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## HAZARDOUS CHEMICALS

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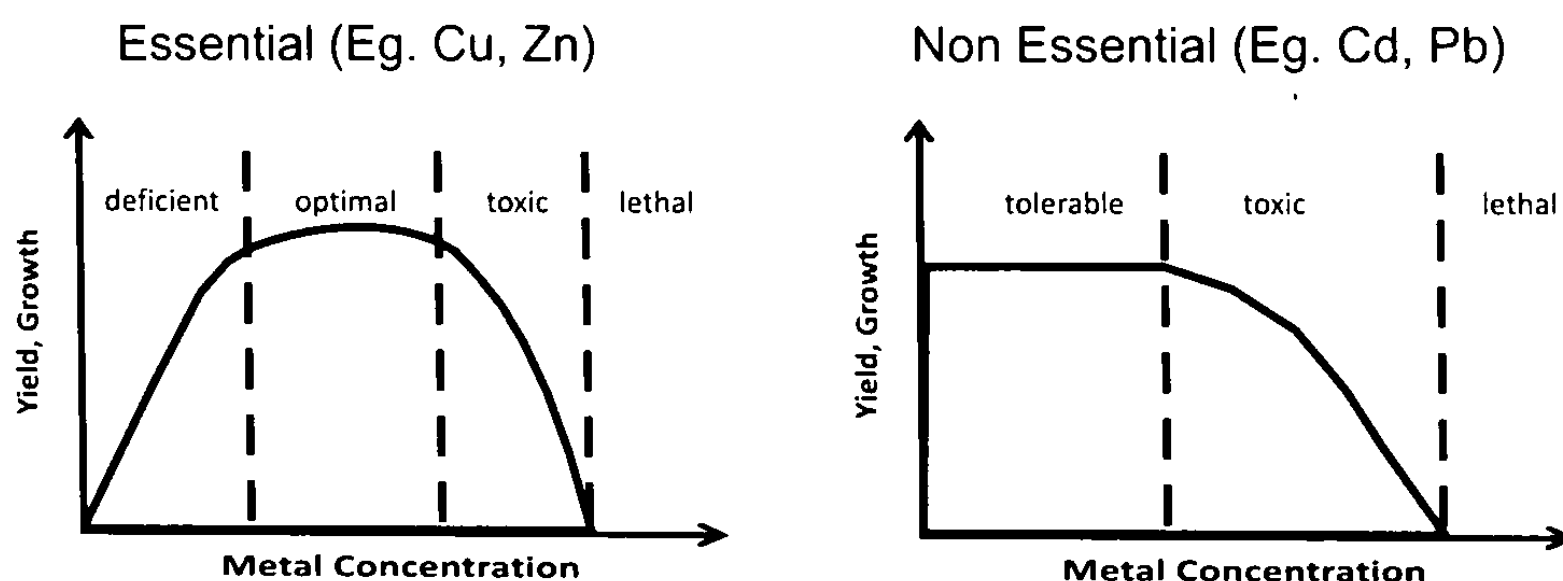
### Introduction

Toxicity is the ability of a substance to cause harmful health effects. These effects can be harmful in many ways. It may strike a single cell, a group of cells, an organ system, or the entire body. A toxic effect may be visible damage, or a decrease in performance or function measurable only by a test. The dose-response relationship shows that any chemical can cause harm at a certain level (Fig. 1). The toxicity of a substance is the potential of that substance to cause harm, and is only one factor in determining whether a hazard exists. The hazard of a chemical is the practical likelihood that the chemical will cause harm.

The toxicity of a substance depends on three factors: its chemical structure, the extent to which the substance is absorbed by the body and the body's ability to detoxify the substance i.e., change it into less toxic substances and to eliminate it from the body<sup>1</sup>.

### Basic Toxicology

The science of toxicology is based on the principle that there is a relationship between a toxic response and the amount of poison received (the dose). There are two basic assumptions in toxicology. The first important assumption is that, there is almost always a dose below which no response occurs or can be measured. The second assumption is that once a maximum response is reached, any further increases in the dose will not result in any increased effect.



**Figure 1.** The dose-response relationship and toxicity to essential and non-essential elements  
Source: Dissanayake and Chandrajith, 2009<sup>2</sup>

It is necessary to understand the cause and effect relationship between chemical exposure and illness. According to Paracelsus (1493 – 1543), the German-Swiss physician and botanist who is considered the father of toxicology, “The right dose differentiates a poison from a remedy.” We should keep in mind that the toxicity of a chemical is an inherent quality of the chemical and cannot be changed without changing the chemical to another form. However, the toxic effects on an organism are related to the amount of exposure.

