-96-7	100
Butyl Perbenzoate (Tertiary)	614-45-9	7500
Carbonyl Chloride (see Phosgene)	75-44-5	100
Carbonyl Fluoride Cellulose Nitrate (concentration > 12.6% nitrogen)	9004-70-0	2500
Chlorine	7782-50-5	1500
Chlorine Dioxide	10049-04-4	100
Chlorine Pentafluoride	13637-63-3	1000
Chlorine Trifluoride	7790-91-2	1000
Chlorodiethylaluminum (also called Diethylaluminum Chloride)	96-10-6	5000
1-Chloro-2,4-Dinitrobenzene	97-00-7	5000
Chloromethyl Methyl Ether	107-30-2	500
Chloropicrin	76-06-2	500
Chloropicrin and Methyl Bromide mixture	None	1500
Chloropicrin and Methyl Chloride mixture	None	1500
Cumene Hydroperoxide	80-15-9	5000
Cyanogen	460-19-5	2500
Cyanogen Chloride	506-77-4	500
Cyanuric Fluoride	675-14-9	100
Diacetyl Peroxide (Concentration > 70%)	110-22-5	5000
Diazomethane	334-88-3	500
Dibenzoyl Peroxide	94-36-0	7500
Diborane	19287-45-7	100

Dibutyl Peroxide (Tertiary)	110-05-4	5000
Dichloro Acetylene	7572-29-4	250
Dichlorosilane	1109-96-0	2500
Diethylzinc	557-20-0	10000
Diisopropyl Peroxydicarbon- ate	105-64-6	7500
Dilaluroyl Peroxide	105-74-8	7500
Dimethyldichlorosilane	75-78-5	1000
Dimethylhydrazine, 1,1-	57-14-7	1000
Dimethylamine, Anhydrous	124-40-3	2500
2,4-Dinitroaniline	97-02-9	5000
Ethyl Methyl Ketone Peroxide (also Methyl Ethyl Ketone Peroxide; concentration > 60%)	1338-23-4	5000
Ethyl Nitrite	109-95-5	5000
Ethylamine	75-04-7	5000
Ethylene Fluorohydrin	371-62-0	100
Ethylene Oxide	75-21-8	5000
Ethyleneimine	151-56-4	1000
Fluorine	7782-41-4	1000
Formaldehyde (Formalin)	50-00-0	1000
Furan	110-00-9	500
Hexafluoroacetone	684-16-2	5000
Hydrochloric Acid, Anhydrous	7647-01-0	5000
Hydrofluoric Acid, Anhydrous	7664-39-3	1000
Hydrogen Bromide	10035-10-6	5000
Hydrogen Chloride	7647-01-0	5000
Hydrogen Cyanide, Anhydrous	74-90-8	1000
Hydrogen Fluoride	7664-39-3	1000
Hydrogen Peroxide (52% by weight or greater)	7722-84-1	7500
Hydrogen Selenide	7783-07-5	150
Hydrogen Sulfide	7783-06-4	1500
Hydroxylamine	7003-49-8	2500
Iron, Pentacarbonyl	13463-40-6	250
Isopropylamine	75-31-0	5000
Ketene	463-51-4	100
Methacrylaldehyde	78-85-3	1000
Methacryloyl Chloride	920-46-7	150
Methacryloyloxyethyl Isocyanate	30674-80-7	100
Methyl Acrylonitrile	126-98-7	250
Methylamine, Anhydrous	74-83-9	2500
Methyl Bromide	74-83-9	2500
Methyl Chloride	74-87-3	15000
Methyl Chloroformate	79-22-1	500
Methyl Ethyl Ketone Peroxide (concentration > 60%)	1338-23-4	5000
Methyl Fluoroacetate	453-18-9	100
Methyl Fluorosulfate	421-20-5	100
Methyl Hydrazine	60-34-4	100
Methyl Iodide	74-88-4	7500
Methyl Isocyanate	624-83-9	250

Methyl Mercaptan	74-93-1	5000
Methyl Vinyl Ketone	79-84-4	100
Methyltrichlorosilane	75-79-6	500
Nickel Carbonyl (Nickel Tetracarbonyl)	13463-39-3	150
Nitric Acid (94.5% by weight or greater)	7697-37-2	500
Nitric Oxide	10102-43-9	250
Nitroaniline (para Nitro-aniline)	100-01-6	5000
Nitromethane	75-52-5	2500
Nitrogen Dioxide	10102-44-0	250
Nitrogen Oxides (NO; NO ₂ ; N ₂ O ₄ ; N ₂ O ₃)	10102-44-0	250
Nitrogen Tetroxide (also called Nitrogen Peroxide)	10544-72-6	250
Nitrogen Trifluoride	7783-54-2	5000
Nitrogen Trioxide	10544-73-7	250
Oleum (65% to 80% by weight; also called Fuming Sulfuric Acid)	8014-94-7	1000
Osmium Tetroxide	20816-12-0	100
Oxygen Difluoride (Fluorine Monoxide)	7783-41-7	100
Ozone	10028-15-6	100
Pentaborane	19624-22-7	100
Peracetic Acid (concentration > 60% Acetic Acid; also called Peroxyacetic Acid)	79-21-0	1000
Perchloric Acid (concentration > 60% by weight)	7601-90-3	5000
Perchloromethyl Mercaptan	594-42-3	150
Sulfuric Anhydride (also called Sulfur Trioxide)	7446-11-9	1000
Tellurium Hexafluoride	7783-80-4	250
Tetrafluoroethylene	116-14-3	5000
Tetrafluorohydrazine	10036-47-2	5000
Tetramethyl Lead	75-74-1	1000
Thionyl Chloride	7719-09-7	250
Trichloro (chloromethyl) silane	1558-25-4	2500
Trichloro (dichlorophenyl) Silane	27137-85-5	2500
Trichlorosilane	10025-78-2	5000
Trifluorochloroethylene	79-38-9	10000
Trimedthyoxysilane	2487-90-3	1500

*Chemical Abstract Service Number.

**Threshold Quantity in Pounds (Amount necessary to be covered by this standard).

Table 2. Initial List of Extremely Hazardous Substances

ammonia

bromine

chlorine

ethylene oxide,

hydrogen chloride

hydrogen cyanide,

hydrogen fluoride

hydrogen sulfide,

methyl chloride

methyl isocyanate

phosgene

sulfur dioxide

sulfur trioxide

toluene diisocyanate,

vinyl chloride

Table 3. Guidelines for prevention of industrial accidents in less developed countries.

Establish an information base on safe handling of hazardous materials.

Charge industrial management with assessing risks, identifying means of reducing hazards, making periodic safety audits.

Scrap decaying, unproductive, unsafe industries.

Identify and draw up emergency preparedness plans for potential accident areas.

Include intrinsic safety in town planning and integrate plans for chemical emergencies in national disaster management policy.

Establish no-risk, light industry between hazardous zones and human settlements

Establish infrastructure for safety within industrial complexes and designate technical safety officers.

Use safe technological options in design, fabrication, installation, operation and maintenance.

Establish an inspection system with the capability of assessing hazard, evaluating risk and recommending appropriate action.

Develop the capability to evaluate toxicity of chemicals.

END

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