DEVELOPMENT OF A CHEMICAL HEALTH RISK ASSESSMENT TOOL TO ASSESS THE RISK TO HEALTH FROM EXPOSURE TO HAZARDOUS CHEMICALS

by

Aira Amira Abd Raman

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

MAY 2011

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CERTIFICATION OF APPROVAL

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Approved by,

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MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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AIRA AMIRA BINTI ABD RAMAN

ABSTRACT

People working in the process industries are exposed to chemicals on a daily basis. Some of these chemicals can cause health disorders or even fatalities depending on its dosage. It is required that all work place be assessed on its risk to health from exposure to chemicals at work. However, the assessment requires competency in the field and takes some time due to the manual steps that need to be taken. Therefore, the objective of this project is to develop an application called the Chemical Health Risk Assessment Tool (CHRAT), which is able to determine the risk rating of an exposed chemical at work.

CHRAT is developed using Visual Basic (VB) programming language. The development of this software has been divided into four different stages, which are planning the application, building the graphical user interface, writing the computer programme and software validation and verification.

The methodology of the project includes determining the hazard rating and exposure rating first before assessing the risk rating. The hazard rating can be done in two ways which are hazard rating based on hazard categories and hazard rating based on risk phrases. The exposure rating is primarily based on the frequency of exposure, the duration of exposure and the intensity or magnitude of exposure. Once the risk rating has been determined, steps are given to provide adequate control measures to control the risk of the exposure to the chemical.

The case study result using CHRAT proofs that the software is capable to assess the risk rating of an exposure to hazardous chemical as well as provide adequate control measure if necessary.

CHRAT is useful and feasible because it is simple, user-friendly, able to function as a stand-alone application and it is compatible with all windows operating system. Furthermore, the cost of developing the software is cheap and the application incorporates the risk tolerability limit for Malaysia.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Chemical substances are an important part of the process industry. Exposure to some of these chemicals can cause health disorders and fatalities. In the management of chemical substances it is important to always remember what Paracelsus (1493–1541), the father of modern toxicology, said, "All chemical substances are poisons and there is none which is not a poison and only the right dose differentiates a poison and a remedy".

Adverse health effects of chemical substances depend on many factors, including the toxicity of the candidate chemical, the duration or period of exposure, and the exposed individual's age and health status, among others (Dikshith, 2009). The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Health risk assessment plays a vital role in health and safety management. Conducted either qualitatively or quantitatively or a combination of both, these methods helps in determining the value of risk in daily works. One way to measure the risk value based on these factors is through a system rating approach. Using qualitative and quantitative method with system rating allows the severity of the hazard and the chance of overexposure to be rated on a five-scale rating. The result of the assessment decides on the type of control measures that are adequate in controlling the threat. Performing a health risk assessment on the exposure of hazardous chemicals at work provides the means to control and manage the hazards of these chemicals.

Risk assessment tools and methodologies help organizations in assessing their risks. Familiar health risk assessment tools include checklists, a useful tool in identifying hazards, guidance documents, handbooks, brochures, questionnaires, and computerized tools (EU-OSHA, 2010). Using computerized tools means utilizing a software application in conducting risk assessment. This method uses the qualitative or quantitative approach or a combination of both with the help of analytical tools to analyze and estimate the risks.

In order to assess the risk of exposure to hazardous chemicals, the first step required is to obtain hazard information of the chemicals. A complete Chemical Safety Data Sheets (CSDS) provides useful information such as the hazard description, the toxicity data and the acute and chronic health effects. Mathematical equations can be used to estimate the risk to health from exposure to hazardous chemicals. They consist of sets of equations and assumed data on the chemical source. This allows a factor of uncertainty in the rating value as these conditions are based on assumptions and involve known and unknown risks, uncertainties and other factors which may cause the actual results to be materially different from any future results.

Integrating current health risk assessment tools with computer-aided programs allows minimization of failures as well as quicker results. With the necessary database within a common and interactive graphical user interface (GUI), this provides a powerful and user-friendly risk analyzing tool.

1.2 Problem Statement

People are exposed to chemicals on a daily basis. This exposure can be fatal or harmless depending on the dosage. Protecting employees from the adverse effects of chemicals is one of the primary duties of an employer under the Occupational Safety and Health Act 1994. Under the Occupational Safety and Health Regulations 2000, the duty to perform an assessment of health risk arising from the use of chemical hazardous to health at the place of work is mandatory whereby employees are not permitted to use any chemicals hazardous to health unless an assessment has been conducted (DOSH, 2000).

Implementing a manual Chemical Health Risk Assessment (CHRA) might proof difficult due to the following reasons:

- Calculations done manually can cause absolute error.
- Manually browsing through CSDS to identify hazard information for the candidate chemical can be tedious thus resulting in difficulty to keep track of them.
- A CHRA requires step by step procedures that need to be carried out by an assessor which would be time consuming.
- Requires an assessor who is an expert in the field to do the assessment manually.

This project is mainly to develop a CHRA tool that incorporates the existing risk assessment tool with computer programs. Mathematical equations and necessary data can be integrated into the developed tool using programming languages such as Visual Basic (VB). Through VB a graphic user interface (GUI) is created to allow users to input chemical data such as concentration, duration of exposure, toxicity data, and etc. in order to assess the risk rating. The developed tool will allow the risk to be calculated and presents the adequate control measures graphically which in turn help enhance the safety of the process industry.

1.3 Objectives of Study

The objectives of this study are:

i. To develop a chemical heat risk assessment tool that can be used to assess the risk to health from exposure to hazardous chemicals within the place of work.
ii. To incorporate Malaysian standards and regulations into the developed tool.
iii. To test and evaluate the degree of exposure of employees to the chemicals hazardous using the developed tool through a real case study.
iv. To verify the validity of the results from the developed application by comparing the results obtained with other results from established data, published literature and laboratory.

1.4 Scope of Work

This study is conducted to develop a software using Visual Basic programming which is able to assess the risk to health from exposure to hazardous chemicals at work. Current risk assessment methodologies are used and integrated with this software in developing a Chemical Health Risk Assessment tool.

The purpose of a Chemical Health Risk Assessment tool is to enable decisions to be made on appropriate control measures required to protect the health of employees who may be exposed to chemical hazardous to health. The assessment shall contain the following:

a) The nature of the hazard to health.
b) The potential health risk to an employee as a result of chemical hazardous exposure (Hazard Rating).
c) The degree of exposure to such hazardous chemicals (Frequency, Duration and Magnitude, Exposure Rating).
d) The risk to health created by the use and the release of chemicals from work processes (Risk Rating).
e) Measures and procedures required to control any accidental emission of hazardous chemicals.

By obtaining the hazard rating, frequency rating, duration rating, magnitude rating and exposure rating of the chemical exposure, the risk rating and consequently the control measures of the risk can be assessed.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The twentieth century according to Dikshith (2009) could well be called the "age of chemistry". It is without question that during the past several decades chemicals play an essential part to human activities. Tremendous amount of chemicals are manufactured and used daily, and new chemicals are constantly being introduced (Manassaram et al., 2003). Further, reports of the World Health Organization (WHO) in the year 2002 estimates the annual production of chemical substances, amounts to about $1.5 trillion.

With the use of chemical substances one cannot deny the potential risks it brings. The workplace is a potentially hazardous environment. Research done by both Boss and Day (2001) and Arunraj and Maiti (2009) agreed that of the high-risk industries, chemical industry is one of the most hazardous sectors. Hardly a day goes by when one does not open a newspaper and find some new threat to human health and safety that originates within the industrial complex.

Analyzed data from Hazardous Substances Emergency Events Surveillance (HSEES) system describes the incident and consequences of acute releases of hazardous substances. Evaluating the data for past hazardous substances events, including those not resulting in injuries, can be useful for risk assessment, preparedness and prevention planning, and employee education (Manassaram et al., 2003). Table 2-1 show the summary of data collected by HSEES from 2007-2008 of sudden, uncontrolled, or illegal release or threatened release of at least one hazardous substance with the number victims in each substance category.

Table 2-1 Distribution of substances released in chemicals and allied products related events and events with victims in each substance category (HSEES, 2007-2008)

Substance category	All releases		Released with victims		Percentage of releases with victims percent
	Number	Percent	Number	Percent	
Volatile organic compounds	2496	19.9	106	8.4	4.2
Mixture	1640	13.1	219	17.4	13.4
Acids	1607	12.8	254	20.2	15.8
Other inorganic compounds	1537	12.3	95	7.6	6.2
Paints and dyes	1118	8.9	13	1.0	1.2
Ammonia	962	7.7	136	10.8	14.1
Bases	958	7.7	100	8.0	10.4
Unclassified substances	755	6.0	86	6.8	11.4
Polychlorinated biphenyls	725	5.8	92	7.3	12.7
Chlorine	541	4.3	155	12.3	28.7
Pesticides	175	1.4	1	0.1	0.6
Total	**12514**	**100.0**	**1257**	**100.0**	**10.0**

Table 2-2 Distribution of injuries among victims (HSEES, 2007-2008)

Injury category	Fixed facility		Transportation		All events	
	Number	Percent	Number	Percent	Number	Percent
Respiratory irritation	1779	28.6	170	27.4	1949	28.5
Dizziness/CNS* symptoms	945	15.2	54	8.7	999	14.6
Headache	879	14.1	36	5.8	915	13.4
Eye irritation	720	11.6	49	7.9	769	11.2
Gastrointestinal effects	722	11.6	44	7.1	766	11.2
Trauma	208	3.3	187	30.2	395	5.8
Burns	313	5.0	27	4.4	340	5.0
Skin irritation	254	4.1	33	5.3	287	4.2
Shortness of breath	178	2.9	8	1.3	186	2.7
Other	146	2.3	7	1.1	153	2.2
Heart problems	55	0.9	5	0.8	60	0.9
Heat stress	19	0.3	0	0.0	19	0.3
Total	**6218**	**100.0**	**620**	**100.0**	**6838**	**100.0**

*Central Nervous System

From the analyzed data in Table 2-2, it can be seen that commonly reported injuries among employees were respiratory irritation (28.5%), dizziness (14.6%), headache (13.4%), eye irritation (11.2%), and gastrointestinal effects (11.2%). This data supports the study done by Plog and Quinlan (2002) and Bisesi (2003) where they concluded that inhalation is the major route of entry for hazardous chemicals in the work environment.

In the last decades, the world has seen a wide range of major accidents with a number of fatalities, economic losses, and damage to the environment. In fact, recent reports indicate that as many as 350,000 people died worldwide from unintentional poisoning (Dikshith, 2009). Human exposure to a variety of chemical substances and the subsequent poisonings and fatalities has caused significant global concern and are now receiving international attention. Many have endeavored to make our outdoor environment cleaner and safer. World Health Organization (WHO) Member States in the European Region, at the ministerial conference on environment and health held in Budapest (2004), agreed that action should be taken without delay to reduce the possible effects of chemicals on human health. Proper management of chemicals can minimize the hazards of these chemicals.

2.2 Chemical Substances

Chemical substances are required for health, progress, and societal development. Proper usage of chemical substances has tremendously improved the quality of life. In contrast, the misuse of chemical substances has caused health disorders and fatalities. Societal development requires use of chemical substances with pragmatism, as well as proper and good management (Dikshith, 2009). Many people are not fully aware of the short- and long-term possible health hazards posed by chemical substances to which they are directly or indirectly exposed daily.

All chemical substances are toxic and there is no absolute safety. It is the manner of use of a chemical substance that brings either good or danger to the user, to the immediate workplace, and to the society at large. Indeed, in view of the fact that any chemical is toxic at an appropriate dose or concentration, then all flammable, corrosive, and reactive materials, as well as radiological and some biological agents, are also toxic. Bisesi (2003) argues that the reverse is not necessarily true. All toxic materials do not exhibit other hazardous characteristics.

We are exposed daily to a variety of substances which are not hazardous under usual circumstances. However, any substance contacting or entering the body is injurious at some excessive level of exposure and theoretically can be tolerated without harmful effect at some lower exposure (Plog and Quinlan, 2002). Although external

exposure to chemical agents can occur via ingestion, dermal absorption, and injection, inhalation is considered the most common mode of entry in most occupational and even many non-occupational environments. (Plog and Quinlan, 2002; Bisesi, 2003)

2.2.1 Toxicity Versus Hazards

Plog and Quinlan (2002) stated that the toxicity of a material is not synonymous with its hazard. Toxicity, along with the chemical and physical properties of a substance, determines the level or degree of hazard. Two liquids can possess the same degree of toxicity but present different degrees of hazard. Toxicity is the capacity of a material to produce injury or harm when the chemical has reached a sufficient concentration at a certain site in the body. Hazard is the probability that this concentration in the body will occur. This degree of hazard is determined by many factors or elements.

The human toxicity of chemical agents is related to several factors including the duration of exposure, concentration, and mode of contact (Bisesi, 2003). Many chemicals essential for health in small quantities are highly toxic in larger quantities (Plog and Quinlan, 2002). The basic principle of toxicology is that the size of the dose of a material or chemical determines the health effect. Dose refers to the ratio of the amount of hazardous substance to the body weight and the time over which that dose is administered. Toxicological studies are essential to understanding the possible adverse effects that a candidate chemical or combination of chemicals may cause to animals, humans, fauna, and flora, and to make relevant, reliable, reproducible predictions (Table 2-3).

Table 2-3 Signs and Symptoms of Toxicity (Dikshith, 2009)

Clinical Side Effect	Yes/No	Clinical Side Effect	Yes/No
Drowsiness	**Yes**	**Hypertension**	**Yes**
Anorexia	**Yes**	**Nausea**	**No**
Insomnia	**Yes**	**Depression**	**Yes**
Dizziness	**No**	**Fatigue**	**No**
Increased appetite	**Yes**	**Sedation**	**Yes**
Constipation	**Yes**	**Tremor**	**Yes**
Dry mouth	**Yes**	**Tinnitus**	**No**
Perspiration	**Yes**	**Nervousness**	**Yes**
Weight gain	**Yes**	**Dermatitis**	**Yes**
Epigastric distress	**No**	**Hypotension**	**Yes**
Headache	**No**	**Vertigo**	**No**
Vomiting	**Yes**	**Heartburn**	**No**
Palpitation	**Yes**	**Weakness**	**Yes**
Diarrhea	**Yes**	**Blurred vision**	**Yes**
Skin rash	**Yes**	**Lethargy**	**Yes**

The hazard presented by a chemical substance has two components: (i) the inherent capacity to do harm; and (ii) the ease with which a chemical substance can come into contact with a person. These two components together determine the risk, the likelihood or probability that a chemical substance will cause harm (Dikshith, 2009). Many factors contribute to determining the degree of hazard—route of entry, quantity of exposure, physiological state, environmental variables, and other factors. Assessing a hazard involves estimating the probability that a substance will cause harm.

2.3 Risk Assessment

Almost any work environment has either potential or actual environmental hazards that the health and safety professional must recognize, measure, and monitor. Risk assessment in chemical process industry plays an important role in handling this issue. This assessment provides a systematic evaluation of the factors that might result in an adverse human health effect through the identification, quantification and communication of the risk and the potential hazard or harm (Anderson and Albert,

1999; Draggan, 2007; Arunraj and Maiti, 2009). The need to evaluate hazards is driven by the acknowledgment that chemical, biological, and physical agents can cause injury, disease, and premature death among exposed workers. Assessing the human health risk of chemical substances will benefit any industry trying to manage chemical use.

During the 1970s, risk assessment procedures for all chemicals were reevaluated, improved, and more importantly, formalized (Extoxnet, 1993). Part of this development was the initiation of the WHO Environmental Health Criteria Programme in 1973, with the following objectives:

- to assess information on the relationship between exposure to environmental pollutants and human health, and to provide guidelines for setting exposure limits;
- to identify new or potential pollutants;
- to identify gaps in knowledge concerning the health effects of pollutants;
- to promote the harmonization of toxicological and epidemiological methods in order to have internationally comparable results.

The first Environmental Health Criteria (EHC) monograph, on mercury, was published in 1976, and since that time an ever-increasing number of assessments of chemicals and of physical effects have been produced (WHO, 1999).

Risk assessment provides the basis for deciding how, and to what extent, a given agent (e.g., a carcinogen or noncarcinogen) should be regulated and, if so, in what media, with what toxicological endpoint, and to what degree. Risk assessment has become a powerful tool because it provides a systematic way of organizing what is known and not known about the toxicology of an agent and the interpretation(s) of the data as the basis for making regulatory decisions (Anderson and Albert, 1999).

According to Boss and Day (2001), chemical risk assessment is a twofold process. One part occurs off-site as known chemical information is assessed and calculations based on accepted formulas are done. The second stage is the actual accumulation of data during which workers must be protected against these hazards.

In conducting risk assessments, the National Academy of Science (NAS) risk assessment paradigm has been widely accepted as a framework for estimating risk from exposure to environmental chemicals (NAS, 1983).This paradigm divides the risk assessment process into four distinct steps: hazard identification, dose-response assessment, exposure assessment and risk characterization. Of these, the first two are concerned primarily with properties of particular chemical agents and the characterization of expected toxic effects under a variety of circumstances. In contrast, the second two components of the NAS paradigm, exposure assessment and risk characterization, will be particular to the specific exposure context in which the compound is experienced. Risk assessment, comprising of these elements is now recognized as an essential tool by many national, regional and international bodies, and it is also recognized that it is a continuously evolving process which has changed considerably in the last two decades (NAS, 1983; Somers, 1987; UK HSE, 1989; Scala; 1991; Ballantyne et al., 1993; Somers, 1993; EC, 1996).

The Department of Occupational Safety and Health, Malaysia has compiled a manual to provide guidelines for employers and safety and health practitioners in conducting a chemical health risk assessment (CHRA). This manual is necessary due to the enforcement of the Occupational Safety and Health (Classification, Packaging and Labelling of Hazardous Chemicals) Regulations 1997 (OSH-CPL Regulations 1997), and the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulation 2000 (OSH-USECHH Regulations 2000) by the Malaysian government. And such assessment can only be conducted by a competent assessor registered with the Department of Occupational Safety and Health. The CHRA incorporate Malaysian standards and regulations into the assessment with four fundamental steps which are:

- Hazard Identification
- Exposure Assessment
- Risk Characterization
- Risk Management

Risk assessment processes for new and existing chemicals have been published and put into use by several different countries in Europe, the Americas and Asia for several years (WHO, 1999). These processes are relatively similar and include

consideration of hazard identification, dose-response evaluation, exposure assessment and risk characterization.

2.3.1 Hazard Identification

Chemical health hazard is the potential of a chemical to cause harm or adversely affect health of people in the workplace (DOSH, 2000). Chemical substances include different classes and categories of materials and some are inherently more dangerous than others. Hazard identification is the first stage in risk assessment and it involves gathering and evaluating data on the types of health effect and diseases caused by these chemicals. Once the presence and concentrations of specific chemicals or classes of chemicals have been established, the hazards associated with these chemicals will be determined by referring to standard reference sources for data and guidelines on toxicity, flammability, and other hazards (Boss and Day, 2001; Leeuwen et al., 2007).

Hazard information can be obtained from various sources. An important source of information is the material safety data sheets (MSDS) which provides a summary of the important health, safety, and toxicological information on the chemical or the mixture ingredients. Based on this information the hazard of each chemical can be evaluated and assigned a hazard rating. The summary of the necessary information and its sources is given by Table 2-4:

Table 2-4 Summary of necessary chemical information and its sources (DOSH, 2000)

Information	Source
Chemical classification	Label, CSDS, ICS card
Health effects, LC_{50}, LD_{50}	CSDS, MSDS, ICS card, Poison centre, chemical safety literature
Risk phrases	Label, CSDS, ICS Card

Chemical hazardous to health can be categorized into two groupings; systemic injury and local injury. Examples of systemic injury include liver and kidney damage, reproductive toxicity, developmental toxicity affecting the fetus, and cancer. Local injuries include skin irritation, rash, blisters or other injury at the site of contact with

the agent. These groupings are on the basis of route of entry by which the hazardous material enters the human system.

2.3.2 Exposure Assessment

Draggan (2007) states that exposure assessment is a key phase in the risk assessment process since without an exposure, even the most toxic chemical does not present a threat. Exposures are evaluated by assessing the likelihood of contact with the hazardous chemical; the route of exposure; the frequency and duration of exposure; and the intensity or magnitude of each exposure. The more frequent or the longer the duration a hazardous chemical is used, the higher is the degree of exposure (DOSH, 2000).

