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AN OSHA BASED APPROACH TO SAFETY ANALYSIS FOR NONRADIOLOGICAL HAZARDOUS MATERIALS

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SAFETY ANALYSIS
NONRADIOLOGICAL HAZARDOUS MATERIALS

Background

DOE Order 5481.1B requires preparation of appropriate safety analyses for each DOE operation. This requirement includes the analysis of hazards associated with non-radioactive hazardous materials in DOE facilities. No further guidance is provided about the details of the analysis. Consequently, the PNL approach to safety analysis for non-radioactive hazardous materials was conceptualized and is developed below. For the purposes of this document, safety analysis consists of two parts, 1) chemical hazard classification and 2) chemical hazard assessment.

The philosophical bases for the PNL approach for both chemical hazard classification and chemical hazard assessment are listed below:

- Within the DOE community and in the public's perception, the risk of and consequences from radiological accidents greatly exceeds that from chemical releases.
- Experience has shown that hazard classification and safety analysis of radiological and chemical operations cannot be handled in the same manner. Since the perception of the level of hazard is dramatically different for the two types of operations, two different models are needed to rank and to analyze the hazards.
- There are Occupational Safety and Health Administration (OSHA) general industry standards, DOE orders and other national consensus standards for hazardous chemical operations. These standards focus on routine operations and emergencies such as spills and adequately address the precautions (both engineering and administrative) necessary for employee and property protection.
- General industry standards, however, may not adequately address the precautions necessary to prevent large uncontrolled releases that could result in catastrophic consequences.

Processes handling highly hazardous chemicals present the potential for accidents that could have catastrophic results. [Highly hazardous refers to those materials which possess toxic, flammable, reactive, or explosive properties.]

Therefore, the PNL approach for chemical safety analysis emphasizes the management of hazards associated with highly hazardous chemicals. Importantly, "management" includes taking credit for existing comprehensive controls routinely in place. These include engineering and adminstrative safeguards routinely in place in chemical process operations as required by OSHA, chemical industry best management practices, and other safety and health related codes.

CHEMICAL HAZARD CLASSIFICATION

Introduction

The PNL method for chemical hazard classification defines major hazards by means of a list of hazardous substances (or chemical groups) with associated trigger quantities. In addition, the functional characteristics of the facility being classified is also be factored into the classification. In this way, installations defined as major hazard will only be those which have the potential for causing very serious incidents both on and off site.

Because of the diversity of operations involving chemicals, it may not be possible to restrict major hazard facilities to certain types of operations. However, this hazard classification method recognizes that in the industrial sector major hazards are most commonly associated with activities involving very large quantities of chemicals and inherently energetic processes. These include operations like petrochemical plants, chemical production, LPG storage, explosives manufacturing, and facilities which use chlorine, ammonia, or other highly toxic gases in bulk quantities.

The basis for this methodology is derived from concepts used by OSHA in its proposed chemical process safety standard, the Dow Fire and Explosion Index Hazard Classification Guide, and the International Labor Office's program on chemical safety.

For the purpose of identifying major hazard facilities, this method uses two sorting criteria, 1) facility function and processes and 2) quantity of substances to identify facilities requiring classification. Then, a measure of chemical energy potential (material factor) is used to identify high hazard class facilities.

Objective

The objective of the PNL chemical hazard classfication methodology is to provide a realistic basis for establishing uniform requirements for the preparation and review of safety analyses for DOE operations involving the use of chemicals.

Hazard Class Determination - Chemical Operations

Step 1

a. Offices, maintenance shops, paint shops and other facilites where chemcials are used in quantities and in a manner that a consumer might use them or are used for routine maintenance acitivites are **routine hazard class facilities.**

b. Research laboratory facilities, analytical laboratory facilities (not associated with other chemical operations) or other operating facilities in which chemicals are in small volume packages, containers and allotments making a massive release unlikely are designated **general hazard class facilities.**

The defintion of a laboratory is closely linked to the concept of "laboratory scale" as defined by OSHA. "Laboratory scale" means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person.