Route of exposure describes the way the chemical enters the body. Chemicals may have serious effects by one route, and minimal effects by another. The main routes of entry are:

i) Inhalation

The respiratory tract is the most common route of entry for gases, vapors, and particulate matter including dusts, fumes, smokes, aerosols, and mists. Inhalation, as a route of entry, is particularly important because of the rapidity with which a toxic material can be absorbed in the lungs, pass into the bloodstream, and reach the brain. Inhalation is the major route of entry for hazardous chemicals in the work environment (Plog and Quinlan, 2002; Bisesi, 2003).

ii) Skin and Eye Absorption

The simplest way for chemicals to enter the body is through direct contact with the skin or eyes. Absorption through the skin can occur quite rapidly if the skin is cut or abraded. Chemical contact with eyes can be particularly dangerous, resulting in painful injury or loss of sight. Absorption into the bloodstream may then allow the chemical to cause toxic effects on other parts of the body.

iii) Ingestion

Ingestion of chemicals can occur directly and indirectly. In the workplace, people can unknowingly eat or drink harmful chemicals. Hazardous materials may enter the

body as a result of handling materials prior to eating or smoking. Toxic compounds can be absorbed from the gastrointestinal tract into the blood.

So the first step in an exposure assessment is to decide which sources are releasing the pollutant of concern. Once the identity and location of the source(s) are known, the next step is to determine the amount of a pollutant released in a specific time period and how it moves away from the source(s). Factors such as distance from the source to exposed persons, wind speed and direction, and smokestack height (for factories) affect these estimates. The final step in an exposure assessment is to estimate the amounts each person ingests, inhales, or absorbs.

Exposure can be assessed by measuring exposure concentrations, once chemicals are produced, used and emitted (Leeuwen et al., 2007). In order to properly assess the degree of exposure a distinction has to be made between acute and chronic exposure and toxicity. Acute toxicity results from a single, short exposure. Effects usually appear quickly and are often reversible. For assessing the likelihood of acute effects, the frequency of exposure is determined. The exposure will be based on instantaneous measurement result. Chronic toxicity results from repeated exposure over a long period of time. Effects are usually delayed and gradual, and may be irreversible. A duration rating is used to assess chronic or routine exposures.

Estimating intensity or magnitude rating can be done either quantitatively or qualitatively. Quantitative evaluation of exposure is carried out for inhalation exposures if air-sampling data for the exposed employees are available. Where exposure data is limited or unavailable the assessment should be done qualitatively.

The degree of risk of handling a given substance depends on the magnitude and duration of exposure (Plog and Quinlan, 2002). Depending on the purpose of an exposure assessment, the numerical output may be an estimate of either the intensity, rate, duration or frequency of contact exposure or dose.

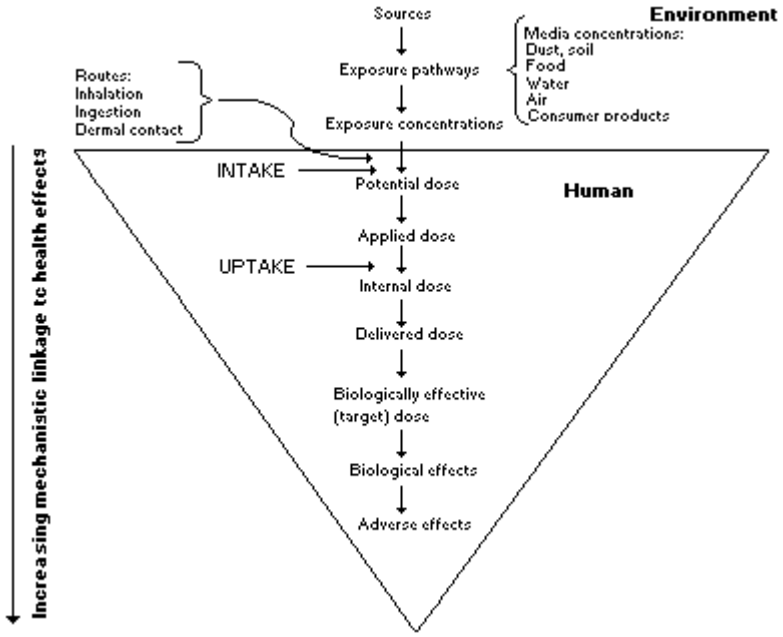


Figure 2-1 Environmental health paradigm showing the role of exposure [adapted from Sexton et al. (1995) and IPCS (1993)]

2.3.3 Risk Characterization

Risk is a function of both hazard and exposure. This phase determines the probability of an adverse effect to a human population by a toxic substance and outlines permissible exposure levels from which standards of exposure are set. The risk characterization step involves bringing together the information obtained in the previous steps for decision making.

2.3.4 Risk Management

Risk management decisions follow the identification, quantification and communication of risk that are determined by risk assessments (Draggan, 2007). The risk management decision process is composed of two factors, the hazard presented by an activity and the probability of the hazard actually occurring. When the potential hazard is low and the probability is low, the decision is easy— there is very little risk. And when both the probability and the hazard are high, the decision is easy—do not take the risk of the proposed action. The difficulty is when one factor is high and the other is fairly low (Griffin, 2009).

Control measures are all the steps taken to prevent or minimize risks. These control procedures may include the substitution of harmful or toxic materials with less dangerous ones, changing of work processes to eliminate or minimize work exposure, installation of exhaust ventilation systems, good housekeeping (including appropriate waste disposal methods), and the provision of proper personal protective equipment (Plog and Quinlan, 2002). Control equipment is equipment used for controlling risks, such as a local exhaust ventilation system, water spray or enclosure. In trying to control the identified risks, the measures taken should be in a certain hierarchy or order of priority (DOSH, 2000).

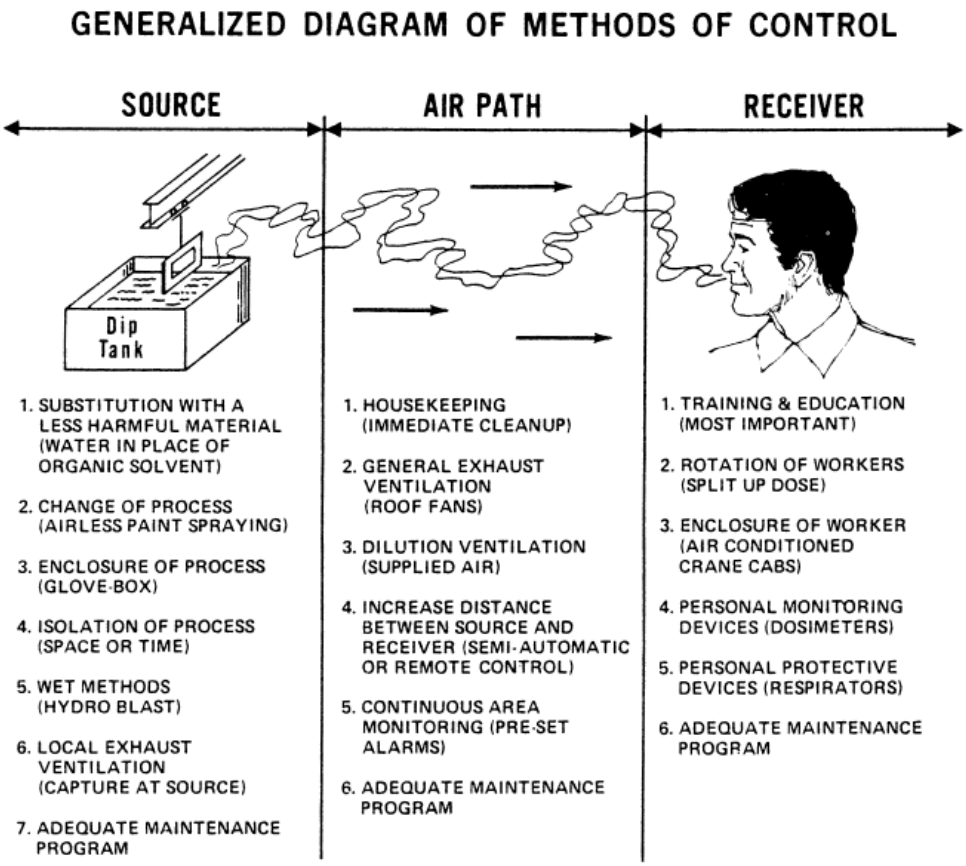


Figure 2-2 Generalized diagram of methods of control (Plog and Quinlan, 2002)

CHAPTER 3: METHODOLOGY

The overall methodology required for this project is divided into two stages as shown in Figure 3-1. The research stage involves background study and literature review of the project. Important data to be gathered includes hazard information of the chemicals and necessary calculation required in determining the exposure extend. These data is to be measured up with current Malaysian standards and regulations and incorporated into the developing tool. The next stage of this project involves the development of the software. Using computer program, a graphical user interface (GUI) is created and once the interfaces are completed, the results will be validated with results from real life case studies.

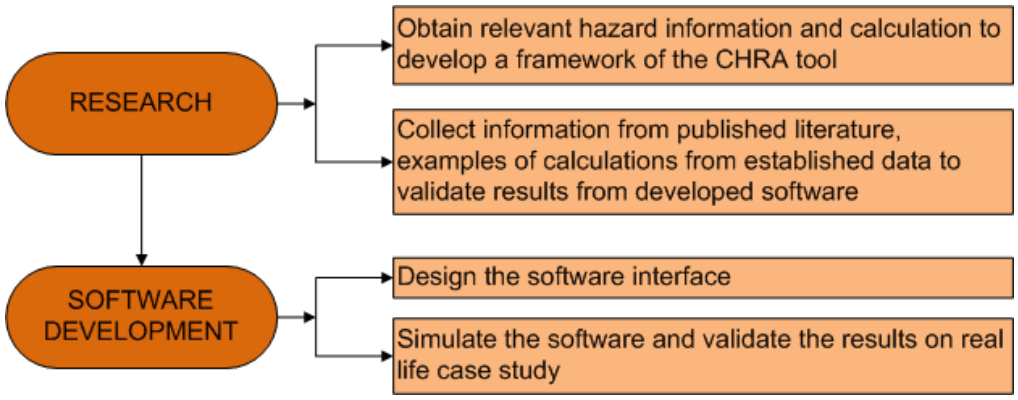


Figure 3-1 Workflow of CHRA tool development

In developing a Chemical Health Risk Assessment (CHRA) tool it is important to identify the current methodology of risk assessment practiced in Malaysia as well as in the global scale. The NAS risk assessment paradigm has been widely accepted and it divides the risk assessment process into four distinct steps: hazard identification, dose-response assessment, exposure assessment and risk characterization. Once the risk assessment of the chemical has been completed the risk management process follows which includes assessing the adequacy of the control measures.

Risk assessment and risk management are two distinct processes but this project incorporates both these stages into one tool. The relationship between risk assessment and risk management is shown in Figure 3-2. For the purpose of this

project, the dose-response assessment has been eliminated and only the exposure assessment is taken into consideration.

Figure 3-2 Relationship between risk assessment and risk management (Draggan, 2007)

For each step proposed in the CHRA tool, exposure parameters and relevant calculations are gathered. These data are used to develop a stand-alone user friendly software package using Visual Basic. Utilizing the graphical user interface (GUI), users are able to input necessary data into the tool and obtain a risk rating followed by an assessment of the adequacy of the control measures for that particular exposure. A framework of the proposed CHRA tool is constructed as shown in Figure 3-3.

The first step in conducting a Chemical Health Risk Assessment is the hazard identification stage to determine the hazard rating of the exposed chemical. Once the hazard of the chemical has been assessed, the exposure rating is determined based on the frequency or duration of exposure and the magnitude of exposure. The value of hazard rating and exposure rating will then determine the risk rating of the chemical. By obtaining the risk rating, the software will be able to assess the adequacy of the control measures and shall conclude the assessment.

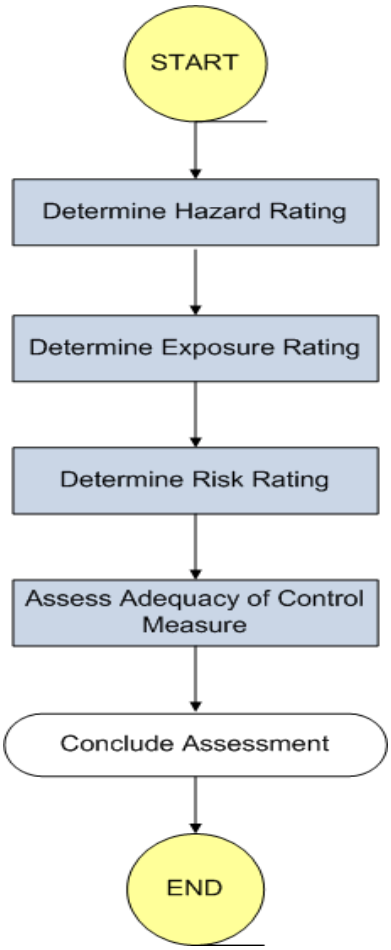


Figure 3-3 Framework of Chemical Health Risk Assessment tool

3.1 Determine Hazard Rating

The first step is to gather hazard information on the types of health effect and diseases caused by the chemical. Hazard information can be obtained from various sources. A complete Chemical Safety Data Sheet (CSDS) provides useful information such as the hazard description, the toxicity data and the acute and chronic health effects. Refer to Table 2-4 for the summary of necessary chemical information and its sources.

Chemicals hazardous to health need to be categorized into two groupings based on systemic and local effects. These groupings are to differentiate the route of exposure of the chemicals whether through inhalation, absorption or ingestion. Inhalation and ingestion causes systemic effects (Group 1) while absorption, either through the skin or eyes, most of the time causes local effects (Group 2).

Group 1 hazard categories based on OSH-CPL Regulations 1997:

Very toxic	R26-28, 39, 45(1), 46(1), 47(1), 49(1)
Toxic	R23-25, 39, 48, 45(2), 46(2), 47(2), 49(2)
Harmful	R20-22, 40, 40(3), 40(M2), 48,
Respiratory sensitiser	R42
Respiratory irritant	R37

Group 2 hazard categories based on OSH-CPL Regulations 1997:

Corrosive to skin/eye	R34, 35
Skin and eye irritants	R41, 38, 36

This information would then be used by the tool to assess the exposure and assign a hazard rating. Table 3-1 presents the hazard rating based on the adverse health effects of the chemical.

Table 3-1 Hazard Rating based on health effect description (DOSH, 2000)

HAZARD RATING	HEALTH EFFECTS	HAZARD CATEGORY
5	Local: Injury to the skin, eyes, or mucous membranes of sufficient severity to threaten life by single exposure	Very Toxic chemicals:- -LD_{50}<25 mg/kg (oral) -LD_{50}<50 mg/kg (skin) -LC_{50}<0.5 mg/litre
	Systemic: Severe irreversible effects (e.g. central nervous system effects, kidney necrosis, liver lesions, anemia or paralysis) after a single exposure	
	Known human carcinogens, mutagens or teratogens	Category 1 carcinogen, mutagen and teratogen
4	Local: Injury to the skin, eyes, or mucous membranes of sufficient severity to cause permanent impairment, disfigurement or irreversible change from single or repeated exposure	Very Corrosive (R35: Causes severe burn) Toxic chemicals:- -LD_{50}: 25-200mg/kg(oral) -LD_{50}: 50-400mg/kg(skin) -LC_{50}: 0.5-2 mg/litre
	Systemic: Very serious physical or health impairment by repeated or prolonged exposure	
	Probable human carcinogens, mutagens or teratogens based on animal studies	Category 2 carcinogen, mutagen and teratogen
3	Local: Serious damage to skin, eyes or mucous membranes from single or repeated exposure	Corrosive(R34:Cause burn) Respiratory sensitisers Irritant-serious eye damage Harmful chemicals:- -LD_{50}:200-500mg/kg(oral) -LD_{50}:400-2000mg/kg(sk) -LC_{50}: 2-20 mg/litre
	Systemic: Severe effects after repeated or prolonged exposure	
	Possible human or animal carcinogens or mutagens, but for which data is inadequate	Category 3 carcinogen and mutagen
2	Local: Reversible effects to the skin, eyes or mucous membranes not severe enough to cause serious health impairment	Skin sensitisers Skin irritants
	Systemic: Changes readily reversible once exposure ceases	
1	No known adverse health effects	Not classified as hazardous

Table 3-2 presents the hazard rating based on the risk phrases assigned to the hazardous chemical substance under the OSH-CPL Regulations 1997. Appendix B gives the meaning of the risk phrases codes.

Table 3-2 Hazard rating based on hazard categories or hazard classification or risk phrases (DOSH, 2000)

EFFECT	ACUTE/ CHRONIC	ROUTES OF EXPOSURE					HAZARD RATING
		INHALA-TION	DERMAL		INGES-TION	NOT SPECIFIED	
			SKIN	EYE			
Very Toxic	Acute	R26	R27		R28	R39	**5**
	Chronic	-	-		-	-	
Toxic	Acute	R23	R24		R25	R39	**4**
	Chronic	-	-		-	R48, R39	
Harmful	Acute	R20	R21		R22	R40	**3**
	Chronic	-	-		-	R48, R40	
Corrosive	Acute		R35				**4**
			R34				**3**
Irritant	Acute	R37	-	R41			**3**
		-	R38	R36			**2**
Sensitising	Acute	R42	-				**3**
		-	R43				**2**
Carcinogenic	Chronic	R49(1)				R45(1)	**5**
		R49(2)				R45(2)	**4**
		-				R40(3)	**3**
Mutagenic						R46(1)	**5**
						R46(2)	**4**
						R40(M2)	**3**
Teratogenic						R47(1)	**5**
						R47(2)	**4**
EXPOSURE ASSESSMENT REQUIRED		**Inhalation**	**Skin**	**Eyes**	**Ingestion**	**All Routes**	

3.2 Determine Exposure Rating

Estimation of the degree of exposure is primarily based on these parameters:

- Frequency of exposure (acute effects) or
- Duration of exposure (chronic effects)
- Magnitude of exposure

An exposure rating is assigned based in the frequency or duration rating and the magnitude rating (Table 3-3).

Table 3-3 Exposure rating (DOSH, 2000)

		MAGNITUDE RATING				
		1	**2**	**3**	**4**	**5**
FREQUENCY RATING/ DURATION RATING	**1**	1	2	2	2	3
	2	2	2	3	3	4
	3	2	3	3	4	4
	4	2	3	4	4	5
	5	3	4	4	5	5

3.2.1 Determine Frequency of Exposure

The frequency of exposure is used for assessing the likelihood of acute effects (DOSH, 2000). Estimation is done from observation of the work activities and feedback from the workers and management (Table 3-4).

Table 3-4 Frequency rating based on frequency of exposure (DOSH, 2000)

RATING	DESCRIPTION	DEFINITION
5	Frequent	Potential exposure one or more time per shift or per day
4	Probable	Exposure greater than one time per week
3	Occasional	Exposure greater than one time per month
2	Remote	Exposure greater than one time per year
1	Improbable	Exposure less than one per year

3.2.2 Determine Duration of Exposure

A duration rating is used to assess chronic or routine exposures (DOSH, 2000). Based on the total duration of exposure in hours, the duration rating is determined (Table 3.5).

Table 3-5 Duration rating based on duration of exposure (DOSH, 2000)

RATING	TOTAL DURATION OF EXPOSURE*		
	% WORK HOUR	DURATION	
		PER 8-HR SHIFT	PER 40-HR WEEK
5	> 87.5%	> 7 hrs/shift	>35 hrs/week
4	50 - 87.5%	4 to 7 hrs/shift	20 to 35 hrs/week
3	25 - 50%	2 to 4 hrs/shift	10 to 20 hrs/week
2	12.5 - 25%	1 to 2 hrs/shift	5 to 10 hrs/week
1	< 12.5%	< 1 hr/ 8 hr shift	< 5 hrs/week

**Note: Total duration of exposure = (Number of exposure) x (Average duration of each exposure)*

3.2.3 Determine Magnitude Rating

In determining exposure magnitude or intensity there are two possible ways, either quantitatively or qualitatively (Figure 3-4).

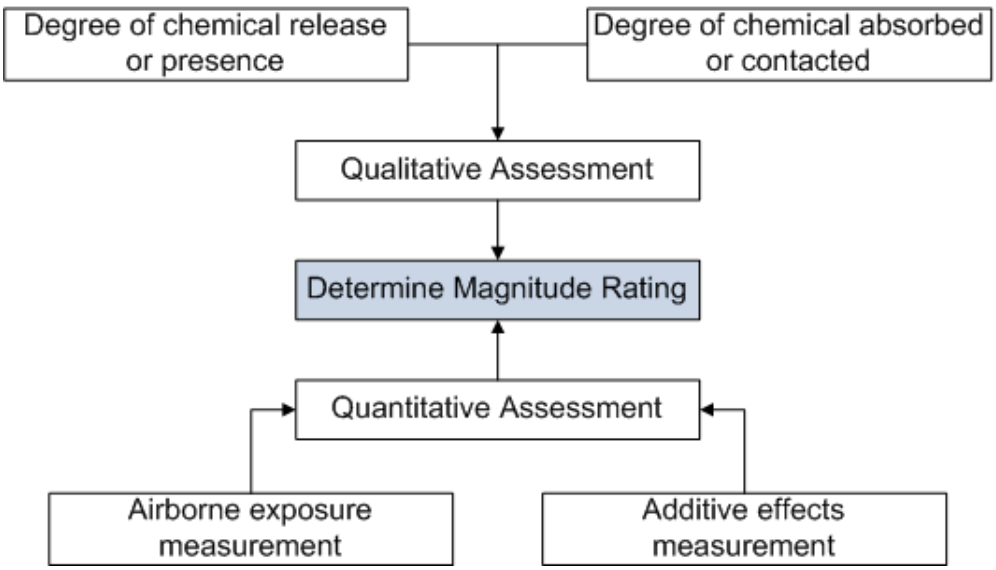


Figure 3-4 Summary of determining magnitude rating

Quantitative evaluation of exposure is carried out for inhalation exposure if air-sampling data for the exposed employees are available. If data are not available or limited, qualitative evaluation should be done. If a chemical do not have a PEL (Permissible Exposure Limit), then the qualitative assessment method for estimating exposure should be used.