In addition, "laboratory" means a facility where small quantities of chemicals are use on a non-production basis. Pilot scale operations would not be included in this defintion of "laboratory" or "laboratory scale."

c. Facilites or operations where explosives activities are performed and controlled according to the requirements established in the DOE Explosives Safety Manual (DOE/EV/06194) are designated **general hazard class facilities.**

If the explosives activities cannot comply with the requirements in the DOE Explosives Safety Manual (DOE/EV/06194) or if the donor facility/operation is not designed to contain the effects of an explosion on a threshold quantity of chemical either within the donor facility or in an adjacent facility, these facilities are designated **major hazard class facilities.**

Step 2

For the selection of major hazard class chemical operations, a list of substances and threshold quantities is provided in Appendix A. When the quantity of any substance present exceeds the given threshold quantity, then a contributing hazard factor related to chemical process safety is evaluated.

A measure of chemical energy potential (material factor) is determined. The material factor is determined using only two properties of the substance, flammability and reactivity. Appendix B lists material factors for some common industrial chemicals. If a material factor is not listed for a substance, use the matrix in Table 1 to determine one. The material factor is obtained from the matrix by using the substance's National Fire Protection Association (NFPA) ratings for flammability (N_f) and reactivity (N_r). If the substance has not been rated by the NFPA, use the combination of the adiabatic decomposition temerpature and the flash point for the substance to determine the flammability and reactivity ratings.

Note: The quantities present in Appendix A relate to operations in each facility or group of facilities belonging to the same contractor where the distance between the facilities is not sufficient to avoid, in foreseeable circumstances, any aggravation of major accident hazards. For the purposes of this methodology, a chemical operation is defined as the aggregate of operations in all facilities within a distance of 500 meters of each other and belonging to the same contractor.

Step 3

Go to Table 2 to identify major hazard class facilities.

Table 1 - Determination of Material Factor

		Adiabatic decomposition temp. Td K	<830	830-935	935-1010	1010-1080	>1080
			reactivity				
Flash point °C		Nf \ Nr	0	1	2	3	4
None	flammability	0	0	14	24	29	40
> 100		1	4	14	24	29	40
40 - 100		2	10	14	24	29	40
-20 - +40		3	16	16	24	29	40
< -20		4	21	21	24	29	40
			Material Factor MF				

Table 2 - Determination of Hazard Class

Quantity Present	MF $\geq$ 21	MF < 21
$\geq$ TQ	major hazard class	general hazard class
< TQ	general hazard class	routine hazard class

CHEMICAL HAZARD ASSESSMENT

Introduction

A chemical hazard assessment is performed on all facilties identifed as major hazard class facilites. Like chemical hazard classification, the chemical hazard assessment relies upon the substance/quantity definition as the method of defining a major chemical hazard requiring additional analysis. Importantly, the concept of a "major hazard" for both chemical hazard classification and chemical hazard assessment is an operation requiring controls over and above those applied in normal operations, in order to provide an enhanced level of protection to workers and the public.

Furthermore, because of the inherent difficulty of defining appropriate chemical risk criteria, chemical hazard assessment relies upon a consequence based approach to perform the analysis.

Objective

Major hazard class facilities must be operated to a standard of safety which ensures that major hazards can be successfully controlled during normal and upset conditions. In order to control a major hazard, certain questions must be answered. These include:

a. Do toxic, flammable or explosive materials in a facility constitute a major hazard?
b. Which accidents or failures can lead to a catastrophic release?
c. If a catastrophic release occurs, what are the consequences for employees and the public?
d. What is being (or can be) done to mitigate the release or to reduce the consequences of a release?

The objectives of the chemical hazard assessment are to provide answers to the above questions, to define the chemical related safe operating envelop, and to assure that the major hazard facility can be operated safely.

Chemical Hazard Assessment: Chemical Facilities

A chemical hazard assessment shall be performed on facilities classified as major hazard class facilities. The analysis shall evaluate both process equipment and hazard control systems, considering the quantity of materials at or above the threshold quantities, the toxicity of the materials and special process parameters which may increase the likelihood of a catastrophic release or increase the consequences of a release. These parameters include but are not limited to flammability, reactivity, explosivity, process pressure, process temperature, and operations in or near the flammable range.