3.2.3.1 Quantitative Evaluation

For chemicals with acute effects, the magnitude rating is based on the fraction of the measurement result to the ceiling limit or the maximum exposure limit, whichever result in a higher exposure rating (Table 3-6).

For chemicals with chronic exposures the time period for assessment period is one week and will be based on the 8 hours time-weighted-average (TWA) exposure. The magnitude is assigned based on the ratio of the TWA to the 8-hour TWA limit (Table 3-6).

The TWA is calculated using Equation (3.1):

$$\text{TWA} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{T_1 + T_2 + \ldots + T_n} \tag{3.1}$$

C = concentration of the sample

T = sampling time for that sample

If an employee is exposed to a particular chemical at various job tasks, estimation of the 8-hour exposure may be determined based on Equation (3.2) (Table 3-6).

$$\text{TWA} = \frac{D_1C_1 + D_2C_2 + \ldots + D_nC_n}{D_1 + D_2 + \ldots + D_n} \tag{3.2}$$

C = average concentration for each task

D = average duration for each task

Table 3-6 Magnitude rating based on airborne exposure measurement (DOSH, 2000)

TIME-WEIGHTED AVERAGE (TWA) or MAXIMUM CONCENTRATION	MAGNITUDE RATING
≥ 3 × P.E.L*	**5**
≥ P.E.L but < 3 × P.E.L	**4**
≥ 0.5 P.E.L but < P.E.L	**3**
≥ 0.1 P.E.L but < 0.5 P.E.L	**2**
< 0.1 P.E.L	**1**

**Note: 3 x PEL (Permissible Exposure Limit) is the Maximum Exposure Limit under the USECHH Regulations 2000*

If an employee is exposed to two or more chemicals that are not known to act independently of each other, they should be treated as acting additively and a "combined P.E.L" can be made which should not exceed unity. Refer Table 3-7.

Table 3-7 Magnitude rating for additive effects (DOSH, 2000)

SUM OF RATIOS OF AIR CONCENTRATION TO O.E.L	MAGNITUDE RATING
> 3	**5**
1 - 3	**4**
0.5 - 1	**3**
0.1 - 0.5	**2**
< 0.1	**1**

3.2.3.2 Qualitative Estimation of Magnitude of Exposure

The magnitude of exposure is assessed based on the estimated absorbed dose through inhalation and skin absorption. For this estimation the degree of chemical release or presence (Table 3-8) and the degree of chemical absorbed or likely to be absorbed at the exposure boundary (Table 3-9) is taken into consideration.

Table 3-8 Degree of chemical release or presence (DOSH, 2000)

DEGREE	OBSERVATION
LOW	• Low or little release into the air. • No contamination of air, clothing and work surfaces with chemicals capable of skin absorption or causing irritation or corrosion.
MODERATE	• Moderate release such as: a) Solvents with medium drying time* in uncovered containers or exposed to work environment; b) Detectable odour **of chemicals with odour thresholds exceeding the PELs. • Evidence of contamination of air, clothing and work surfaces with chemicals capable of skin absorption or causing irritation or corrosion.
HIGH	• Substantial release such as: a) Solvents with fast drying time* in uncovered containers; b) Sprays or dust clouds in poorly ventilated areas; c) Chemicals with high rates of evaporation exposed to work environment; d) Strong odour of chemicals with odour thresholds exceeding the PELs. • Gross contamination of air, clothing and work surfaces with chemicals capable of skin absorption or causing irritation or corrosion.

Refer to **Table A1 in Appendix*

Refer to **Table A2 in Appendix*

Table 3-9 Degree of chemical absorbed or contacted (DOSH, 2000)

DEGREE	OBSERVATION/CONDITION
LOW	• Low breathing rate (light work)* • Source far from breathing zone • Contact with chemical other than those described under "Moderate" and "High". • Small area of contact with chemicals capable of skin absorption -limited to palm (intact skin). <2% or 0.04m2 • No indication of any skin conditions. Intact/normal skin • No contamination of skin or eyes
MODERATE	• Moderate breathing rate (moderate work)*. • Source close to breathing zone • Contact with eye or skin irritants, sensitisers or chemicals capable of skin penetration, except those described under 'High'. • Moderate area of contact- one or both hands up to the elbows. Skin area >2% or 0.04m2 • Skin dryness and detectable skin condition. Dry, red skin
HIGH	• High breathing rate (heavy work)*. • Source within breathing zone. • Gross contamination of eye or skin with skin or eye irritants, sensitisers or chemicals capable of skin absorption -skin soaked or immersed in chemical capable of skin penetration. • Area of contact not only confined to hands but also other parts of body. Skin area>50% or 1m2 • Follicle rich areas. • Skin damaged. • Severe drying, peeling and cracking.

Refer to **Table A3 in Appendix*

Once the qualitative estimation of the magnitude of exposure is done on the degree of chemical release and absorbed, Table 3-10 is used to estimate its magnitude rating.

Table 3-10 Magnitude rating based on qualitative estimation (DOSH, 2000)

DEGREE OF RELEASE	DEGREE OF ABSORPTION	MAGNITUDE RATING
LOW	LOW	1
	MODERATE	2
	HIGH	3
MODERATE	LOW	1
	MODERATE	2
	HIGH	3
HIGH	LOW	1
	MODERATE	2
	HIGH	3

3.3 Determine Risk Rating

Risk is evaluated as either "significant" or "not significant". Risk ratings located above the dotted line is considered as not significant whereas risk ratings located below the dotted line is considered as significant risks.

Table 3-11 Risk rating (DOSH, 2000)

		EXPOSURE RATING				
		1	**2**	**3**	**4**	**5**
HAZARD RATING	**1**	1	2	2	2	3
	2	2	2	3	3	4
	3	2	3	3	4	4
	4	2	3	4	4	5
	5	3	4	4	5	5

Category 1

Category 2

Based on Table 3-11 control strategies can be identified and prioritized. For the purpose of prioritizing action to control risks, two categories can be assigned under significant risk:

Category 1

Risks is to be controlled to below the permissible exposure limits or to as low as reasonably practicable (ALARP) where no limits are specified. Under the Occupational Safety and Health Act 1994, practicable means practicable after taking into considerations:

- the severity of the risk;
- the state of knowledge about the risk and the availability and suitability of ways of removing or mitigating the risk; and
- the cost of removing or mitigating the risk.

Category 2

This is considered intolerable risk, where the chemical hazardous to health should be eliminated. If this is not possible then substitution of the hazardous chemical with a less hazardous chemical; total enclosure of the process and handling system; or isolation of the work to control emission of chemicals hazardous to health is to be adopted so that employees exposure are kept well below the permissible exposure limits.

3.4 Control Measures

Significant risk arising from the use of chemical hazardous to health is to be controlled, in this following order: -

a) Elimination of chemical hazardous to health from the workplace;
b) Substitution of chemical hazardous to health with a less hazardous chemical;
c) Total enclosure of process and handling systems;
d) Isolation of the work to control the emission of chemicals hazardous to health;
e) Modification of the process parameters;
f) Application of engineering control equipment;
g) Adoption of safe work systems and practices that eliminate or minimize the risk to health; and
h) Provision of approved personal protective equipment.

The existing control measures need to be assessed whether they are adequate or not. The factors that need to be taken into consideration are:

- Suitability;
- Use
- Effectiveness; and
- Maintenance.

A control measure is considered adequate if:

a) It is suitable for protecting the employees, taking into consideration the physical form and toxicity of the chemical, the nature of work, the routes of entry of the chemical and not prejudice to the health of the employees;
b) It is used according to the manufacturers' instructions & recommendations;
c) It is effective in preventing or minimising exposure; and
d) It is regularly maintained in good working condition.

3.5 Conclusion of the Assessment

Based on the risk decision and the assessment of existing control measures conclusions could be reached from the assessment. These conclusions are denoted by C1, C2, C3, C4 or C5.

C1: Risks not significant now and not likely to increase in future

If the assessment shows that a hazardous chemical is: -

- Already controlled or can be readily controlled in accordance with the CSDS; and
- There is not a significant risk to health then the assessment is complete. The likely conclusion is that the risks are not significant now and not likely to increase in future.

C2: Risk significant but already adequately controlled could increase in future.

This conclusion applies to conditions where adverse health effects could increase in future, due to control measures failure or deterioration. Risks, while at present adequately controlled, could increase in future.

C3: Risks significant now and not adequately controlled

This conclusion applies to conditions where workers are at risk of adverse health effects since their exposure to the hazardous chemical is not adequately controlled.

C4: Uncertain about Risk: Insufficient information

This conclusion is arrived at if there is insufficient information to determine the degree of hazard.

C5: Uncertain about Risk: Uncertain about degree and extent of exposure

This conclusion is arrived at if the level of exposure cannot be estimated with confidence.

The conclusion of the assessment, taking into considerations the significance of risk and the adequacy of control measures, is summarized in Table 3-12.

Table 3-12 Conclusion of Assessment (DOSH, 2000)

RISK DECISION	ADEQUACY OF CONTROL MEASURES	CONCLUSION
Risk Not Significant	-	C1
Risk Significant	Adequate	C2
	Not Adequate	C3
Insufficient Information	-	C4
Uncertain about Exposure	-	C5

3.6 Software Development

The application used in developing the Chemical Health Risk Assessment (CHRA) tool is Microsoft Visual Basic 6.0. Visual Basic (VB) is relatively simple to learn due to its graphical development features. Even without extensive experience in coding or programming, a VB user is able to use it efficiently. The programming codes used are built using VB language, which consists of a graphic user interface (GUI) as front end and mathematical models as back end (source code).

The development of this software has been divided into four different stages, which are:

- Planning the application
- Building the graphical user interface (GUI)
- Writing the computer program
- Software validation and verification

3.6.1 Planning the application

The first step in application planning is identifying the various tasks that the application needs to perform. The second step is to determine how these tasks are logically related and to identify the objects to which each task will be assigned. This is followed by classifying the events needed to trigger an object into executing its assigned tasks. Lastly, a sketch of the GUI is prepared. A flowchart of the CHRA tool is shown in Figure 3-5.

3.6.2 Building the Graphical User Interface (GUI)

The application designed is based on object-oriented programming. It has been designed using multiple Graphical User Interfaces. GUI is easy to use and users can easily insert data into the tool to be analyzed by the software by just a few clicks.

3.6.3 Writing the computer program

The application is written in standard Microsoft Visual Basic 6.0 and distributed in object format with the source code. After creating the interface for the application, it is necessary to write the code that defines the applications behavior.

3.6.4 Software Validation and Verification

Validation and verification of computational simulations is the most important step to build confidence and quantify results. Verification assesses the accuracy of a solution to a computational model. Validation on the other hand, is the assessment of the accuracy of a computational simulation by comparison with experimental data.

The validation process confirms that a correct system is being made (i.e., the system requirements are correct, complete, consistent, operationally and technically feasible and verifiable). The verification process ensures that the design solution has met the systems requirement and that the system is ready for use in the operational environment for which it is intended.

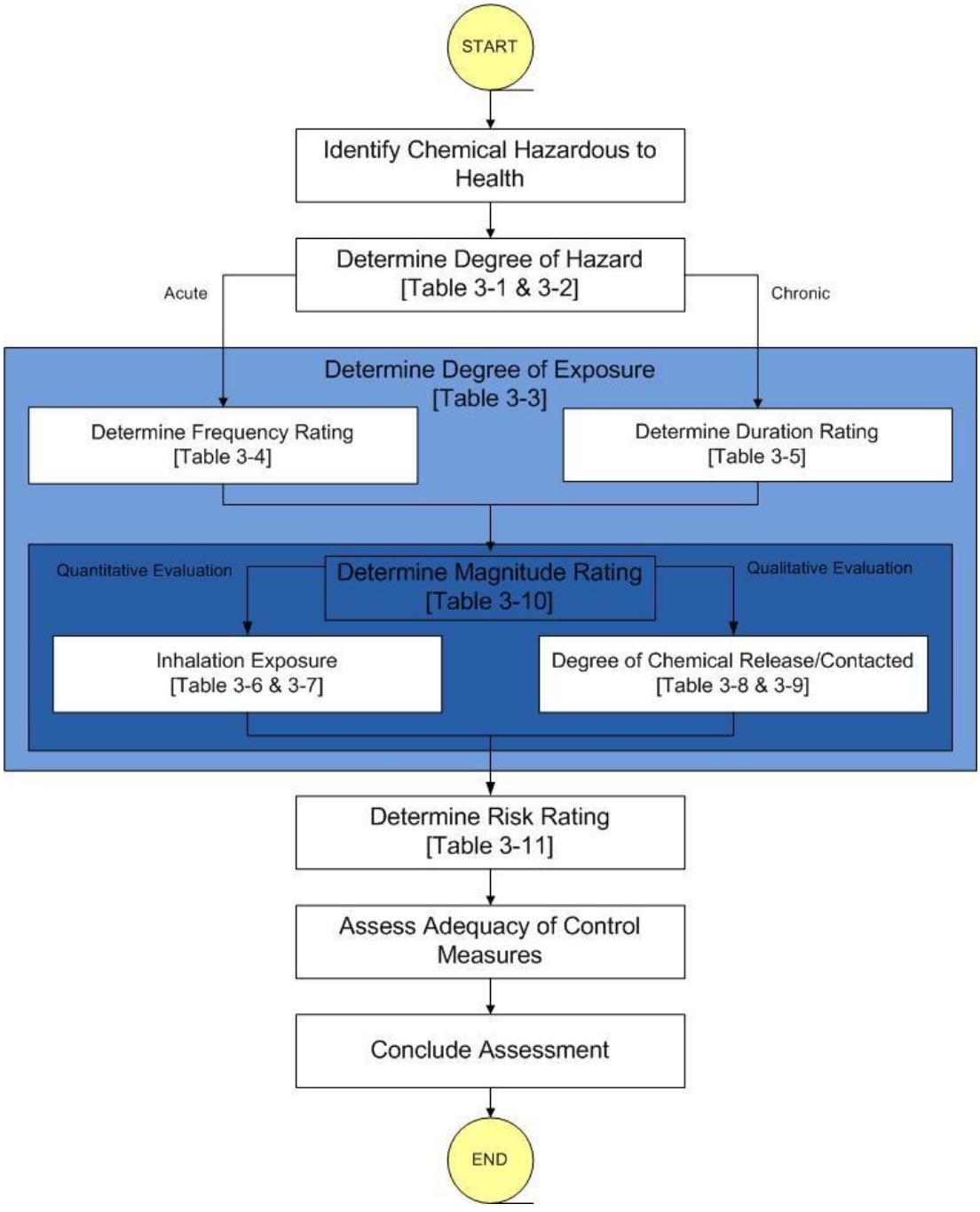
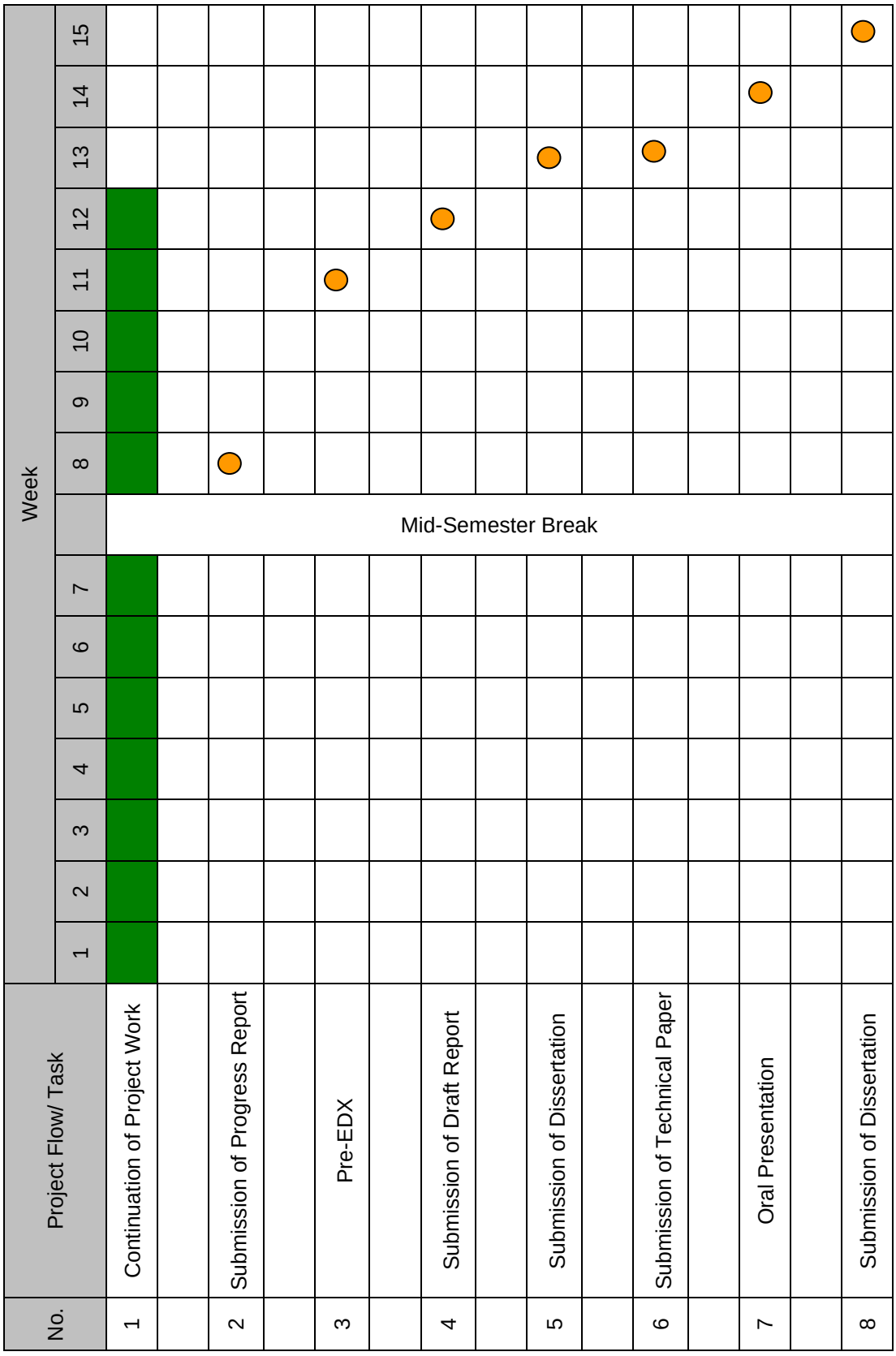


Figure 3-5 Flowchart of Chemical Health Risk Assessment tool

3.7 Gantt chart for Final Year Project II

Table 3-13 Gantt chart for FYP II



CHAPTER 4: RESULTS AND DISCUSSION

This chapter explains and discusses the results obtained from the current research in the context with the findings of earlier studies. The Chemical Health Risk Assessment tool has been successfully developed and implemented in an interactive Visual Basic (VB) environment. The software is designed to be user-friendly to simulate the risk assessment

4.1 Software Introduction Interface

After accessing the software, the interface shown below (Figure 4-1) would appear on the screen. User would then be able to choose between determining the hazard rating or exposure rating first. When the user has selected his choice it will lead directly to the chosen rating interface.