Bounding accidents, credible release scenarios and modeling should be used to develop realistic release amounts and to determine airborne concentrations. Since the toxicity of many chemicals has been established in the literature, the assessment should rely on a determination of the consequences of the release to evaluate the operating safety of the facility.

The consequences may be presented as text or in tabular form. The discussion should include a description of the expected impacts to workers and to the public. In addition, the assessment should address the potential for the release to incapacitate personnel both within the facility and in adjacent major hazard class facilities (chemical facilities) and high hazard class facilities (nuclear facilities). The assessment also should include an anlysis of the possibility for subsequent releases of either radiological or chemical sources caused by operator incapacitation.

An example of the consequence based assessment approach is presented in Appendix C.

Safety Analysis: Nuclear Facilities

DOE nuclear operations require safety analysis reports (SARs), technical safety requirements (TSRs) and evlauation of unreviewed safety questions (USQs) according to the 5480 series of orders. The requirements in this series of orders are presented as applying to nuclear operations only. Currently, there is no DOE guidance for applying comparable requirements to nonnuclear operations.

Consequently, PNL SARs for nuclear facilities will include an analysis of chemicals in the facility only as they have the potential to impact the radiological source terms. Most frequently, this evaluation will examine the two most important aspects of large radiological and large chemical sources in the same facility. Namely, 1) the potential for chemicals to provide an energy source for the release of radionuclides and 2) the potential for a chemical release within the facility to incapacitate operations personnel such that a radiological hazard would be created or the consequences of a radiological incident would be increased.

CHEMICAL name	CAS*	TQ**
Acetaldehyde	75-07-0	2500
Acrolein (2-Propenal)	107-02-8	150
Acrylyl Chloride	814-68-6	250
Allyl Chloride	107-05-1	1000
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	542-88-1	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 Hydroperoxide (Tertiary)	75-91-2	5000
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	1000
Chlorine Pentrafluoride	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	4109-96-0	2500
Diethylzinc	557-20-0	10000
Diisopropyl Peroxydicarbonate	105-64-6	7500
Dilauroyl 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	7500
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	7803-49-8	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	74-89-5	1000
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 Nitroaniline	100-01-6	5000
Nitromethane	75-52-5	2500
Nitrogen Dioxide	10102-44-0	250
Nitrogen Oxides (NO; NO_2; N204; N203)	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
Perchloryl Fluoride	7616-94-6	5000
Peroxyacetic Acid (concentration >60% Acetic Acid; also called Peracetic Acid)	79-21-0	1000
Phosgene (also called Carbonyl Chloride)	75-44-5	100
Phosphine (Hydrogen Phosphide)	7803-51-2	100
Phosphorus Oxychloride (also called Phosphoryl Chloride)	10025-87-3	1000
Phosphorus Trichloride	7719-12-2	1000
Phosphoryl Chloride (also called Phosphorus Oxychloride)	10025-87-3	1000
Propargyl Bromide	106-96-7	100
Propyl Nitrate	627-3-4	2500
Sarin	107-44-8	100
Selenium Hexafluoride	7783-79-1	1000
Stibine (Antimony Hydride)	7803-52-3	500
Sulfur Dioxide (liquid)	7446-09-5	1000
Sulfur Pentafluoride	5714-22-7	250
Sulfur Tetrafluoride	7783-60-0	250
Sulfur Trioxide (also called Sulfuric Anhydride)	7446-11-9	1000
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	100
Trichloro (dichlorophenyl) Silane	27137-85-5	2500
Trichlorosilane	10025-78-2	5000
Trifluorochloroethylene	79-38-9	10000
Trimethyoxysilane	2487-90-3	1500

*Chemical Abstract Service Number.

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

APPENDIX A
THRESHOLD QUANTITY DETERMINATION

1. This appendix contains a listing of toxic and reactive chemicals and their associated threshold quantities (TQs). It is believed that these chemicals present a potential for a catastrophic event at or above the threshold quantity. This list is not intended to be all inclusive but represents many of the highly hazardous chemicals routinely used in large amounts in industrial operations.

2. If a TQ has not been determined for a chemical, use the scheme presented below to establish a TQ for the purpose of performing a hazard classification.

   a. If the chemical is determined to be highly toxic, use 100 pounds.

      For this hazard classification method, highly toxic is defined as:

      LD50 $\leq$ 5 mg/kg oral or

      LD50 $\leq$ 1 mg/kg skin or

      LC50 $\leq$ 10 ppm inhalation
      $\leq$ 0.1 mg/l

   b. If the chemical is determined to be toxic, use 1000 pounds.

      For this hazard classification method, toxic is defined as:

      LD50 5 < 50 mg/kg oral or

      LD50 1 < 200 mg/kg skin or

      LC50 10 < 200 ppm inhalation
      0.1 < 2 mg/l

   c. If a chemical is determined to be moderately toxic, use 5000 pounds.

      For this hazard classification method, moderately toxic is defined as:

      LD50 50 $\leq$ 500 mg/kg oral or

      LD50 200 $\leq$ 1000 mg/kg skin or

      LC50 200 $\leq$ 2000 ppm inhalation
      2 $\leq$ 20 mg/l

d. If a chemical is determined to be low toxicity, use 10,000 pounds.

For this hazard classification method, low toxicity is defined as:

LD50 > 500 mg/kg oral or

LD50 > 1000 mg/kg skin or

LC50 > 2000 ppm inhalation
> 20 mg/l

3. TQ for flammable liquids and gases use 10,000 pounds.

4. TQs for individual chemicals, see list below.

APPENDIX B
NFPA CLASSIFICATIONS AND MATERIAL FACTORS

Name	NFPA classification: Health	Fire	Reactivity	Material factor
Acetaldehyde	2	4	2	24
Acetic acid	2	2	1	14
Acetic anhydride	2	2	1	14
Acetone	1	3	0	16
Acetonitrile	2	3	1	16
Acetyl chloride	3	3	2	24
Acetyl peroxide	1	2	4	40
Acetyl salcyl acid	1	1	0	4
Acetylene	1	4	3	29
Acrolein	3	3	2	24
Acrylic acid	3	2	2	24
Acrylamide	2	1	1	14
Acrylonitrile	4	3	2	24
Allyl alcohol	3	3	1	16
Allylamine	3	3	1	16
Allyl chloride	3	3	1	16
Allyl ether	3	3	2	24
Ammonia	3	1	0	4
tert-Amylacetate	1	3	0	16
Aniline	3	2	0	10
Barium stearate	0	1	0	4
Benzaldehyde	2	2	0	10
Benzene	2	3	0	16
Benzoic acid	2	1	0	4
Benzoyl chloride	3	2	1	14
Benzoyl peroxide	1	4	4	40
Bisphenol A	2	1	0	4
Bromobenzene	2	2	0	10
Butane	1	4	0	21
1.3-Butadiene	2	4	2	24
Butanol	2	3	0	16
1-Butene	1	4	0	21
n-Butyl acetate	1	3	0	16
Butyl alcohol	1	3	0	16
n-Butylamine	2	3	0	16
Butyl bromide	2	3	0	16
n-Butyl ether	2	3	0	16
tert-Butyl hydroperoxide	1	4	4	40
Butyl nitrate	1	3	3	29
tert-Butyl peroxide	1	3	3	29
Butylene	1	4	0	21
Butylene oxide	3	3	2	24
Calcium carbide	1	4	2	24
Calcium stearate	0	1	0	4
Carbon disulphide	2	3	0	16
Carbon monoxide	2	4	0	21
Chlorine dioxide	3	4	3	29