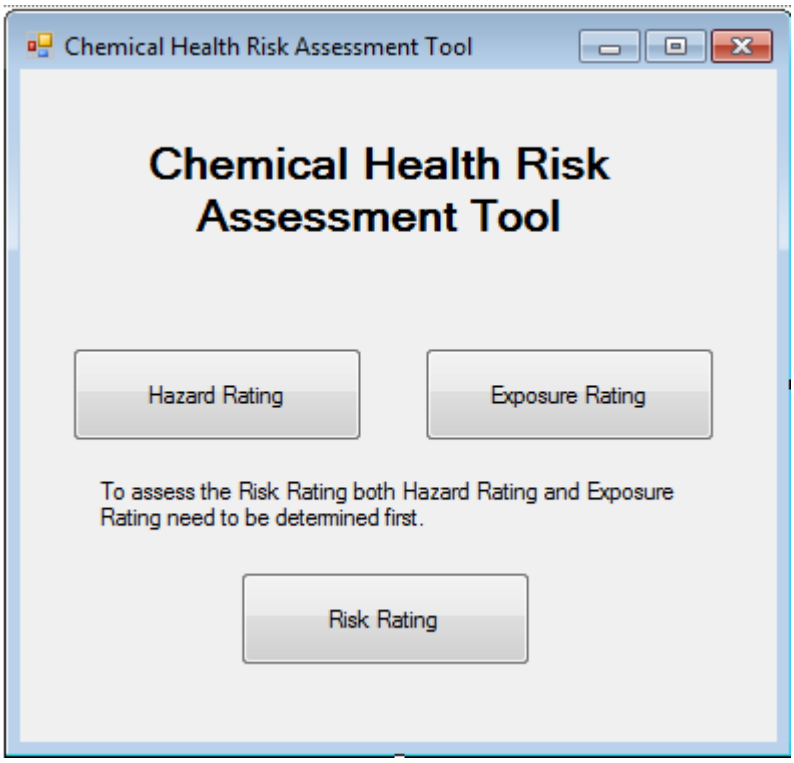


Figure 4-1 Software introduction interface

If the user chooses the risk rating command button before completing the assessment of the hazard rating and exposure rating first, the software will generate a prompt message to remind the user to complete the said assessment (Figure 4-2).

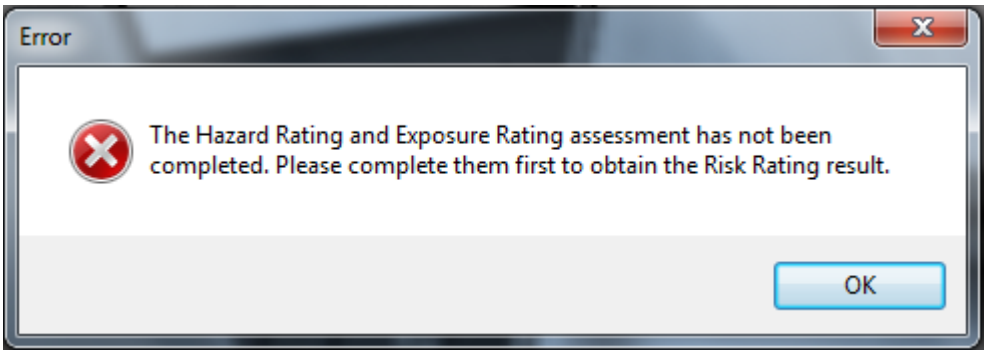


Figure 4-2 Error message generated by CHRAT

4.2 Hazard Rating Interface

Once the user has chosen hazard rating on the introduction interface, the user will be asked to select between two methods of assessing the hazard rating which are basing it on hazard categories or risk phrases.

4.2.1 Hazard Rating based on Hazard Categories Interface

If hazard categories is chosen, the application will gain access to the hazard rating based on hazard categories interface and displays it (Figure 4-3). The user will have to fill in the name of the chemical first before gaining access to the choices. User can only choose one option. Once the option has been chosen and the necessary fields are filled in (if necessary) the user can click the Result button to obtain the hazard rating. If the user failed to do so an error message will be generated to remind the user to complete the assessment (Figure 4-4).

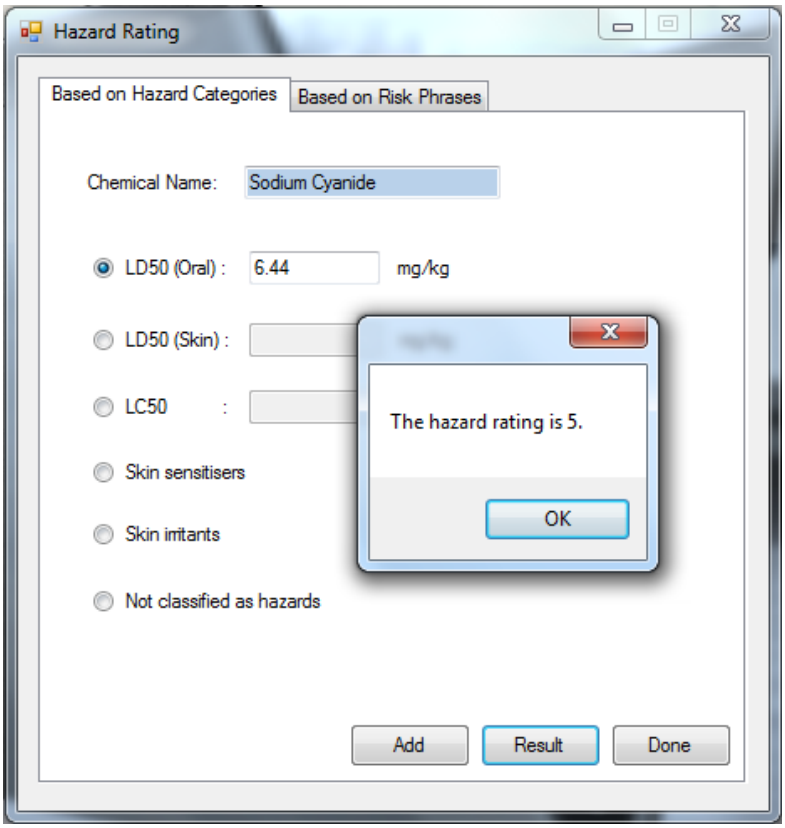


Figure 4-3 Hazard rating based on hazard categories interface

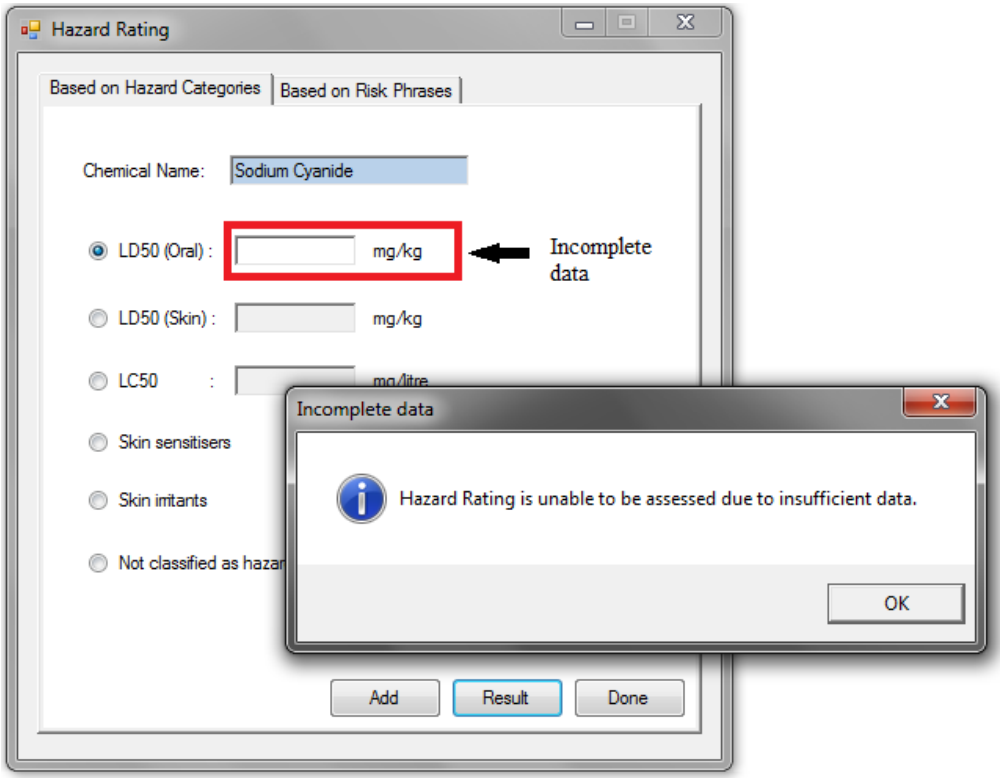


Figure 4-4 Reminder to complete the fields

4.2.2 Hazard Rating based on Risk Phrases Interface

If risk phrases is chosen, the application will gain access to the hazard rating based on risk phrases interface and displays it (Figure 4-5). The user can only choose one option.

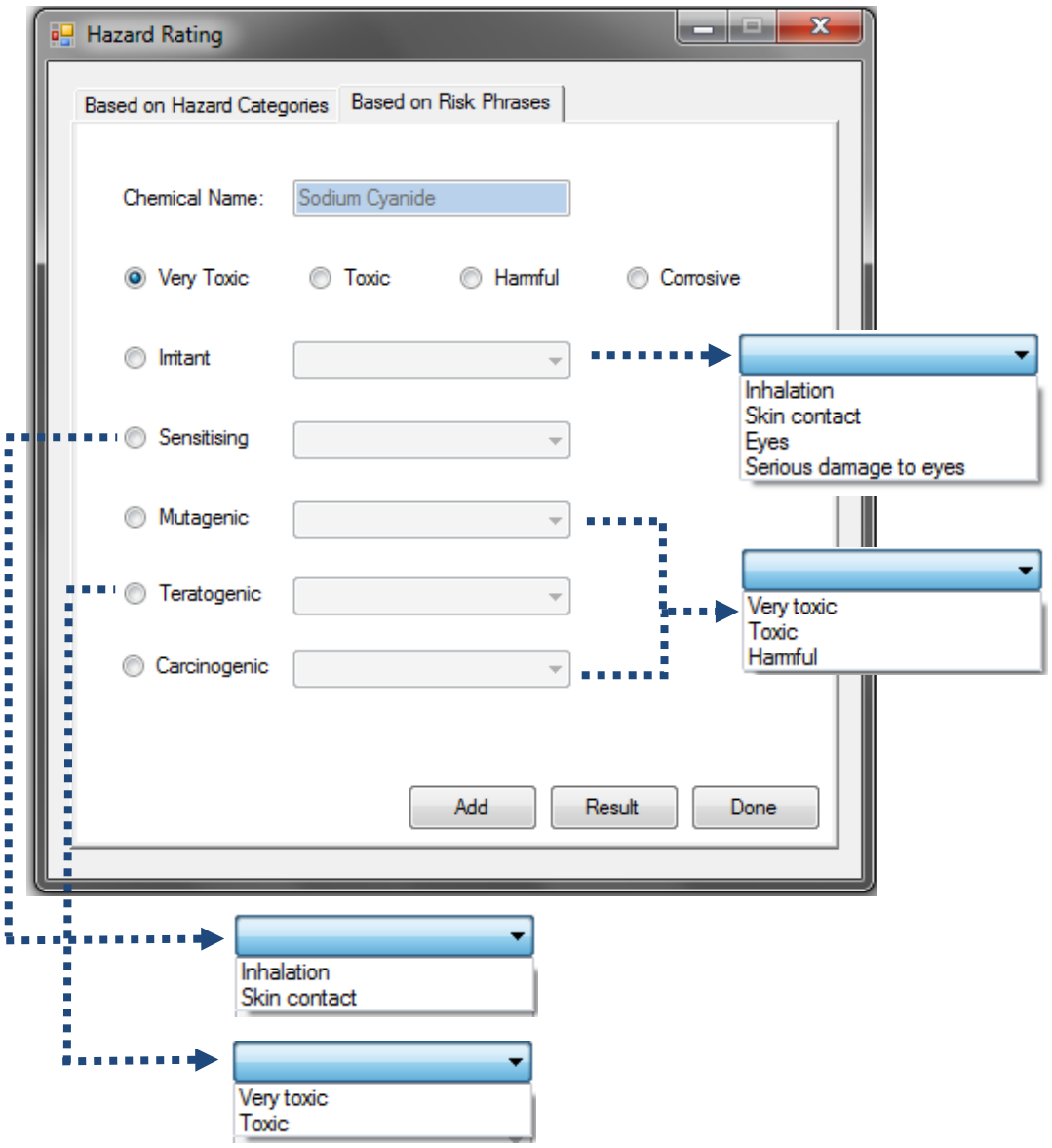


Figure 4-5 Hazard rating based on risk phrases interface

The user will have to fill in the name of the chemical that the workers are being exposed to as well as the required properties. Once all the necessary fields have been filled in the user will be able to click on the Result command button to obtain the hazard rating. If the user has failed to do so, an error message will be generated by

the software to alert the user about the missing field(s) which has not been keyed in (Figure 4-4).

The Add command button allows the user to add properties of another chemical if the user wish to assess the risk of exposure to chemical mixtures. The Return command button will bring the user to the introduction interface of the software.

4.3 Exposure Rating Interface

4.3.1 Frequency Rating Interface

Once the exposure rating command button on the general interface (Figure 4-1) is click by the user the frequency and duration rating interface will be shown. User will be able to choose between assessing the frequency of exposure or the duration of exposure. If frequency of exposure is chosen the application will gain access to the frequency rating interface (Figure 4-6). The user will be required to choose any one of the frequency of exposure that best suits the situation.

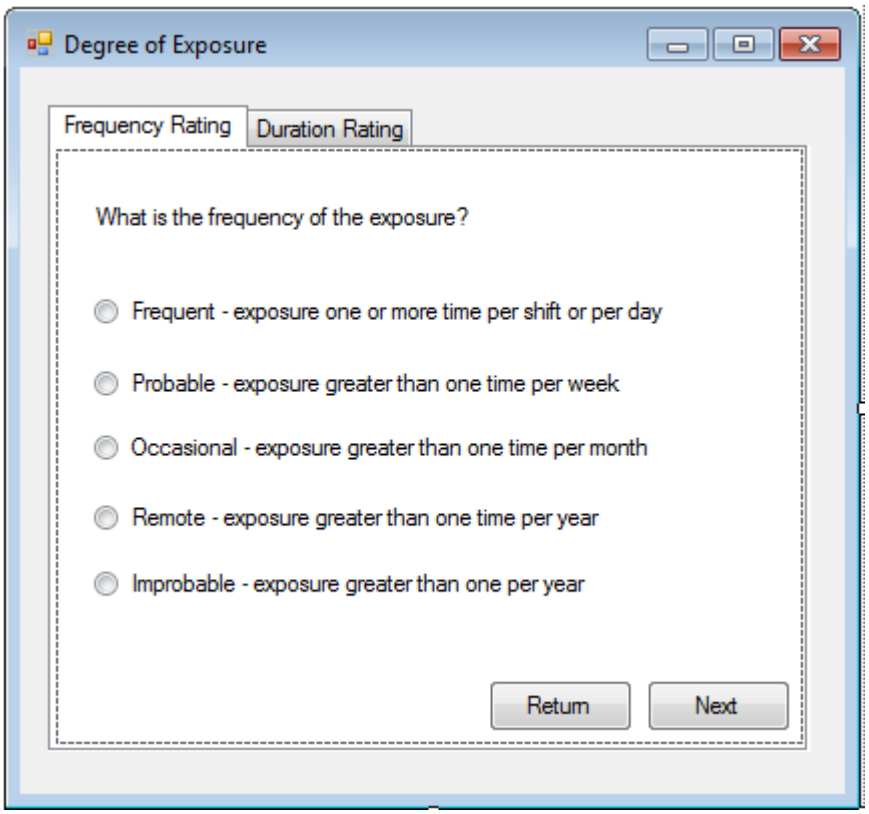


Figure 4-6 Frequency rating interface

4.3.2 Duration Rating Interface

If the user chooses to assess the duration of exposure instead, the duration rating interface will be displayed (Figure 4-7). The user will be required to fill in the value for the number of exposure per week as well as the average duration of exposure. The software will then use these values to calculate the total duration of exposure per week.

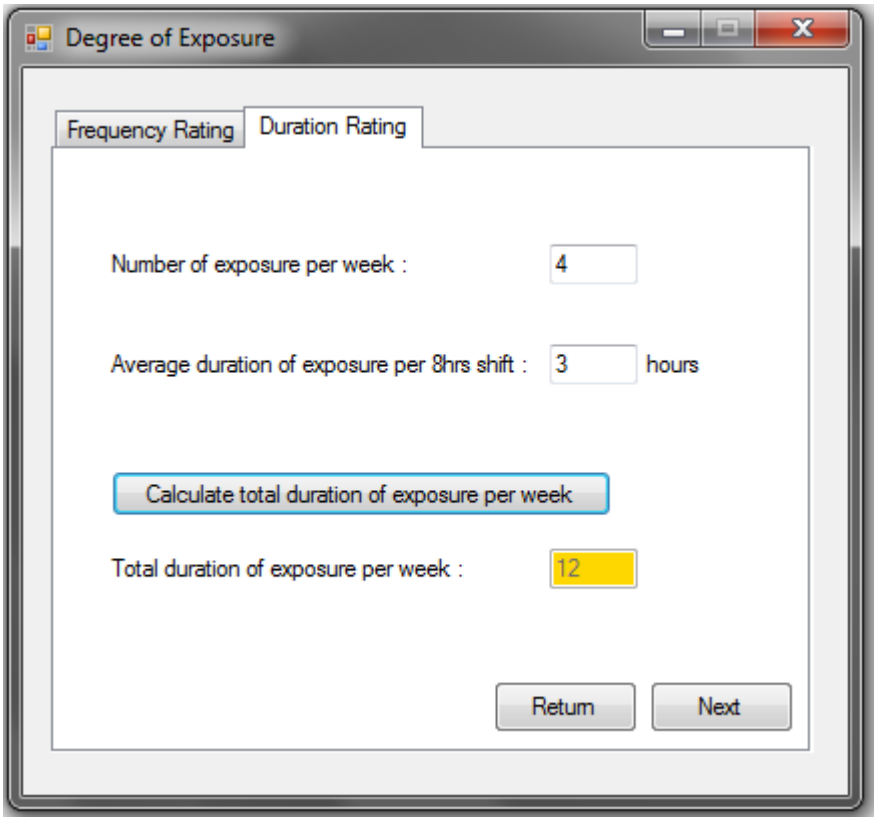


Figure 4-7 Duration rating interface

Once the user has filled in all the necessary fields, the user can click on the Next button to continue with the assessment which is determining the intensity or magnitude rating. If the user failed to do so, clicking the Next button will generate an error message to remind the user to fill in the necessary data (Figure 4-8). If the Return command button is chosen, the user will be directed to the introduction interface.

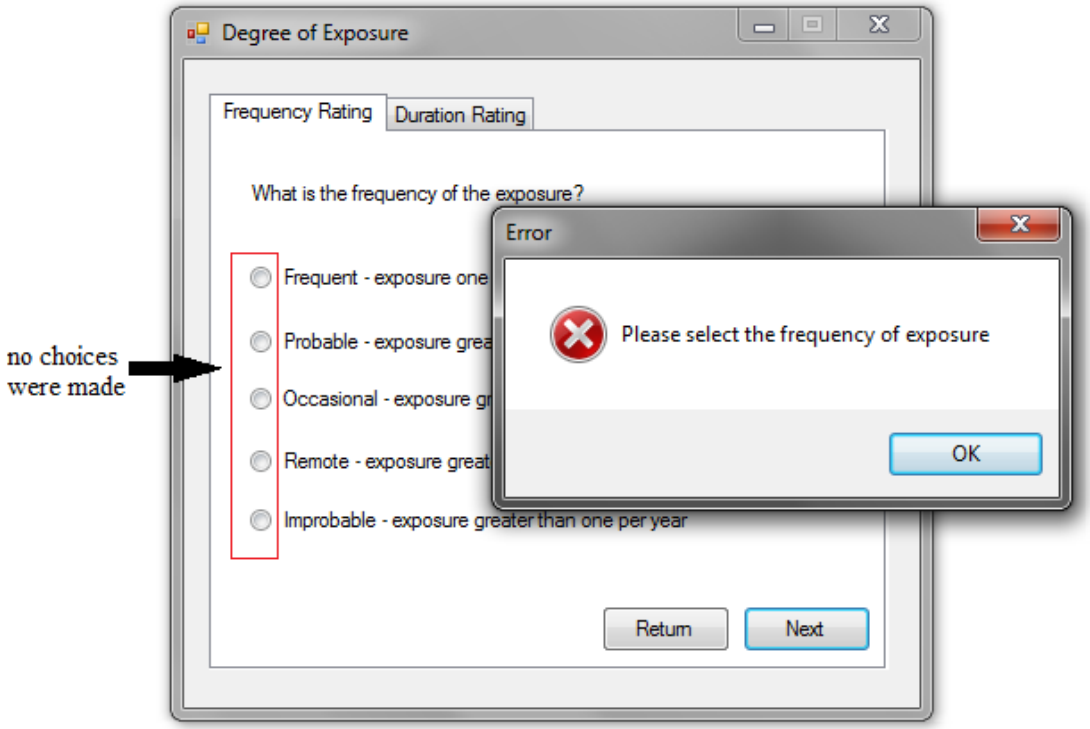


Figure 4-8 Error message generated

4.3.3 Intensity or Magnitude Rating Interface

After the frequency or duration rating has been assessed the user will be asked to assess the intensity or magnitude of exposure. For estimating exposure intensity or magnitude there are two possible ways, either quantitatively or qualitatively.