Name	NFPA classification: Health	Fire	Reactivity	Material factor
1-Chlorobutane	2	3	0	16
Chloroform	2	0	0	0
Chloromethylethyl ether	2	1	0	4
0-Chloro phenol	3	2	0	10
Chloropicrin	4	0	3	29
1-Chloropropane	2	3	0	16
Chlorostyrene	2	2	2	24
Coumarin	2	1	0	4
0-Cresol	2	2	0	10
Cumene	2	3	0	16
Cumene hydroperoxide	1	2	4	40
Cyanuric acid	2	0	1	14
Cyclobutane	1	4	0	21
Cyclohexane	1	3	0	16
Cyclohexanol	1	2	0	10
Cyclopropane	1	4	0	21
Diesel fuel	0	2	0	10
Dibutyl ether	2	3	0	16
0-Dichlorobenzene	2	2	0	10
P-Dichlorobenzene	2	2	0	10
1.2-Dichloroethylene	2	3	2	24
1.2-Dichloropropene	2	3	0	16
2.3-Dichloropropene-crude	2	3	0	16
3.5-Dichlorosalicylic acid	0	1	0	4
Dicumyl peroxide	0	2	3	29
Dicyclopentadiene	1	3	1	16
Diethyl amine	2	3	0	16
Diethyl benzene	2	2	0	10
Diethyl carbonate	2	3	1	16
Diethyl peroxide	0	4	4	40
Diethanolamine	1	1	0	4
Diethylene glycol	1	1	0	4
Diethylamine triamine	3	1	0	4
Diethyl ether	2	4	1	21
Diisobutylene	1	3	0	16
Diisopropylbenzene	0	2	0	10
Dimethyl amine (anhy.)	3	4	0	21
2.2-Dimethyl propanol	2	3	0	16
m-Dinitrobenzene	3	1	4	40
2.4-Dinitro phenol	3	1	4	40
m-Dioxane	2	3	0	16
Dioxolane	2	3	2	24
Diphenyl oxide	1	1	0	4
Dipropylene glycol	0	1	0	4
Di-tert-Butyl peroxide	1	3	4	40
Divinyl benzene	1	2	2	24
Divinyl ether	2	3	2	24

Name	NFPA classification			Material factor
	Health	Fire	Reac-tivity	
Dowtherm A heat tr. agt.	2	1	0	4
Epichlorohydrin	3	3	2	24
Ethane	1	4	0	21
2-Ethanolamine	2	2	0	10
Ethyl acetate	1	3	0	16
Ethyl acrylate	2	3	2	24
Ethyl alcohol	0	3	0	16
Ethyl benzene	2	3	0	16
Ethyl bromide	2	3	0	16
Ethyl chloride	2	4	0	21
Ethylene	1	4	2	24
Ethylene carbonate	2	1	1	14
Ethylene diamine	3	2	0	10
Ethylene dichloride	2	3	0	16
Ethylene glycol	1	1	0	4
Ethylene oxide	2	4	3	2[illegible]
Ethylenimine	3	3	2	24
Ethyl nitrate	2	4	4	40
Ethylamine	3	4	0	21
Formaldehyde	2	4	0	21
Glycerine	1	1	0	4
Heptane	1	3	0	16
Hexane	1	3	0	16
n-Hexanol	2	2	0	10
Hydrazine	3	3	2	24
Hydrogen	0	4	0	21
Hydrogen sulphide	3	4	0	21
Isobutane	1	4	0	21
Isobutyl alcohol	1	3	0	16
Isopentane	1	4	0	21
Isopropanol	1	3	0	16
Isopropyl acetate	1	3	0	16
Isopropyl chloride	2	4	0	21
Isopropyl ether	2	3	1	16
Jet fuel	1	3	0	16
Lauroyl peroxide	0	2	3	29
Maleic anhydride	3	1	1	14
Magnesium	0	1	2	24
Methane	1	4	0	21
Methanol	1	3	0	16
Methyl acetate	1	3	0	16
Methyl acetylene	2	4	2	24
Methyl amine	3	4	0	21
Methyl chloride	2	4	0	21
Methyl chloracetate	2	2	1	14
Methyl cyclohexane	2	3	0	16
Methylene chloride	2	0	0	0
Methyl ether	2	4	0	21
Methyl ethyl ketone	1	3	0	16
Methyl hydrazine	3	3	1	16
Methyl isobutyl ketone	2	3	0	16
Methyl mercaptan	2	4	0	21
Methyl styrene	2	2	0	10
Mineral oil	0	1	0	4
Monochlorobenzene	2	3	0	16
Monoethanolamine	2	2	0	10
Naphtha	1	3	0	16
Naphthalene	2	2	0	10
Nitroethane	1	3	3	29
Nitroglycerine	2	2	4	40
Nitromethane	1	3	4	40
Nitropropane	1	2	3	29
2-Nitrotoluene	2	1	4	40
Octane	0	3	0	16
Pentane	1	4	0	21
Peracetic acid	3	2	4	40
Phenol	3	2	0	10
P-Phenylphenol	3	1	0	4
Potassium perchlorate	1	0	2	24
Propane	1	4	0	21
Propargyl alcohol	3	3	3	29
Propargyl bromide	4	3	4	40
Proprionitrile	4	3	1	16
Propylene	1	4	1	21
Propylene dichloride	2	3	0	16
Propylene glycol	0	1	0	4
Propylene oxide	2	4	2	24
Sodium dichromate	1	0	1	14
Stearic acid	1	1	0	4
Styrene	2	3	2	24
Sulphur	2	1	0	4
Sulphur dioxide	2	0	0	0
Toluene	2	3	0	16
1,2,3-Trichlorobenzene	2	1	0	4
1,1,1-Trichloroethane	3	1	0	4
Trichoethylene	2	1	0	4
Triethanolamine	2	1	1	14
Triethylene glycol	1	1	0	4
Triethyl aluminium	3	3	3	29
Triisobutyl aluminium	3	3	3	29
Triisopropanol amine	2	1	0	4
Triisopropyl benzene	2	3	0	16
Trimethyl aluminium	3	3	3	29
Trimethyl amine	2	4	0	21
Tripropylamine	2	2	0	10
Vinyl acetate	2	3	3	24
Vinyl acetylene		4	3	29