4.3.3.1 Quantitative Evaluation Interface

The quantitative evaluation interface requires the user to key in the concentration of the exposed chemical, the sampling time as well as the occupational exposure limit of the said chemical (Figure 4-9). The chemical name would have already been provided by the user during the hazard rating assessment and does not need to be filled in by the user again.

If the user has filled in all the necessary fields then the user would be able to click the Result command button which will evaluate the exposure rating. If the user failed to do so, an error message will be generated by the software to remind the user to fill in the required field(s) (Figure 4-8). If the user does not have the PEL value for the

said chemical the user may click on the hyperlink List of Chemical's Permissible Exposure Limit which will open a PDF file containing the list of PEL values for common chemicals (Table A1).

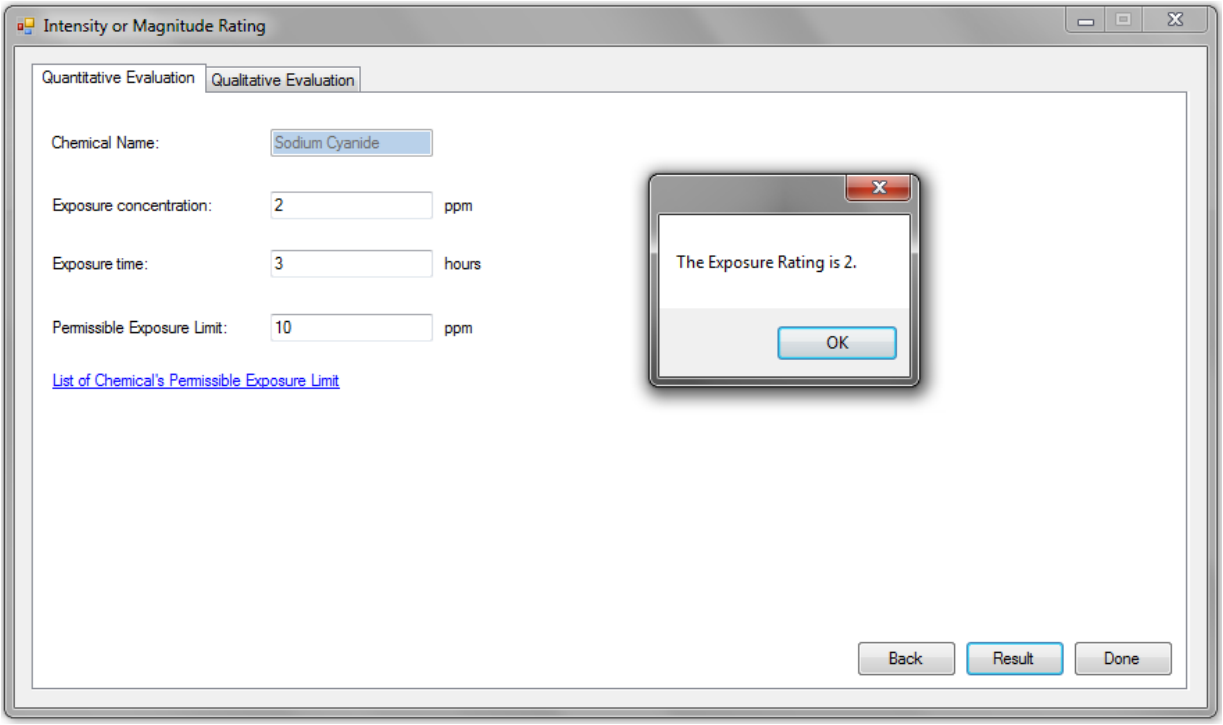


Figure 4-9 Quantitative evaluation interface

4.3.3.2 Qualitative Evaluation Interface

The qualitative evaluation interface will require the user to determine both the degree of chemical release or presence and the degree of chemical absorbed or contacted (Figure 4-10). The degree of chemical release or presence is divided to three categories which are low, moderate and high. The user is given the choice to choose only one of the categories that best suit the current situation. The user would be able to reconfirm the assessment by checking the Solvent Drying Time (Appendix A2) and Solvent Odour Thresholds (Appendix A3) through the link provided at the bottom of the interface.

The degree of chemical absorbed or contacted are also divided to three categories; low, moderate and high. The user can only choose one that best describes the situation at hand. A link is provided for more information on determining the degree

of physical activities and breathing rate (Appendix A4) to assist the user on deciding which category to choose.

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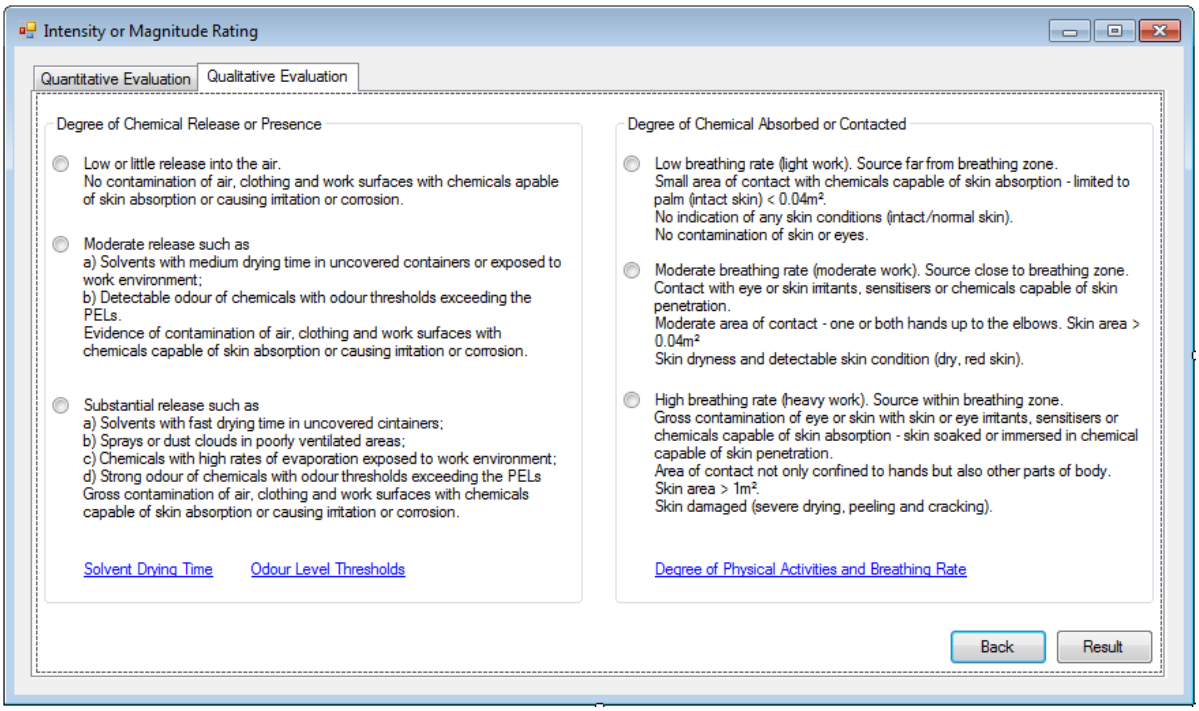

Figure 4-10 Qualitative evaluation interface

Both this assessment will be used to determine the intensity or magnitude rating. Once the user has chosen the category for both degrees, the user will be able to click on the Result button command to obtain the exposure rating. If no choices are made, the software will generate an error message prompting the user to complete the assessment (Figure 4-8).

If the Back command button is click it will bring the user back to the frequency or duration rating interface.

4.4 Risk Rating

Once the user has completed both the hazard rating and exposure rating assessment, the user would be able to click on the Risk Rating button on the general interface. This will prompt the software to produce a risk rating report based on the assessment that the user has done. The report will be presented in Microsoft Office Word

document and the user can choose to save the report depending on the user's preferences (Figure 4-11).

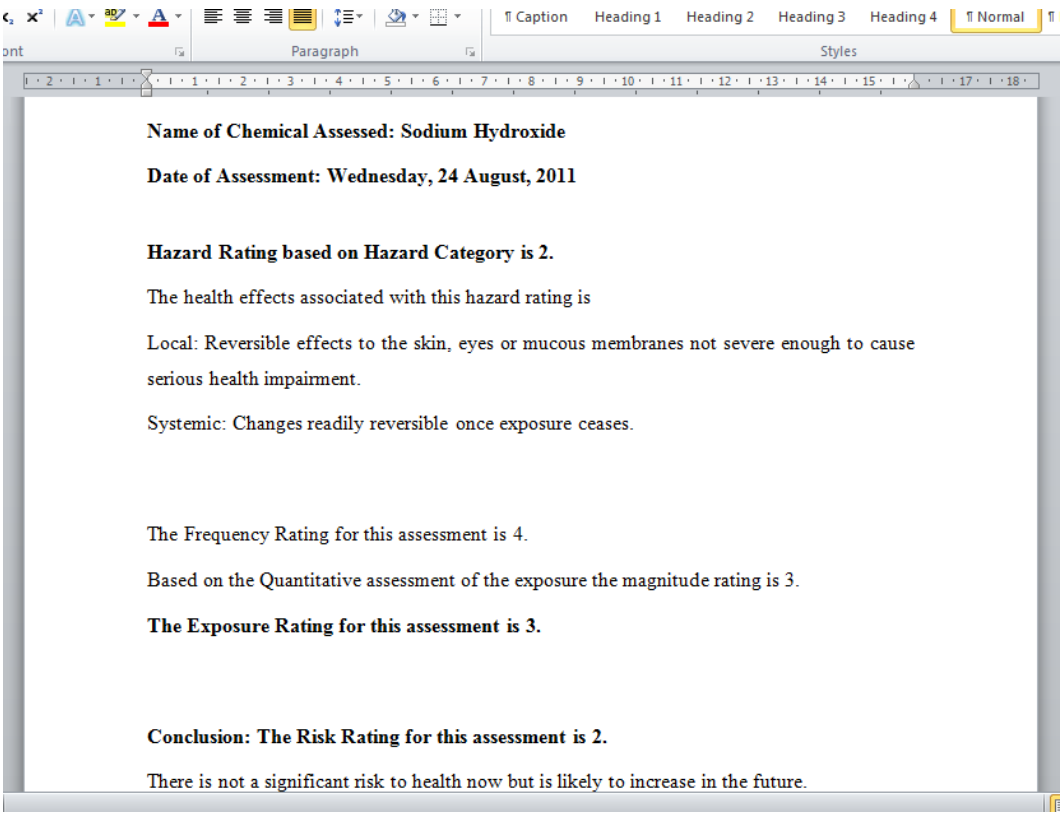

Figure 4-11 Risk rating assessment report

4.5 Case Study

The CHRAT software is to be applied in assessing the risk rating of an exposure to hazardous chemical. Currently no software has been developed to be compared with CHRAT. Therefore a case study was done to compare the result of CHRAT with the current risk rating assigned through manual chemical health risk assessment.

The chosen case study is to assess to risk to health of exposure to chemicals found in Lab 04-01-13, Block 4, Universiti Teknologi PETRONAS. Currently the lab is equipped with proper ventilation system, appropriate signs to identify specific hazards within an area and the use of personal protective equipment.

The CHRAT software gave a risk rating of 2 where the risk is found to be significant and could increase in the future due to:

- Undetected deterioration in the efficiency of control measures.
- Plant, equipment, personal protective equipment or system failure.
- Human error, from lack of awareness or inadequate training.
- A significant increase in the quantity of chemical used.

It can be concluded that the results obtained from CHRAT has a good agreement with the current risk rating assigned to Lab 04-01-13.

CHAPTER 5: CONCLUSION

Workers are exposed to chemicals on a daily basis especially in process industries. This exposure can cause minor and major effects to the health of the worker. A chemical health risk assessment is required at all work place to assess the risk to health from exposure to chemicals at work. However, this manual assessment is difficult to apply mainly because of the following reasons: (i) calculations done manually can cause absolute error, (ii) manually browsing through CSDS to identify hazard information for the candidate chemical can be tedious thus resulting in difficulty to keep track of them (iii) a CHRA requires step by step procedures that need to be carried out by an assessor which would be time consuming and (iv) it requires an assessor who is an expert in the field to do the assessment manually. For these reasons, the assessment is best carried out by using a developed software.

This report describes the stages of the software's development. The Chemical Health Risk Assessment Tool was developed using Visual Basic (VB) programming language. This tool allows the user to assess the risk rating of an exposed chemical through the assessment of its hazard and exposure rating. The hazard rating can be assessed through two ways; hazard rating based on hazard categories and hazard rating based on risk phrases. The exposure rating is obtained from assessing the frequency/duration rating and the intensity or magnitude rating of the exposed chemical. The risk rating obtained gives the user adequate control measures and steps that need to be taken by the user to ensure the safety of all the people.

The result of the CHRAT is compared with existing manual chemical health risk assessment as there is currently no developed software. It is proven that the results are consistent with no significant deviation.

The Chemical Health Risk Assessment tool is practical and feasible because it is user-friendly, able to function as a stand-alone application and it is compatible with all windows operating system. In addition, Malaysian standards and regulations are incorporated into the developed tool, whereby users are able to compare their results to the risk tolerability limit for Malaysia.

CHAPTER 6: RECOMMENDATIONS

1. Develop a chemical database containing required information for input data (LC_{50}, LD_{50}, PEL etc.) at which user may add, delete and update them if necessary.

REFERENCES

ALOHA, 2007. User's Manual, U.S. Environmental Protection Agency, Washington. Retrieved 2nd September 2010, http://www.epa.gov/swercepp/cameo/pubs/ALOHAManual.pdf.

Anderson, E.L., and Albert, R.E., 1999. *Risk Assessment and Indoor Air Quality*, Lewis Publishers, USA.

Arunraj, N.S. and Maiti, J., 2009. A methodology for overall consequence modeling in chemical industry. *Journal of Hazardous Materials*, 169(2009), pp. 556-574.

Ballantyne, B., Marrs, T., and Turner, P. 1993. *General and Applied Toxicology, Vol. 2*, Stockton, Stockton Press, pp 1069-1158.

Bisesi, M.S., 2003. *Industrial Hygiene Evaluation Methods, Second Edition*, Lewis Publishers, USA.

Boss, M.J., and Day, D.W., 2001. *Air Sampling and Industrial Hygiene Engineering*, CRC Press LLC, USA.

Dikshith T.S.S., 2009. *Safe Use of Chemicals, A Practical Guide*, Taylor and Francis Group, LLC, USA.

DNV (Det Norske Veritas), 2010. SAFETI QRA – Managing your process industry risks safely and responsibly. Retrieved 2nd September 2010, http://www.dnv.com/services/software/products/safeti/safetiqra/index.asp

DOSH (Department of Occupational Safety and Health), 2000. *Assessment of the Health Risks Arising from the Use of Hazardous Chemicals in the Workplace*. Ministry of Human Resources, Malaysia.

Draggan, S., 2007. *Risk assessment of chemical substances*, National Library of Medicine. [First published in the Encyclopedia of Earth October 4, 2006; Last revised May 20, 2007; Retrieved August 30, 2010] http://www.eoearth.org/article/Risk_assessment_of_chemical_substances

EC, 1996. Technical Guidance Document in Support of the Commission Directive 93/67/EEC on Risk assessment for New Notified Substances and Commission Regulation 1488/94/EEC on Risk assessment for Existing Chemicals. Brussels, European Comission.

El-Harbawi, M., 2006. *Design and Development of an Integrated Chemical Accident System Software for Monitoring Risk Potential of Hazard Installation*, Ph.D. Thesis, Universiti Putra Malaysia.

EU-OSHA, 2009. European Agency for Safety and Health at Work Annual Report 2009.

Extoxnet. The Extension Toxicology Network. 1993. Toxicology Information Briefs. *Risk Assessment Background*, Retrieved 6th September 2010 http://extoxnet.orst.edu/tibs/riskasse.htm

Griffin, R.D., 2009. *Principles of Hazardous Materials Management, Second Edition*, Taylor and Francis Group, LLC, USA.

HSEES (Hazardous Substances Emergency Events Surveillance), 2000. Agency for Toxic Substances and Disease Registry, Hazardous Substances Emergency Events Surveillance Annual Report, US Department of Health and Human Services, Atlanta, 1997.

Khan, F.I., Abbasi, S.A., (1998). Techniques and methodologies for risk analysis in chemical process industries, *Journal of Loss Prevention in the Process Industries*, 11 (4) (1998), pp.261–277.

Khan, F.I., Abbasi, S.A., (1999). HAZDIG: a new software package for assessing the risks of accidental release of toxic chemicals, *Journal of Loss Prevention in the Process Industries*, 12 (1999), pp.167–181.

Leeuwen, C.J., Vermeire, T., and Vermeire, T.G., 2007. *Risk Assessment of Chemicals: An Introduction*, Springer, USA

Manassaram, D.M., Orr, M. F., and Kaye, W.E., 2003. Hazardous substances events associated with the manufacturing of chemicals and allied products. *Journal of Hazardous Materials*, 104(2003), pp.123-135.

Plog, B.A., and Quinlan, P.J., 2002. *Fundamentals of Industrial Hygiene, Fifth Edition*, National Safety Council, USA.

Rhomberg, L. R., 1997. A Survey of Methods for Chemical Health Risk Assessment Among Federal Regulatory Agencies, Report Prepared for the National Commission on Risk Assessment and Risk Management

Scala, R.A., 1991. Risk assessment. In: Amdur MO, Doull J, & Klaasen CD, ed. Casarett and Doull's Toxicology. 4th edition, New York, Oxford, Beijing, Frankfurt, Sao Paulo, Sydney, Tokyo, Toronto, Pergamon Press, pp 985-996

Somers, E., 1987. *Making decisions with numbers*. Regul Toxicol Pharmacol, 8: 35-42.

UK HSE, 1989. Health and Safety Executive. *Quantified risk assessment: Its input to decision making*. London, Her Majesty's Stationery Office (HMSO).

Somers, E., 1993. *Perspectives on Risk Management*. [Presented at Managing Risks to Life and Health Meeting, 18 October]. Ottawa, Royal Society of Canada.

US NAS (1983) National Academy of Science: Risk Assessment in the Federal Government: Managing the Process. National Research Council, Committee

on the Institutional Means for Assessment of Risks to Public Health. Washington DC, National Academy Press, pp 1-50.

WHO (World Health Organization), 1999. Environmental Health Criteria 210: Principles for the Assessment of Risks to Human Health from Exposure to Chemicals. Geneva:World Health Organization.

WHO (World Health Organization), 2004. Fourth Ministerial Conference on Environment and Health "The future for our children", Budapest, Hungary, 23–25 June 2004. Copenhagen: World Health Organization Regional Office for Europe; 2004. Available from http://www.euro.who.int/budapest2004.