Name	NFPA classification			Material factor
	Health	Fire	Reactivity	
Vinyl allyl ether	2	3	3	24
Vinyl benzyl chloride	2	1	0	4
Vinyl chloride	2	4	1	21
Vinyl cyclohexane	2	3	2	24
Vinyl ethyl ether	2	4	2	24
Vinyl toluene	2	2	1	14
Vinylidene chloride	2	4	2	24
Xylene	2	3	0	16
Zinc stearate	0	1	0	4

APPENDIX C

EXAMPLES OF CONSEQUENCE PRESENTATION FOR CHEMICAL HAZARD ASSESSMENT

Example 1: Chlorine Release - Discussion of Consequences

Chlorine can be dangerous to human health at concentrations of 10-20 parts per million (ppm) for an exposure of 30 minutes. The gas becomes fatal at concentrations of 100-150 ppm with exposure durations of 5-10 minutes. Exposure to chlorine for much shorter periods can be fatal at concentrations of 1000 ppm. In addition, The American Industrial Hygiene Association's Emergency Response Planning Guidelines (ERPG) for chlorine are:

ERPG-1: 1 ppm
The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

ERPG-2: 3 ppm
The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG-3: 20 ppm
The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Conclusion

The bounding accident analysis of the chlorine release for this facility showed that the peak airborne concentration of chlorine at the site boundary would be approximately 3 ppm. This concentration would be transient and would disperse to non-detectable levels within 5-10 minutes. Recent human test data have demonstrated that exposure to 1 ppm chlorine for up to one hour resulted in no more than slight transient effects. Consequently, based upon chlorine's toxicology, the acute, short-term exposure to chlorine experienced from this release would cause no more than transient irritation in exposed individuals.

Example 2: Chlorine Release - Tabular Presentation of Consequences

Airborne Concentration(ppm)	Duration(min)	Effect
1	60 min	slight transient irritation
10-20	30 min	possible adverse health effects
100-150	5-10	fatal
1000	< 5	fatal
1	up to 60	ERPG-1: mild, transient health effects
3	up to 60	ERPG-2: no irreversible health effects
20	up to 60	ERPG-3: no life-threatening health effects

Conclusion

The bounding accident analysis of the chlorine release for this facility showed that the peak airborne concentration of chlorine at the site boundary would be approximately 3 ppm. This concentration would be transient and would disperse to non-detectable levels within 5-10 minutes. Consequently, based upon chlorine's toxicology, the acute, short-term exposure to chlorine experienced from this release would cause no more than transient irritation in exposed individuals.

END

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