APPENDIX A

Table A1 Solvent Drying Time

SOLVENT	DRY TIME RELATION	DEGREE OF DRYING
Ethyl Ether C.P	1	FAST
Petrolene	1.8	
Carbon Tetrachloride	1.9	
Acetone	2	
Methyl Acetate 2.0	2	
Ethyl Acetate 85-88%	2.5	
Trichlorethylene	2.5	
Benzol (Industrial)	2.6	
Methyl Ethyl Ketone	2.7	
Isopropyl Acetate 85%	2.7	
Ethylene Dichloride	3	
Solvsol 19/27	3.7	
Ethylene Chloride	4	
Propylene Dichloride	4.1	
Troluoil	4.1	
Methanol	5	MEDIUM
Toluol (Industrial)	5	
Methyl Propyl Ketone	5.2	
V.M & P	5.8	
Perchlorethylene	6	
Nor. Propyl Acetate	6.1	
Sec. Butyl Acetate	6.5	
Solox (Anhydrous)	6.5	
Isobutyl Acetate 90%	7	
Apco thinner	7	
Ethyl Alcohol, Den. No. 1	7.7	
Solox	8	
Isoproply Alcohol 99%	8.6	
Nor. Propyl Alcohol	9.1	
Solvsol 24/34	9.4	
Nor. Butyl Acetate	9.6	
Diethyl Carbonate	9.6	
Methyl Butyl Ketone	9.7	
Xylol (Industrial)	9.7	
Monochlor Benzol	10	
Tertiary Butyl Alcohol	11.9	
Sec. Butyl Alcohol	14	

SOLVENT	DRY TIME RELATION	DEGREE OF DRYING
Sec. Amyl Acetate	16.9	
Amyl Acetate	17.4	
Isobutyl Alcohol	17.7	
Methyl Cellosoive	18	
Butyl Propionate	18	
Pentacetate	20	
Turpentine	20	
Butanol	21	
Sec. Amyl Alcohol	25	
2-50- W Hi-Flash Naphtha	27.5	
Amyl Alcohol (Fusel Oil)	32.1	
Di Isopropyl Ketone	33.9	
Ethyl Cellosolve	36.2	SLOW
Odorless Mineral Spirits	38.6	
Ethyl Lactate	40	
Sec. Hexyl Alcohol	41.7	
Solvsol 30/40	43.2	
Pentasol	45	
Hi-Solvency Mineral Spirits	46.7	
No. 380 Mineral Spirits	47	
No. 10 Mineral Spirits	55	
Distilled Water	60	
Apco No. 125	60.5	
Cellosolve Acetate	65	
Sec. Butyl Lactate	73	
Sec. Hexyl Acetate	76.5	
Butyl Cellosolve	88.5	
Dipentene	89.2	
No. 140 Thinner	91	
Octyl Acetate	152.5	
Isobutyl Lactate	156.5	
Hexalin	177.5	
Solvsol 40/50	270	NIL
Methyl Hexalin	276.5	
Butyl Lactate	339	
Excellence	384	
Special Heavy Naphtha	403	
Dispersol	425	
No. 50 Kerosene	626.7	
Triethylene Glycol	Over 5200.0	
Dibutyl Phthalate	Over 5200.0	

Table A2 Odour Level Thresholds

	**TLV (ppm)	*OT (ppm)	OT/TLV
Acetaldehyde	c25	0.5	0.02
Acetic acid (glacial)	10	2	0.2
Acetone	750	2	0.003
Acrolein	0.1	2	20
Acrylonitrile	2	20	10
Allyl alcohol	2	2	1
Ammonia	25	20	0.8
Aniline	2	1	0.5
Arsine	0.05	0.5	10
Benzene	10	2	0.2
Butane	800	5000	6.25
2-Butanone (MEK)	200	5	0.025
n-Butyl Acetate	150	10	0.07
Carbon disulphide	10	0.1	0.01
Carbon tetrachloride	5	70	14
Chlorine	0.5	3	6
Chloroform	10	100	10
Cyclohexane	300	300	1
Dioxane	25	150	6
Ethyl Acetate	400	10	0.025
Ethyl alcohol	1000	5	0.005
Ethyl ether	400	1	0.0025
Ethylene oxide	1	1	1
Formaldehyde	c0.3	1	3.3
Hexone (MIBK)	50	0.5	0.01
Hydrogen chloride	c5	10	2
Hydrogen cyanide	c4.7	1	0.2
Hydrogen selenide	0.05	0.5	10
Hydrogen sulphide	10	0.0002	0.00002
Isopropyl alcohol (IPA)	400	50	0.125
Methyl alcohol	200	10	0.05
Methyl methacrylate	100	0.2	0.002
Methylene chloride	50	200	4
Nitrobenzene	1	0.005	0.005
Nitrogen dioxide	3	1	0.3
Perchloroethylene (tetrachloroethene)	25	5	0.2
Phenol	5	0.3	0.06
Phosgene	0.1	0.5	5
Phosphine	0.3	0.02	0.07
Pyridine	5	0.01	0.002
Stibine	0.1	0.05	0.5
Styrene, monomer	50	0.05	0.001
Toluene	50	2	0.04
Toluene-2,4-diisocyanate	0.005	0.2	40
Trichloroethylene (TCE)	50	20	0.4
Vinyl toluene	50	25	0.5
Xylene	100	0.5	0.005

* Odour threshold (Ref.: Fundamentals of Industrial Hygiene)

** Threhold limit values (Ref.: TLV s and BEIs -ACGIH Handbook)

Table A3 Degree of physical activities and breathing rate

PHYSICAL ACTIVITY	BREATHING RATE
Light Work • Sitting, moderate arm and trunk movements (E.g. desk work, typing) • Sitting, moderate arm and leg movements (E.g. playing organ, driving car in traffic) • Standing, light work at machine or bench, mostly arms	LOW
Moderate Work • Sitting, heavy arms and legs movement • Standing, light work at machine or bench, some walking about • Standing, moderate work at machine or bench, some walking about • Walking about, with moderate lifting or pushing	MEDIUM
Heavy Work • Intermittent heavy lifting, pushing or pulling (E.g. pick and shovel work) • Hardest sustained work	HIGH

Table A4 List of Permissible Exposure Limits for Chemical Contaminants

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
75070	Acetaldehyde	25	45	C
64197	Acetic acid	10	25	40 ppm
108247	Acetic Anhydride	5	20	C
67641	Acetone	500	1200	3000 ppm
75868	Acetone cyanohydrin as CN	4.7	5	C
75058	Acetonitrile	40	70	
98862	Acetophenone	10	49	
53963	2-Acetylaminofluorene; N-fluoren-2-yl acetamide;			
74862	Acetylene	(h)		
540590	Acetylene dichloride; see 1,2Dichloroethylene			
79276	Acetylene tetrabromide:1,1,2,2-tetrabromoethane	1	14	
79345	Acetylene tetrachloride; see 1,1,2,2-Tetrachloroethane			
50782	Acetylsalicylic acid (Aspirin)		5	
107028	Acrolein	0.1	0.25	C
79061	Acrylamide	--	0.03	
79107	Acrylic acid	2	5.9	
107131	Acrylonitrile; see Section 5213	2	4.5	
124049	Adipic acid	--	5	
111693	Adiponitrile	2	8.8	
309002	Aldrin; 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-			
	hexahydro-endo-1,2-exo-5,8-dimethanonaphthalene	--	0.25	
107186	Allyl alcohol	0.5	1.25	
107051	Allyl chloride	1	3	
106923	Allyl glycidyl ether; AGE	0.2	0.93	
2179591	Allyl propyl disulfide	2	12	
1344281	Alumina; see Particulates not otherwise regulated			
	Aluminum, alkyls (not otherwise classified)	--	2	
	Aluminum soluble salts	--	2	
	Aluminum metal and oxide	--		
	Total dust	--	10	
	Respirable fraction[(n)]	--	5[(n)]	
	Aluminum pyro powders	--	5	
	Aluminum welding fumes	--	5	
300925	Aluminum distearate	--	10	
7047849	Aluminum stearate	--	10	
637127	Aluminum tristearate	--	10	
1300738	Aminodimethylbenzene; see Xylidene			
92671	4-Aminodiphenyl			
141435	2-Aminoethanol; see Ethanolamine			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
91598	2-Aminonapthalene; see beta-Naphthylamine,			
504290	2-Aminopyridine	0.5	2	
61825	Amitrole	--	0.2	
7664417	Ammonia	25	18	
3825261	Ammonium perfluorooctanoate	--	0.1	
12125029	Ammonium chloride fume	--	10	
1002897	Ammonium stearate	--	10	
7773060	Ammonium sulfamate	--		
	Total dust	--	10	
	Respirable fraction[(n)]	--	5	
620111	3-Amyl acetate; See Pentyl acetate			
628637	n-Amyl acetate; See Pentyl acetate			
626380	sec-Amyl acetate (all isomers and mixtures); See Pentyl acetate			
625161	tert-Amyl acetate; See Pentyl acetate			
62533	Aniline	2	7.6	
29191524	Anisidine (ortho and para isomers)	0.1	0.5	
	Antimony and compounds, as Sb	--	0.5	
86884	ANTU; 1-(1-naphthyl)-2-thiourea; Bantu; Rattrack	--	0.3	
7440371	Argon	(h)		
7440382	Arsenic and inorganic arsenic compounds; see also		0.01	
	Section 5214			
	Arsenic, organic compounds, as As	--	0.2	
7784421	Arsine; AsH3	0.05	0.2	
1332-21-4	Asbestos (including actinolite, amosite			
	anthophyllite, chrysotile, crocidolite, and tremolite);			
	see Section 5208			
8052424	Asphalt (petroleum) fumes	--	5	
1912249	Atrazine	--	5	
86500	Azinphos methyl; o,o-dimethyl S-(4-oxo-1,2,3-	--	0.2	
	benzotriazin-3(4H)-ylmethyl) phosphorodithioate			
3333526	2,2'-Azobisisobutyronitrile decomposition product,			
	see Tetramethyl succinonitrile			
7440393	Barium, soluble compounds, as Ba	--	0.5	
7727437	Barium sulfate; see Particulates not otherwise regulated			
17804352	Benomyl			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
71432	Benzene; see also Section 5218	1		
92875	Benzidine; 4,4'-diaminobiphenyl, see Section 5209			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
71432	Benzol; see Benzene			
106514	D-Benzoquinone; see Quinone			
98884	Benzoyl chloride	0.2	1.1	C
94360	Benzoyl peroxide; dibenzoyl peroxide	--	5	
140114	Benzyl acetate	10	61	
100447	benzyl chloride; alpha-chlorotoluene	1	5	
7440417	Beryllium, and beryllium compounds as Be	--	0.0002	0.25mg/m^3
92524	Biphenyl; diphenyl; phenylbenzene	0.2	1.5	
542881	Bis(chloromethyl) ether, see bis-Chloromethyl ether,			
	Section 5209			
3033623	Bis (Dimethylaminoethyl) ether (DMAEE)	0.05	0.328	
1304821	Bismuth telluride			
	Total dust	--	10	
	Respirable fraction[(n)]	--	5	
	Bismuth telluride (selenium-doped)	--	5	
	Borates, tetra, sodium salts			
	Anhydrous	--	5	
	Decahydrate	--	5	
	Pentahydrate	--	5	
1303862	Boron oxide	--	10	
10294334	Boron tribromide	1	10	C
7637072	Boron trifluoride	1	3	C
314409	Bromacil	1	10	
7726956	Bromine	0.1	0.7	C
7789302	Bromine pentafluoride	0.1	0.7	
74975	Bromochloromethane; see Chlorobromethane			
74964	Bromoethane; see Ethyl bromide			
75252	Bromoform; tribromomethane	0.5	5	
74839	Bromomethane, see Methyl bromide			
106945	1-bromopropane, n-propyl bromide	5	25	
75638	Bromotrifluoromethane; see Trifluorobromomethane			
106990	1,3-Butadiene (see also section 5201)	1	2.2	
106978	Butane	800	1900	
109795	1-Butanethiol; see Butyl mercaptan			
71363	1-Butanol; see n-Butyl alcohol			
78933	2-Butanone; see Methyl ethyl ketone			
111762	2-Butoxyethanol (EGBE)	20	97	
123864	n-Butyl acetate	150	710	
105464	sec-Butyl acetate	200	950	
540885	tert-Butyl acetate	200	950	
141322	Butyl acrylate	2	11	
71363	n-Butyl alcohol; 1-butanol	50	150	C
78922	sec-Butyl alcohol	100	305	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
75650	tert-Butyl alcohol	100	300	
109739	Butylamine	5	15	C
1189851	tert-Butyl chromate; di-tert-butyl			
	chromate, as CrO3	--	0.1	
	as Cr			
	(see also Sections 1532.2, 5206 & 8359)			
2426086	n-Butyl glycidyl ether; BGE;	25	0.005	
	1-butoxy-2,3-epoxypropane			
138227	n-Butyl lactate	5	135	
109795	n-Butyl mercaptan	0.5	25	
89725	o-sec-Butylphenol	5	1.5	
98511	p-tert-Butyltoluene	1	30	
7440439	Cadmium metal dust, as Cd			
	(see also Sections 1532 & 5207)	--	6.1	
	Cadmium, soluble salts, as Cd			
	(see also Sections 1532 & 5207)	--	0.005	
1306190	Cadmium oxide fume, as Cd			
	(see also Sections 1532 & 5207)	--	0.005	
7778441	Calcium arsenate; see Arsenic,inorganic (see			
	also Section 5214)			
471341	Calcium carbonate; see Particulates not otherwise regulated		--	
156627	Calcium cyanamide	--	0.5	
1305620	Calcium hydroxide	--	5	
1305788	Calcium oxide	--	2	
	Calcium silicate; see Particulates not otherwise regulated			
1344952	Calcium silicate (synthetic): see Particulates not otherwise regulated			
1592230	Calcium stearate	--	10	
7778189	Calcium sulfate; see Particulates not otherwise regulated			
76222	Camphor (synthetic)	--	2	
105602	Caprolactam dust	--	1	
105602	Caprolactam vapor	5	20	
2425061	Captafol	--	0.1	
133062	Captan	--	5	
63252	Carbaryl; 1-naphthyl N-methylcarbamate	--	5	
1563662	Carbofuran	--	0.1	
1333864	Carbon black	--	3.5	
124389	Carbon dioxide	5,000	9,000	
75150	Carbon disulfide	4	12	30 ppm
630080	Carbon monoxide	25	29	200 ppm
558134	Carbon tetrabromide	0.1	1.4	
56235	Carbon tetrachloride	2	12.6	200 ppm
75445	Carbonyl chloride; see Phosgene			
353504	Carbonyl fluoride	2	5	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
120809	Catechol; pyrocatechol	5	20	
9004346	Cellulose (paper fiber); see Particulates not otherwise regulated			
21351791	Cesium hydroxide		2	
57749	Chlordane; 1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-	--	0.5	
	tetrahydro-4,7-methanoindane			
8001352	Chlorinated camphene; toxaphene	--	0.5	
	Chlorinated diphenyl oxide	--	0.5	
7782505	Chlorine	0.5	1.5	
10049044	Chlorine dioxide	0.1	0.3	
7790912	Chlorine trifluoride	0.1	0.4	C
107200	Chloroacetaldehyde	1	3	C
78955	Chloroacetone	1	3.8	C
532274	alpha-Chloroacetophenone;phenacyl chloride	0.05	0.3	
79049	Chloroacetyl chloride	0.05	0.2	
108907	Chlorobenzene; monochlorobenzene	10	46	
2698411	o-Chlorobenzylidene malononitrile; OCBM	0.05	0.4	C
74975	Chlorobromomethane; bromochloromethane	200	1,050	
126998	2-Chloro-1,3-butadiene; see Chloroprene			
75456	Chlorodifluoromethane; Fluorocarbon 22	1,000	3,500	
53469219	Chlorodiphenyl (42% chlorine)	--	1	
11097691	Chlorodiphenyl (54% chlorine)	--	0.5	
106898	1-Chloro-2,3-epoxypropane; see Epichlorohydrin			
75003	Chloroethane; see Ethyl chloride			
107073	2-Chloroethanol; see Ethylene chlorohydrin			
75014	Chloroethylene, see Vinyl chloride, Section 5210			
67663	Chloroform; trichloromethane	2	9.78	
74873	Chloromethane, see Methyl chloride			
107302	Chloromethyl methyl ether; see Methyl			
	chloromethyl ether, Section 5209	0.001	0.005	
542881	bis-Chloromethyl ether, see also Section 5209			
100005	1-Chloro-4-nitrobenzene; see			
	p-Nitrochlorobenzene			
600259	1-Chloro-1-nitropropane	2	10	
76153	Chloropentafluoroethane	1,000	6,320	
76062	Chloropicrin; trichloronitromethane	0.1	0.7	
126998	Chloroprene; 2-chloro-1,3-butadiene	10	36	
598787	2-Chloropropionic acid	0.1	0.44	
2039874	o-Chlorostyrene	50	285	
95498	o-Chlorotoluene	50	250	
1929824	2-Chloro-6-(trichloromethyl)pyridine; see Nitrapyrin			
2921882	Chlorpyrifos	--	0.2	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	Chromite ore processing (chromate), as Cr	--	0.005	
	(see also Sections 1532.2, 5206 & 8359)			
7440473	Chromium metal	--	0.5	
	Chromium (II) compounds, as Cr	--	0.5	
	Chromium (III) compounds, as Cr	--	0.5	
	Chromium (VI) compounds, as Cr	--	0.005	0.1mg/m^3
	(see also Sections 1532.2, 5206 & 8359)			
14977618	Chromyl chloride	0.025	0.15	
2971906	Clopidol	--		
	Total dust	--	10	
	Respirable fraction	--	5	
	Coal (Bituminous) dust			
	<5% quartz, respirable fraction(n)	--	0.9	
	>5% quartz, respirable fraction(n)	--	0.1	
	Coal tar pitch volatiles(i)	--	0.2	
7440484	Cobalt, metal fume and dust, as Co	--	0.02	
	Cobalt carbonyl, as Co	--	0.1	
16842038	Cobalt hydrocarbonyl, as Co	--	0.1	
	Coke oven emissions, see Section 5211		0.15	
7440508	Copper metal fume, as Cu	--	0.1	
	Copper salts, dusts and mists, as Cu	--	1	
	Corundum, see Particulates not otherwise regulated			
	Cotton dust, see also Section 5190	--	1[(j)]	
1319773	Cresol (all isomers)	5	22	
123739	Crotonaldehyde; beta-methylacrolein			0.3
299865	Crufomate	--	5	
98828	Cumene; isopropylbenzene	50	245	
420042	Cyanamide	--	2	
	Cyanide, as CN	--	5	
460195	Cyanogen	10	20	
506774	Cyanogen chloride	0.3	0.6	
110827	Cyclohexane	300	1,050	
108930	Cyclohexanol	50	200	
108941	Cyclohexanone	25	100	
110838	Cyclohexene	300	1,015	
108918	Cyclohexylamine	10	40	
121824	Cyclonite; RDX; cyclotrimethylenetrinitramine	--	0.07	
542927	Cyclopentadiene	75	200	
287923	Cyclopentane	600	1,720	
13121705	Cyhexatin; tricyclohexyltin hydroxide		5	
94757	2,4-D;2,4-dichlorophenoxyacetic acid	--	10	
50293	DDT; 1,1,1-trichloro-2,2-bis-			
	(p-chlorophenyl)ethane	--	1	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
62737	DDVP, see Dichlorvos			
17702419	Decaborane	0.05	0.3	
8065483	Demeton; a mixture of o,o-diethyl			
	o-2(ethylthio)ethyl phosphorothloate and			
	o,o'-diethyl S-2(ethylthio)ethyl phosphorothioate	0.01	0.1	
123422	Diacetone alcohol; 4-hydroxy-4-methyl-			
	2-pentanone	50	240	
107153	1,2-Diaminoethane; see Ethylenediamine			
	Diatomacous earth; see Silica-amorphous			
333415	Diazinon; o,o-diethyl o-(2-isopropyl-6-	--	0.1	
	methyl-4-pyrimidinyl) phosphorothioate			
334883	Diazomethane	0.2	0.4	
94360	Dibenzoyl peroxide; see Benzoyl peroxide			
19287457	Diborane	0.1	0.1	C
2528361	Dibutyl phenyl phosphate	0.3	3.5	
96128	1,2-Dibromo-3-chloropropane; DBCP;	0.001	0.01	
	see Section 5212			
75616	Dibromodifluoromethane; see			
	Difluorodibromomethane			
106934	1,2-Dibromomethane; see Ethylene dibromide,			
	Section 5219			
102818	2-N-Dibutylaminoethanol	2	14	
107664	Dibutyl phosphate	1	5	
84742	Dibutyl phthalate	--	5	
7572294	Dichloroacetylene	0.1	0.4	C
95501	o-Dichlorobenzene	25	150	50 ppm
106467	p-Dichlorobenzene; 1,4-dichlorobenzene	10	60	200 ppm
91941	3,3'-Dichlorobenzidine; 4,4'-diamino-3,3'-			
	dichlorobiphenyl; see Section 5209			
764410	1,4 -Dichloro-2-butene	0.005	0.025	
75718	Dichlorodifluoromethane	1000	4950	6200 ppm
118525	1,3-Dichloro-5,5-dimethyl hydantoin	--	0.2	
75343	1,1-Dichloroethane	100	400	
107062	1,2-Dichloroethane, see Ethylene dichloride			
75354	1,1-Dichloroethylene; see Vinylidene chloride			
540590	1,2-Dichloroethylene; acetylene dichloride	200	790	
111444	Dichloroethyl ether; bis(2-chloroethyl) ether	5	30	
75434	Dichlorofluoromethane; Fluorocarbon 21	10	42	
75092	Dichloromethane; see Methylene chloride			
594729	1,1-Dichloro-1-nitroethane	2	10	
78875	1,2-Dichloropropane; see Propylene dichloride			
542756	Dichloropropene	1	5	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
75990	2,2-Dichloropropionic acid	1	6	
76142	1,2-Dichlorotetrafluoroethane; Fluorocarbon 114	1,000	7,000	
62737	Dichlorvos (DDVP); 2,2-dichlorovinyl			
	dimethyl phosphate	0.1	1	
141662	Dicrotophos	--	0.25	
5124301	Dicyclohexylmethane-4,4'-diisocyanate;			
	see Methylene bis-(4-cyclohexylisocyanate)			
77736	Dicyclopentadiene	5	30	
102545	Dicyclopentadienyl iron	--		
	Total dust	--	10	
	Respirable fraction(n)	--	5	
60571	Dieldrin; 1,2,3,4,10,10-hexachloro-6,7-epoxy-			
	1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-			
	dimethanonaphthalene	--	0.25	
111422	Diethanolamine	0.46	2	
109897	Diethylamine	5	15	C
112367	Diethylene glycol diethyl ether,			
	Ethyl diglyme	5	33	
111966	Diethylene glycol dimethyl ether, Diglyme	1	5.5	
100378	2-(Diethylamino) ethanol	2	9.6	
123911	1,4-Diethylene dioxide; see p-Dioxane			
111400S	Diethylenetriamine	1	4	
60297	Diethyl ether; see Ethyl ether			
298044	Di-(2-ethylhexyl) phthalate;			
	see Di-sec-octyl phthalate			
96220	Diethyl ketone	200	705	
84662	Diethyl phthalate	--	5	
75616	Difluorodibromomethane; dibromodifluoromethane	100	860	
2238075	Diglycidyl ether; DGE; bis(2,3-epoxypropyl)			
	ether	0.1	0.5	
123319	p-Dihydroxybenzene; see Hydroquinone			
108838	Diisobutyl ketone; 2,6-dimethyl-4-heptanone	25	150	
108189	Diisopropylamine	5	20	
108203	Diisopropyl ether; see Isopryl ether			
109875	Dimethoxymethane; see Methylal			
127195	Dimethylacetamide	10	35	
124403	Dimethylamine	5	9.2	
60117	4-Dimethylaminoazobenzene, see Section 5209			
1300738	Dimethylaminobenzene; see Xylidene			
121697	N,N-Dimethylaniline; dimethylphenylamine	5	25	
1330207	Dimethylbenzene; see Xylene			
108849	1,3-Dimethylbutyl acetate; see sec-			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	Hexyl acetate			
300765	o,o-Dimethyl o-(1,2-dibromo-2,2-dichloroethyl)			
	phosphate; see Naled			
14857342	Dimethylethoxysilane	0.5	2.1	
68122	Dimethylformamide; DMF	10	30	
108838	2,6-Dimethyl-4-heptanone; see			
	Diisobutyl ketone			
57147	1,1-Dimethylhydrazine	0.01	0.025	
67641	Dimethyl ketone; see Acetone			
62759	N,N-Dimethylnitrosamine; see			
	N-Nitrosodimethylamine, Section 5209			
131113	Dimethyl phthalate	--	5	
77781	Dimethyl sulfate; methyl sulfate	0.1	0.5	
148016	Dinitolmide; 3,5-Dinitro-o-toluamide	--	5	
528290,	Dinitrobenzene (all (isomers)			
99650,	ortho, meta and			
100254	para isomers	0.15	1	
534521	4,6-Dinitro-o-cresol; 2-methyl-			
	4,6-dinitrophenol	--	0.2	
25321146	2,4-Dinitrotoluene	--	0.15	
123911	p-Dioxane;			
	1,4-dioxacyclohexane;	0.28	1	
	1,4-diethylene dioxide			
78342	Dioxathion	--	0.2	
92524	Diphenyl; see Biphenyl			
122394	Diphenylamine; N-phenylaniline	--	10	
101688	Diphenylmethane diisocyanate; see			
	Methylene bis(phenylisocyanate)			
123193	Dipropyl ketone	50	235	
34590948	Dipropylene glycol methyl ether	100	600	
85007	Diquat; 1,1'-ethylene-2,2'-			
	dipyridinium dibromide	--		
	Total dust	--	0.5	
	Respirable fraction(n)			
117817	Di-sec-octyl phthalate; bis(2 ethylhexyl) phthalate	--	5	
97778	Disulfiram	--	2	
298044	Disulfoton; o,o-diethyl			
	S-2-(ethylthio)ethyl phosphorodithioate	--	0.1	
128370	2,6-Di-tert-butyl-p-cresol	--	10	
330541	Diuron	--	10	
68122	DMF; see Dimethylformamide			
57147	DMH; see 1,1-Dimethylhydrazine			
1321740	Divinyl benzene	10	50	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	Dust, nuisance dust and particulates,			
	see Particulates not otherwise regulated			
12415348	Emery; see Particulates not otherwise regulated			
115297	Endosulfan; 6,7,8,9,10,10-hexachloro-			
	1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,			
	3-benzodioxathiepin-3-oxide	--	0.1	
72208	Endrin; 1,2,3,4,10,10-hexachloro-6,7-epoxy-			
	1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,			
	8-dimethanonaphthalene	--	0.1	
13838169	Enflurane	2	15	
106898	Epichlorohydrin; 1-chloro-2,			
	3-epoxypropane	0.05	0.19	
2104645	EPN; o-ethyl o-(p-nitrophenyl)			
	phenylphosphonothioate	--	0.1	
75569	1,2-Epoxypropane; see Propylene oxide			
556525	2,3-Epoxypropanol; see Glycidol			
74840	Ethane	(h)	--	
75081	Ethanethiol; see Ethyl mercaptan			
64175	Ethanol; see Ethyl alcohol			
141435	Ethanolamine; 2-aminoethanol	3	8	
563122	Ethion	--	0.4	
110805	2-Ethoxyethanol	5	18	
111159	2-Ethoxyethyl acetate	5	27	
141786	Ethyl acetate	400	1,400	
140885	Ethyl acrylate	5	20	
64175	Ethyl alcohol; ethanol	1,000	1,900	
75047	Ethylamine	5	9.2	C
541855	Ethyl sec-amyl ketone; 5-methyl-3-heptanone	25	130	
100414	Ethylbenzene	100	435	
74964	Ethyl bromide	5	22	
106354	Ethyl butyl ketone; 3-heptanone	50	230	
75003	Ethyl chloride; chloroethane	100	264	
7085850	Ethyl cyanoacrylate	0.2	1.02	
673923	Ethyl tert-butyl ether	5	21	
74851	Ethylene	(h)	--	
107073	Ethylene chlorohydrin; 2-chloroethanol	1	3	C
107153	Ethylenediamine; 1,2-diaminoethane	10	25	
106934	Ethylene dibromide; 1,2-dibromoethane,			
	see Section 5219	0.13	1	C
107062	Ethylene dichloride; 1,2-dichloroethane	1	4	200ppm
107211	Ethylene glycol (vapor)	40	100	C
629141	Ethylene glycol diethyl ether, 1,2-diethoxyethane	5	24	
110714	Ethylene glycol dimethyl ether,	1	3.7	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	1,2-dimethoxyethane, Glyme			
628966	Ethylene glycol dinitrate		(k)	
110805	Ethylene glycol monoethyl ether, see			
	2-Ethoxyethanol			
109864	Ethylene glycol monomethyl ether, see			
	2-Methoxyethanol			
110496	Ethylene glycol monomethyl ether acetate;			
	see 2-Methoxyethyl acetate			
151564	Ethyleneimine; see also Section 5209	0.5	1	
75218	Ethylene oxide; see Section 5220	1	2	
60297	Ethyl ether	400	1,200	
109944	Ethyl formate	100	300	
75343	Ethylidene chloride; see 1,1-Dichloroethane			
16219753	Ethylidene norbornene	5	25	C
75081	Ethyl mercaptan; ethanethiol	0.5	1	
78933	Ethyl methyl ketone; see Methyl ethyl ketone			
100743	N-Ethylmorpholine; 4-ethyl-1,			
	4-tetrahydrooxazine	5	23	
78104	Ethyl silicate; tetraethyl silicate	10	85	
22224926	Fenamiphos		0.1	
115902	Fensulfothion	--	0.1	
55389	Fenthion	--	0.2	
14484641	Ferbam; ferric N,N-dimethylthiocarbamate	--	10	
12604589	Ferrovanadium dust	--	1	
14808607	Fibrous glass, see Glass			
	Flour dust		0.5$^{(s)}$	
	Fluorides, as F	--	2.5	
782414	Fluorine	0.1	0.2	
75694	Fluorocarbon 11; see Trichlorofluoromethane			
75718	Fluorocarbon 12; see Dichlorodifluoromethane			
75434	Fluorocarbon 21; see Dichlorofluoromethane			
75456	Fluorocarbon 22; see Chlorodifluoromethane			
76120	Fluorocarbon 112; see 1,1,2,2-Tetrachloro-			
	1,2-difluoroethane			
76131	Fluorocarbon 113; see 1,1,2-Trichloro-1,2,2-			
	trifluoroethane			
	Fluorocarbon 114; see 1,2-			
	Dichlorotetrafluoroethane			
75694	Fluorotrichloromethane; see			
	Trichlorofluoromethane			
944229	Fonofos	--	0.1	
50000	Formaldehyde, see Section 5217	0.75	--	
75127	Formamide	10	18	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
64186	Formic acid	5	9	
98011	Furfural	2	8	
98000	Furfuryl alcohol	10	40	
8006619	Gasoline	300	900	
7782652	Germanium tetrahydride	0.2	0.6	
	Glass, fibrous	1.0 f/cc(q)		
111308	Glutaraldehyde (t)	0.05	0.2	C
56815	Glycerin mist; see Particulates not otherwise regulated			
123944	Glyceryl stearate	--	10	
556525	Glycidol; 2,3-epoxy-1-propanol	2	6.1	
111762	Glycol monobutyl ether; see 2-Butoxyethanol			
110805	Glycol monoethyl ether; see 2-Ethoxyethanol			
109864	Glycol monoethyl ether; see 2-Methoxyethanol			
107222	Glyoxal, 1,2-ethanedione		0.1[(s), (u)]	
	Grain dust (oat, wheat, barley)	--	10	
7782425	Graphite, natural respirable dust		2.5	
	Graphite, synthetic			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
13397245	Gypsum; Calcium sulfate dihydrate; see			
	Particulates not otherwise regulated			
7440586	Hafnium	--	0.05	
151677	Halothane	2	16	
822060	HDI; see Hexamethylene diisocyanate			
7440597	Helium	(h)	--	
76448	Heptachlor; 1,4,5,6,7,8,8-hepta-chloro-			
	3a,4,7,7a-tetrahydro-4,7-methanoindene	--	0.05	
142825	n-Heptane	400	1,600	
118741	Hexachlorobenzene	--	0.002	
87683	Hexachlorobutadiene	0.02	0.24	
77474	Hexachlorocyclopentadiene	0.01	0.11	
67721	Hexachloroethane; perchloroethane	1	10	
1335871	Hexachloronaphthalene	--	0.2	
684162	Hexafluoroacetone; 1,1,1,3,3,3-hexafluoro-			
	2-propanone	0.1	0.7	
822060	Hexamethylene diisocyanate; HDI	0.005	0.034	
110543	n-Hexane	50	180	
	Hexane, other isomers	500	1800	
124094	1,6-Hexanediamine	0.5	2.3	
591786	2-Hexanone; see Methyl butyl ketone			
592416	1-Hexene	50	180	
108101	Hexone; see Methyl isobutyl ketone			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
108849	sec-Hexyl acetate; 4-methyl-2-pentyl acetate;			
	1,3-dimethyl-butyl acetate	50	300	
107415	Hexylene glycol	25	125	C
302012	Hydrazine	0.01	0.013	
10035106	Hydrobromic acid; see Hydrogen bromide			
7647010	Hydrochloric acid; see Hydrogen chloride			
74908	Hydrocyanic acid; see Hydrogen cyanide			
7664393	Hydrofluoric acid; see Hydrogen fluoride			
1333740	Hydrogen	(h)	--	
61788327	Hydrogenated terphenyls	0.5	5	
10035106	Hydrogen bromide	3	10	C
7647010	Hydrogen chloride; muriatic acid	5	7	C
74908	Hydrogen cyanide	4.7	5	C
7664393	Hydrogen fluoride, as F	3	2.5	
7722841	Hydrogen peroxide, as H2O2	1	1.4	
7783075	Hydrogen selenide, as Se	0.05	0.2	
7783064	Hydrogen sulfide	10	14	
123319	Hydroquinone; 1,4-benezendiol	--	2	
999611	2-Hydroxypropyl acrylate	0.5	3	
95136	Indene	10	48	50ppm
7440746	Indium	--	0.1	
	Indium compounds	--	0.1	
7553562	Iodine	0.1	1	
75478	Iodoform	0.6	10	
4098719	IPDI; see Isophorone diisocyanate			
1309371	Iron oxide fume	--	5	
13463406	Iron pentacarbonyl, as Fe	0.1	0.8	
	Iron salts, soluble, as Fe	--	1	
123922	Isoamyl acetate; 3-methylbutyl acetate; see Pentyl acetate			
123513	Isoamyl alcohol; 3-methylbutanol	100	360	
110190	Isobutyl acetate; 2-methylpropyl acetate	150	700	
78831	Isobutyl alcohol; 2-methylpropanol	50	150	
26675467	Isoflurane	2	15	
26952216	Isooctyl alcohol	50	270	
78591	Isophorone; 3,5,5-trimethyl-2-cyclohexene-			
	1-one	4	23	
4098719	Isophorone diisocyanate; IPDI	0.005	0.045	
109591	Isopropoxyethanol	25	105	
108214	Isopropyl acetate	250	950	
67630	Isopropyl alcohol	400	980	
75310	Isopropylamine	5	12	
768525	N-isopropylaniline	2	10	
108203	Isopropyl ether; diisopropyl ether	250	1,050	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
4016142	Isopropyl glycidyl ether; IGE;			
	1,2-epoxy-3-isopropoxypropane	50	240	
1332587	Kaolin; (respirable dust containing no			
	asbestos and <1% crystaline silica)	--	2	
463514	Ketene; ethenone	0.5	0.9	
	Lead arsenate, see Sections 5214 and 5198			
7758976	Lead chromate, as Pb	--	0.02	
	as Cr	--	0.005	
	(see also Section 5198, 1532.1, 1532.2, 5206 & 8359)			
	Lead (metallic) and inorganic compounds, dust			
	and fume, as Pb (see also Section 5198)	--	0.05	
78002	Lead tetraethyl, see Tetraethyl lead			
75741	Lead tetramethyl, see Tetramethyl lead			
1317653	Limestone; calcium carbonate; see			
	Particulates not otherwise regulated			
58899	Lindane; 1,2,3,4,5,6-hexachlorocyclohexane,			
	gamma isomer	--	0.5	
7580678	Lithium hydride	--	0.025	
	L.P.G.; liquefied petroleum gas	1,000	1,800	
4485125	Lithium stearate	--	10	
13717005	Magnesite; magnesium carbonate; see			
	Particulates not otherwise regulated			
1309484	Magnesium oxide fume, as Mg	--	10	
557040	Magnesium stearate	--	10	
121755	Malathion; o,o-dimethyl S-1(1,2-			
	dicarboethyoxyethyl) phosphorodithioate	--	10	
108316	Maleic anhydride; cis-butenedioic anhydride	0.1	0.4	
	Manganese and compounds, as Mn	--	0.2	
7439965	Manganese fume, as Mn	--	0.2	
12079651	Manganese, cyclopentadienyl-tricarbonyl,			
	as Mn	--	0.1	
	Manganese tetroxide	--	0.2	
	Marble; calcium carbonate; see			
	Particulates not otherwise regulated			
101779	MDA; see 4,4'-Methylene dianiline			
101688	MDI; see Methylene bis(phenylisocyanate)			
7439976	Mercury alkyls, as Hg	--	0.01	0.04 mg/M^3
7439976	Mercury, metallic and inorganic compounds as Hg	--	0.025	0.1 mg/M^3
7439976	Mercury aryl compounds as Hg	--	0.01	C
108678	Mesitylene; see 1,3,5-Trimethylbenzene			
141797	Mesityl oxide; 4-methyl-3-pentene-2-one	15	60	
79414	Methacrylic acid	20	70	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
74828	Methane	(h)	--	
74931	Methanethiol; see Methyl mercaptan			
67561	Methanol; see Methyl alcohol			
16752775	Methomyl	--	2.5	
72435	Methoxychlor; 1,1,1-trichloro-2,			
	2-bis(p-methoxyphenyl)ethane	--	10	
109864	2-Methoxyethanol	5	16	
110496	2-Methoxyethyl acetate	5	24	
76380	Methoxyflurane	2	13	
150765	4-Methoxyphenol	--	5	
79209	Methyl acetate	200	610	
74997	Methyl acetylene; propyne	1,000	1,650	
	Methyl acetylene-propadiene mixture; MAPP	1,000	1,800	
96333	Methyl acrylate	10	35	
126987	alpha-Methylacrylonitrile	1	3	
624419	2-Methylbutyl acetate; see Pentyl acetate			
109875	Methylal; dimethoxymethane	1,000	3,100	
67561	Methyl alcohol; methanol	200	260	1000ppm
74895	Methylamine	5	6.4	
108112	Methyl amyl alcohol; see Methyl			
	isobutyl carbinol			
110430	Methyl n-amyl ketone; 2-heptanone	50	235	
100618	N-Methylaniline; monomethylaniline	0.5	2	
95534	o-Methylaniline; see o-Toluidine			
74839	Methyl bromide	1	3.88	20 ppm
591786	Methyl n-butyl ketone; 2-hexanone	1	4	
74873	Methyl chloride	50	105	300 ppm
71556	Methyl chloroform; 1,1,1-trichloroethane	350	1900	800 ppm
107302	Methyl chloromethyl ether; see Section 5209			
75058	Methyl cyanide; see Acetonitrile			
137053	Methyl 2-cyanoacrylate	0.2	0.908	
108872	Methylcyclohexane	400	1,600	
25639423	Methylcyclohexanol (meta- and			
	para-isomer mixture)	50	235	
583608	o-Methylcyclohexanone	50	230	
12108133	2-Methylcyclopentadienyl manganese			
	tricarbonyl, as Mn	--	0.2	
8022002	Methyl demeton; a mixture of o,o-dimethyl			
	o-(2-(ethylthio)ethyl) phosphorothioate and			
	o,o-dimethyl S-(2-(ethylthio)-ethyl)			
	phosphorothioate	--	0.5	
101144	4,4'-Methylene bis(2-chloroaniline),	--	0.01	
	see also Section 5215			
5124301	Methylene bis(4-cyclohexylisocyanate);			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	hydrogenated MDI	0.005	0.054	
101688	Methylene bis(phenylisocyanate); MDI;			
	diphenylmethane diisocyanate	0.005	0.051	
75092	Methylene chloride; dichloromethane	25	87	
	(see also section 5202)			
101779	4,4'-Methylene dianiline; MDA	0.01	0.08	
	(see also Sections 1535 and 5200)			
78933	Methyl ethyl ketone; MEK; 2-butanone;			
	ethyl methyl ketone	200	590	
1338234	Methyl ethyl ketone peroxide	0.2	1.5	
107313	Methyl formate	100	250	
60344	Methyl hydrazine; monomethyl hydrazine	0.01	0.019	
74884	Methyl iodide	2	10	
110123	Methyl isoamyl ketone	50	234	
108112	Methyl isobutyl carbinol; 4-methyl-2-pentanol;			
	methyl amyl alcohol	25	100	
108101	Methyl isobutyl ketone; Hexone	50	205	
624839	Methyl isocyanate	0.02	0.05	
563804	Methyl isopropyl ketone	200	705	
74931	Methyl mercaptan	0.5	1	
80626	Methyl methacrylate; methyl			
	2-methyl-2-propenoate	50	205	
298000	Methyl parathion; o,o-dimethyl			
	o-(p-nitrophenyl) phosphorothioate	--	0.2	
107879	Methyl propyl ketone; 2-pentanone	200	700	
681845	Methyl silicate; tetramethyl silicate	1	6	
98839	alpha-Methylstyrene; 1-methyl-			
	1-phenylethene	50	240	
77781	Methyl sulfate; see Dimethyl sulfate			
1634044	Methyl tert-butyl ether; MTBE	40	144	
78944	Methyl vinyl ketone	0.05	0.14	
21087649	Metribuzin	--	5	
7786347	Mevinphos; 2-carbomethoxyl-			
	1-propen-2-yl dimethyl phosphate	0.01	0.1	
	Mica, see Silicates			
	Mineral wool fiber; see Particulates not otherwise regulated	--		
7439987	Molybdenum, insoluble compounds, as Mo	--	10	
	Total dust	--	3	
	Respirable fraction (n)	--	0.5$^{(n)}$	
	Molybdenum, soluble compounds, as Mo	--	0.25	
6923224	Monocrotophos			
100618	Monomethylaniline; see N-Methylaniline			
60344	Monomethylhydrazine; see Methyl hydrazine			

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
110918	Morpholine; tetrahydro-4H-1, 4-oxazine	20	70	
7647010	Muriatic acid; see Hydrogen chloride			
300765	Naled; o,o-dimethyl o-			
	(1,2-dibromo-2,2-dichloroethyl) phosphate	--	3	
8030317	Naphtha, coal tar	100	400	
91203	Naphthalene	10	50	
134327	alpha-Naphthylamine; 1-naphthylamine,			
	see Section 5209			
91598	beta-Naphthylamine; 2-naphthylamine,			
	see Section 5209			
63252	1-Naphthyl N-methylcarbamate; see Carbaryl			
25551284	Naphthalene diisocyanate; NDI	0.01	0.085	C
7440019	Neon	(h)		
13463393	Nickel carbonyl; Ni (CO)4	0.001	0.007	
7440020	Nickel metal, as Ni	--	0.5	
	Nickel, insoluble compounds, as Ni	--	0.1	
	Nickel, soluble compounds, as Ni	--	0.05	
12035722	Nickel subsulfide	--	0.05	
54115	Nicotine; 1-methyl-2-(3-pyridyl)-pyrrolidine	0.075	0.5	
1929824	Nitrapyrin	--		
	Total dust	--	10	
	Respirable fraction(n)	--	5	
7697372	Nitric acid	2	5	
10102439	Nitric oxide; NO	25	30	
100016	p-Nitroaniline	--	3	
98953	Nitrobenzene	1	5	
100005	p-Nitrochlorobenzene;			
	1-chloro-4-nitrobenzene	0.1	0.64	
92933	4-Nitrodiphenyl, see Section 5209			
79243	Nitroethane	100	310	
7727379	Nitrogen	(h)	--	
10102440	Nitrogen dioxide			
	Nitrogen tetroxide; N2O4; see Nitrogen dioxide			
7783542	Nitrogen trifluoride	10	29	
55630	Nitroglycerin		(k)	
75525	Nitromethane	2	5	
108032	1-Nitropropane	25	90	
79469	2-Nitropropane	10	35	
62759	N-Nitrosodimethylamine, see Section 5209			
1321126, 99081, 88722, 99990	Nitrotoluene	2	11	
76062	Nitrotrichloromethane; see Chloropicrin			
10024972	Nitrous oxide	50	90	
111842	Nonane	200	1050	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	Nuisance particulates, see Particulates not otherwise regulated			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
2234131	Octachloronaphthalene	--	0.1	
111659	Octane	300	1,450	
8012951	Oil (mineral) mist, particulate	--	(5)[l]	
	Oil (vegetable) mists (except castor, cashew			
	nut or similar irritant oils); see Nuisance			
	particulates			
	Organic arsenic compounds; see			
	Arsenic, organic			
20816120	Osmium tetroxide, as Os	0.0002	0.002	
144627	Oxalic acid	--	1	
7783417	Oxygen difluoride	0.05	0.1	
10028156	Ozone	0.1	0.2	C
8002742	Paraffin wax fume	--	2	
1910425, 2074502	Paraquat, total particulates	--	0.5	
1910425, 2074502	Paraquat, respirable sizes	--	0.1[n]	
56382	Parathion; o,o-diethyl o-(p-nitrophenyl)			
	phosphorothioate	--	0.1	
	Particulates not otherwise regulated			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
	Particulate polycyclic;			
	aromatic hydrocarbons (PPAH) see			
	Coal tar pitch volatiles			
	PCB; see Chlorodiphenyl			
87865	PCP; see Pentachlorophenol			
19624227	Pentaborane	0.005	0.01	
1321648	Pentachloronaphthalene	--	0.5	
87865	Pentachlorophenol; PCP	--	0.5	
115775	Pentaerythritol; tetrakis-			
	(hydroxymethyl)methane; tetra-methylolmethane;			
	see Particulates not otherwise regulated			
109660	Pentane	600	1800	
107879	2-Pentanone; see Methyl propyl ketone			
628637	Pentyl acetate	50	266	
67721	Perchloroethane; see Hexachloroethane	25	170	300ppm
127184	Perchloroethylene			
594423	Perchloromethyl mercaptan;			
	trichloromethanethiol	0.1	0.8	
7616946	Perchloryl fluoride; C1O3F	3	14	
382218	Perfluoroisobutylene	0.01	0.082	C

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
	Perlite			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
108952	Phenol	5	19	
92842	Phenothiazine; dibenzothiazine	--	5	
106503	p-Phenylenediamine	--	0.1	
101848	Phenyl ether, vapor	1	7	
100425	Phenylethylene; see Styrene			
122601	Phenyl glycidyl ether, PGE;1,2-epoxy-			
	3-phenoxypropane	0.1	0.6	
100630	Phenylhydrazine	5	20	
108985	Phenyl mercaptan	0.5	2	
638211	Phenylphosphine	0.05	0.25	C
298022	Phorate; o,o-diethyl S-(ethylthio)methyl			
	phosphorodithioate	--	0.05	
75445	Phosgene; carbonyl chloride; COCl2	0.1	0.4	
7803512	Phosphine; PH3	0.3	0.4	
7664382	Phosphoric acid	--	1	
7723140	Phosphorus, yellow	--	0.1	
10025873	Phosphorus oxychloride	0.1	0.6	
10026138	Phosphorus pentachloride	0.1	1	
1314803	Phosphorus pentasulfide; P2S5	--	1	
7719122	Phosphorus trichloride	0.2	1.5	
85449	Phthalic anhydride	1	6	
626175	m-Phthalodinitrile	--	5	
1918021	Picloram	--		
	Total dust	--	10	
	Respirable fraction(n)	--	5	
88891	Picric acid; 2,4,6-trinitrophenol	--	0.1	
83261	Pindone; 2-pivalyl-1, 3-indandione		0.1	
142643	Piperazine dihydrochloride	--	5	
26499650	Plaster of Paris; calcium sulfate hemihydrate;			
	see Particulates not otherwise regulated			
7440064	Platinum, metal	--	1	
	Platinum, soluble salts, as Pt	--	0.002	
	Polychlorobiphenyls, see Chlorodiphenyl			
	Polytetrafluoroethylene, decomposition products	--	(m)	
	Portland Cement; see Particulates not otherwise regulated			
1310583	Potassium hydroxide; caustic potash	--	2	C
593293	Potassium stearate	--	10	
74986	Propane	1000	1800 (h)	
107197	Propargyl alcohol; 2-propyn-1-o1	1	2	
57578	beta-Propiolactone, see Section 5209	0.5	1.5	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
79094	Propionic acid	10	30	
114261	Propoxur; 2-isopropoxyphenyl N-methyl			
	carbamate		0.5	
109604	n-Propyl acetate	200	840	
71238	n-Propyl alcohol	200	500	
115071	Propylene	(h)	--	
78875	Propylene dichloride; 1,2-dichloropropane	75	350	
6423434	Propylene glycol dinitrate; PGDN	0.05	0.3	
107982	Propylene glycol monomethyl ether	100	360	
108656	Propylene glycol monomethyl ether acetate	100	541	
75558	Propyleneimine; 2-methylaziridine	2	5	
75569	Propylene oxide; 1,2-epoxy-propane	2	4.75	
627134	n-Propyl nitrate	25	107	
74997	Propyne; see Methylacetylene			
8003347	Pyrethrum	--	5	
110861	Pyridine	5	15	
106514	Quinone	0.1	0.4	
121824	RDX; see Cyclonite			
	Refractory ceramic fiber		0.2f/cc(q)	
108463	Resorcinol	10	45	
7440166	Rhodium, metal	--	0.1	
	Insoluble compounds, as Rh	--	0.1	
	Soluble salts, as Rh	--	0.001	
299843	Ronnel; o,o-dimethyl o-(2,4,5-	--	10	
	trichlorophenyl) phosphorothioite			
	Rosin core solder, pyrolysis products,			
	as formaldehyde	--	0.1	
83794	Rotenone, commercial	--	5	
1309371	Rouge; see Particulates not otherwise regulated			
	Rubber solvent (Naphtha)	400	1,600	
	Selenium compounds, as Se	--	0.2	
7783791	Selenium hexafluoride	0.05	0.4	
136787	Sesone; sodium 2,4-dichloro-phenoxyethyl			
	sulfate			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
61790532	Silica, amorphous			
	Diatomaceous earth			
	Total dust	--	6	
	Respirable fraction(n)	--	3	
	Precipitated and gel	--	6	
	Silica, crystalline			
14464461	Cristobalite, respirable dust	--	0.05	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
14808607	Quartz, respirable dust	--	0.1	
14808607	Quartz, total dust	--	0.3	
60676860	Silica, fused, respirable dust	--	0.1	
15468323	Tridymite, respirable dust	--	0.05	
1317959	Tripoli, respirable dust	--	0.1	
	Silicates (<1% crystalline silica)			
12001262	Mica (respirable dust)	--	3	
	Soapstone, total dust	--	6	
	Soapstone, respirable dust	--	3	
	Talc (containing asbestos); see Section 5208			
14807966	Talc (containing no asbestos fibers),			
	respirable dust	--	2	
	Tremolite (containing no asbestos fibers),			
	respirable dust	--	2	
7440213	Silicon; see Particulates not otherwise regulated			
409212	Silicon carbide; SiC; see Particulates not otherwise regulated			
7803625	Silicon tetrahydride; silane	5	7	
7440224	Silver metal, as Ag	--	0.01	
	Silver, soluble compounds, as Ag	--	0.01	
	Soapstone, see Silicates			
26628228	Sodium azide	0.1	0.3	C
7631905	Sodium bisulfite	--	5	
136787	Sodium 2,4-dichlorophenoxyethyl sulfate;			
	see Sesone			
62748	Sodium fluoroacetate	--	0.05	
1310732	Sodium hydroxide; caustic soda	--	2	C
7681574	Sodium metabisulfite	--	5	
822162	Sodium stearate	--	10	
9005258	Starch; see Particulates not otherwise regulated			
7789062	Strontium chromate, as Cr	--	0.0005	
	(see also Sections 1532.2, 5206 & 8359)			
	Stearates; see specific compound			
7803523	Stibine; SbH3	0.1	0.5	
8052413	Stoddard solvent	100	525	
57249	Strychnine	--	0.15	
100425	Styrene (monomer); phenylethylene	50	215	500ppm
9014011	Subtilisins (as pure crystalline			
	proteolytic enzymes)	--		
57501	Sucrose; see Particulates not otherwise regulated			
74222972	Sulfometuron methyl	--	3.5	
3689245	Sulfotep; tetraethyl dithionopyrophosphate		0.2	
7446095	Sulfur dioxide	2	5	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
2551624	Sulfur hexafluoride	1,000	6,000	
7664939	Sulfuric acid	--	1	
10025679	Sulfur monochloride; S2Cl2	1	6	C
5714227	Sulfur pentafluoride; S2F10	0.01	0.1	C
7783600	Sulfur tetrafluoride	0.1	0.4	C
2699798	Sulfuryl fluoride; SO2F2	5	20	
35400432	Sulprofos		1	
93765	2,4,5-T;2,4,5-trichlorophenoxyacetic acid	--	10	
	Talc; see Silicates			
7440257	Tantalum metal dust, as Ta	--	5	
1314610	Tantalum oxide dust, as Ta	--	5	
78308	TCP; see Triorthocresyl phosphate			
584849	TDI; see Toluene-2,4-diisocyanate			
3689245	TEDP; see Sulfotep			
	Tellurium and compounds, as Te	--	0.1	
7783804	Tellurium hexafluoride	0.02	0.2	
3383968	Temephos; o,o,o' ,o'-tetramethyl o,o'-			
	thiodi-p-phenylene phosphorothioate			
	Total dust	--	10	
	Respirable fraction(n)	--	5	
107493	TEPP; tetraethyl pyrophosphate;	0.004	0.05	
100210	Terephthalic acid	--	10	
	Terphenyls	0.5	5	C
79276	1,1,2,2-Tetrabromoethane; see			
	Acetylene tetrabromide			
76119	1,1,1,2-Tetrachloro-2,2-difluoroethane	500	4170	
76120	1,1,2,2-Tetrachloro-1,2-difluoroethane;			
	fluorocarbon 112	500	4170	
79345	1,1,2,2-Tetrachloroethane; acetylene			
	tetrachloride	1	7	
127184	Tetrachloroethylene; see Perchloroethylene			
56235	Tetrachloromethane; see Carbon tetrachloride			
1335882	Tetrachloronaphthalene	--	2	
3689245	Tetraethyl dithionopyrophosphate; see Sulfotep			
78002	Tetraethyl lead; tetraethylplumbane, as Pb	--	0.075	
107493	Tetraethyl pyrophosphate; see TEPP			
109999	Tetrahydrofuran	200	590	
75741	Tetramethyl lead; tetramethylplumbane, as Pb	--	0.075	
115775	Tetramethylolmethane; see Pentaerythritol			
3333526	Tetramethyl succinonitrile (decomposition			
	product of 2,2'-azobisisobutyronitrile)	0.5	3	
137268	Tetramethyl thiuram disulfide, see Thiram			
509148	Tetranitromethane	0.005	0.04	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
7722885	Tetrasodium pyrophosphate	--	5	
479458	Tetryl; 2,4,6-trinitrophenylmethylnitramine	--	1.5	
	Thallium, soluble compounds, as Tl	--	0.1	
109999	THF; see Tetrahydrofuran			
96695	4,4'-Thiobis(6-tert-butyl-m-cresol)	--		
	Total dust	--	10	
	Respirable fraction(n)	--	5	
68111	Thioglycolic acid	1	3.8	
7719097	Thionyl chloride	1	5	C
137268	Thiram; bis(dimethylthiocarbamoyl) disulfide	--	5	
	Tin, organic compounds, as Sn	--	0.1	
21651194	Tin, tin oxide and inorganic compounds,			
	except SnH4, as Sn	--	2	
13463677	Titanium dioxide, as Ti; see Particulates			
	not otherwise regulated			
137268	TMTD; see Thiram			
118967	TNT; see 2,4,6-Trinitrotoluene			
108883	Toluene; toluol	50	188	500ppm
584849	Toluene-2,4-diisocyanate; TDI	0.005	0.04	0.02ppm
108441	m-Toluidine	2	9	
95534	o-Toluidine; o-methylaniline	2	9	
106490	p-Toluidine	2	9	
8001352	Toxaphene; see Chlorinated camphene			
115866	TPP; see Triphenyl phosphate			
	Tremolite, nonasbestiform; see Silicates			
75252	Tribromomethane; see Bromoform			
126738	Tributyl phosphate	0.2	2.5	
76039	Trichloroacetic acid	1	5	
120821	1,2,4-Trichlorobenzene	5	40	C
50293	1,1,1,-Trichloro-2,2-bis(p-chlorophenyl)ethane;			
	see DDT			
71556	1,1,1-Trichloroethane; see Methyl chloroform			
79005	1,1,2-Trichloroethane	10	45	
79016	Trichloroethylene; trichloroethene	25	135	C
75694	Trichlorofluoromethane; Fluorocarbon 11	1,000	5,600	300ppm
67663	Trichloromethane; see Chloroform			
594423	Trichloromethanethiol; see Perchloromethyl			
	mercaptan			
1321659	Trichloronaphthalene	--	5	
76062	Trichloronitromethane; see Chloropicrin			
93765	2,4,5-Trichlorophenoxyacetic acid			
	see 2,4,5-T			
96184	1,2,3-Trichloropropane	10	60	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
76131	1,1,2-Trichloro-1,2,2- trifluoroethane	1000	7600	2000ppm
78308	Tricresyl phosphate; see Triorthocresyl phosphate			
13121705	Tricyclohexyltin hydroxide; see Cyhexatin			
102716	Triethanolamine	--	5	
121448	Triethylamine	1	4.1	C
112492	Triethylene glycol dimethyl ether, Triglyme	5	36	
75638	Trifluorobromomethane	1,000	6,100	
2451629	1,3,5-Triglycidyl-s-triazinetrione		0.005	
552307	Trimellitic anhydride	0.005	0.04	C
75503	Trimethylamine	5	12	
	Trimethylbenzene, all isomers	25	125	
121459	Trimethyl phosphite	2	10	
88891	2,4,6-Trinitrophenol; see Picric acid			
479458	2,4,6-Trinitrophenylmethyl nitramine; see Tetryl			
118967	2,4,6-Trinitrotoluene; TNT	--	0.5	
78308	Triorthocresyl phosphate	--	0.1	
603349	Triphenylamine	--	5	
115866	Triphenyl phosphate; TPP	--	3	
7440337	Tungsten metal, as W	--	5	
	Tungsten, insoluble compounds, as W	--	5	
	Tungsten, soluble compounds, as W	--	1	
8006642	Turpentine	100	560	
	Uranium (natural), insoluble compounds, as U	--	0.2	
	Uranium (natural), soluble compounds, as U	--	0.05	
110623	Valeraldehyde	50	175	
1314621	Vanadium pentoxide (V2O5), respirable dust and fume	--	0.05[(n)]	
75014	VC; see Vinyl chloride, Section 5210			
	Vegetable oil mists (except castor, cashew nut or similar irritant oils); see Particulates not otherwise regulated			
108054	Vinyl acetate	10	30	
100425	Vinylbenzene; see Styrene			
593602	Vinyl bromide; bromoethylene	0.1	0.44	
75014	Vinyl chloride, see Section 5210	1		
107131	Vinyl cyanide, see Acrylonitrile, Section 5213			
100403	4-Vinyl cyclohexene	0.1	0.4	
106876	Vinyl cyclohexene dioxide	0.1	0.57	
75025	Vinyl fluoride	0.2	0.38	
75354	Vinylidene chloride; 1,1-dichloroethylene	1	4	
75387	Vinylidene fluoride	100	262	
25013154	Vinyltoluene	50	240	

Chemical Abstract Registry Number	Chemical Name	PEL		
		ppm	mg/m^3	ceiling
8030306	VM & P (Varnish Makers and Painters) Naphtha	300	1,350	
81812	Warfarin; 3-(alpha-acetonyl-benzyl)-4-	--	0.1	
	hydroxycoumarin			
	Welding fumes; total particulates (see also			
	individual constituents)	--	5	
	Wood dust	--		
	All soft and hard woods, except Western			
	red cedar	--	5	
	Wood dust, Western red cedar--	--	2.5	
1330207	Xylene; xylol; dimethylbenzene	100	435	300ppm
1477550	m-Xylene-a,a'-diamine	--	0.1	C
1300738	Xylidine; aminodimethylbenzene	0.5	2.5	
	Yttrium compounds, as Y	--	1	
7646857	Zinc chloride fume	--	1	
13530659	Zinc chromate, as Cr	--	0.005	
	(see also Sections 1532.2, 5206 & 8359)			
15930946	Zinc chromate hydroxide, as Cr	--	0.005	
	(see also Sections 1532.2, 5206 & 8359)			
1314132	Zinc oxide fume	--	5	
	Zinc oxide dust, see Particulates not otherwise regulated			
11103869	Zinc potassium chromate, as Cr	--	0.005	
	(see also Sections 1532.2, 5206 & 8359)			
557051	Zinc stearate	--	10	
37300235	Zinc yellow, as Cr	--	0.005	
	(see also Sections 1532.2, 5206 & 8359)			
	Zirconium compounds, as Zr	--	5	

APPENDIX B

Risk Phrases Code

R1 - Explosive when dry.

R2 - Risk of explosion by shock, friction, fire or other source of ignition.

R3 - Extreme risk of explosion by shock, friction, fire or other sources of ignition.

R4 - Forms very sensitive explosive metallic compounds.

R5 - Heating may cause an explosion.

R6 - Explosive with or without contact with air.

R7 - May cause fire.

R8 - Contact with combustible material may cause fire.

R9 - Explosive when mixed with combustible material.

R10 - Flammable.

R11 - Highly flammable.

R12 - Extremely flammable.

R13 - Extremely flammable liquefied gas

R14 - Reacts violently with water.

R15 - Contact with water liberates extremely flammable gases.

R16 - Explosive when mixed with oxidizing substances.

R17 - Spontaneously flammable in air.

R18 - In use, may form inflammable/explosive vapour-air mixture.

R19 - May form explosive peroxides.

R20 - Harmful by inhalation.

R21 - Harmful in contact with skin.

R22 - Harmful if swallowed.

R23 - Toxic by inhalation.

R24 - Toxic in contact with skin.

R25 - Toxic if swallowed.

R26 - Very toxic by inhalation.

R27 - Very toxic in contact with skin.

R28 - Very toxic if swallowed.

R29 - Contact with water liberates toxic gas.

R30 - Can become highly flammable in use.

R31 - Contact with acids liberates toxic gas.

R32 - Contact with acid liberates very toxic gas.

R33 - Danger of cumulative effects.

R34 - Causes burns.

R35 - Causes severe burns.

R36 - Irritating to eyes.

R37 - Irritating to respiratory system.

R38 - Irritating to skin.

R39 - Danger of very serious irreversible effects.

R40 - Limited evidence of a carcinogenic effect.

R41 - Risk of serious damage to the eyes.

R42 - May cause sensitization by inhalation.

R43 - May cause sensitization by skin contact.

R44 - Risk of explosion if heated under confinement.

R45 - May cause cancer.

R46 - May cause heritable genetic damage.

R47 - May cause birth defects

R48 - Danger of serious damage to health by prolonged exposure.

R49 - May cause cancer by inhalation.

R50 - Very toxic to aquatic organisms.

R51 - Toxic to aquatic organisms.

R52 - Harmful to aquatic organisms.

R53 - May cause long-term adverse effects in the aquatic environment.

R54 - Toxic to flora.

R55 - Toxic to fauna.

R56 - Toxic to soil organisms.

R57 - Toxic to bees.

R58 - May cause long-term adverse effects in the environment.

R59 - Dangerous to the ozone layer.

R60 - May impair fertility.

R61 - May cause harm to the unborn child.

R62 - Risk of impaired fertility.

R63 - Possible risk of harm to the unborn child.

R64 - May cause harm to breastfed babies.

R65 - Harmful: may cause lung damage if swallowed.

R66 - Repeated exposure may cause skin dryness or cracking.

R67 - Vapours may cause drowsiness and dizziness.

R68 - Possible risk of irreversible effects.