One of the more commonly used measures of toxicity is the LD<sub>50</sub>. That is, the lethal dose for 50 percent of the animals tested. The LD<sub>50</sub> is usually expressed in milligrams of chemical per kilogram of body weight (mg/kg). A chemical with a small LD<sub>50</sub> (e.g. 5 mg/kg) is very highly toxic while a chemical with a large LD<sub>50</sub> (1,000 to 5,000 mg/kg) is practically non-toxic. The LD<sub>50</sub> says nothing about non-lethal toxic effects. However, a chemical may have a large LD<sub>50</sub> but may produce illness at very small exposure levels. The danger, or risk of adverse effect of chemicals, is mostly determined by how they are used, not by the inherent toxicity of the chemical itself<sup>3</sup>.

### **Routes of Exposure**

It has been estimated that about 70,000 chemicals are used worldwide, and the chemical industry introduces about 200 to 1,000 new chemicals each year<sup>4</sup>. Hence, trace amounts of toxic chemicals may be present in the food, air, and drinking water. Exposure and intake of toxic substances can occur through the three major routes: dermal absorption (through the skin), inhalation (through the nose) and ingestion (through the mouth).

### **Hazardous Chemicals in Laboratories**

The different types of hazardous chemicals found in laboratories include carcinogens, toxins, irritants, corrosives, sensitizers, flammable and combustible liquids and solids, compressed gases and oxidizing agents. These chemicals may cause physical or health threats to workers in the laboratory. The *Globally Harmonized System of Classification and Labeling of Chemicals* (GHS), is a single internationally agreed system of chemical classification and hazard communication through, **Materials Safety Data Sheets** (MSDS) and **Labeling**. The GHS is published by the United Nations and is sometimes referred to as ‘the purple book’. It includes harmonized criteria for the classification of physical hazards, health hazards, and environmental hazards.

### **Material Safety Data Sheets**

A Material Safety Data Sheet (MSDS) is an important document that provides information on the properties of hazardous chemicals and how they affect health and safety in the workplace. A MSDS includes information on:

- the identity of the chemical,
- health and physico-chemical hazards,
- safe handling and storage procedures,
- emergency procedures, and
- disposal considerations

The MSDS generally follows a 16 section format, which is internationally agreed upon (Table 1). The relevant MSDS should be downloaded, printed, studied and displayed in the laboratory.

**Table 1.** Information provided in a Material Safety Data Sheet

Section	Main information	Sub information
1	Chemical product and company identification	Product name, Catalogue numbers, Synonyms, Chemical name, Chemical formula, Contact information of the company, Emergency contact information
2	Composition and information on ingredients	Name, % by weight, Toxicological data on ingredients
3	Hazards identification	Potential acute health effects, Potential chronic health effects
4	First aid measures	Eye, skin contact, inhalation and ingestion
5	Fire and explosion data	Flammability, Auto-ignition temperature, Fire fighting media and instruction
6	Accidental release measures	Small and large spills
7	Handling and storage	Precautions and storage conditions
8	Exposure controls/personal protection	Engineering controls, Personal protection in case of a large spill, Exposure limits
9	Physical and chemical properties	Physical state, Odor, Taste, Molecular Weight, Color, pH (1% solution/water), Boiling Point, Melting Point, Specific Gravity, Vapor Pressure, Volatility, Solubility
10	Stability and reactivity data	Stability, Corrosivity etc.
11	Toxicological information	Routes of entry, Toxicity to animals, Chronic effects on humans
12	Ecotoxicity	BOD <sub>5</sub> , COD, Biodegradation and Biodegraded products
13	Disposal considerations	Waste disposal
14	Transport information	Department of Transportation classification etc.
15	Other regulatory information	
16	Other information	

Students and researchers should download the MSDS, for the relevant chemicals they intend to work with, and study this carefully before commencing their experiments. MSDS can be freely downloaded from the internet.

### Labelling of Hazardous materials

There is a standard, internationally recognized, marking scheme to label hazardous substances. It uses a combination of colors, shapes, and symbols. These symbols may not be found on all chemicals. Depending on the type of hazardous substance and its class, the labels may differ (Fig. 2). In the GHS, hazards are communicated to chemical users through a combination of symbols as well as words, in the form of signal words, hazard statements and precautionary statements. There are nine hazard pictograms plus one for miscellaneous in the GHS which represent the physical, health and environmental hazards (Fig. 2).



Figure 2. Different types of hazardous materials that may be present in a laboratory (Source: <https://www.case.edu/ehs/ChemSafety/shipHazMat.html> accessed 20/06/2014).

### Classes of Hazardous Chemicals

There are nine classes of dangerous goods, each with a characteristic class number and symbol (Fig.2). Some of these classes are divided into divisions. The classes of dangerous goods are listed in order from the most hazardous to the least hazardous. A chemical may belong to more than one of these classes, for example glacial acetic acid is classed as both a flammable liquid and a corrosive substance.

#### Class 1 – Explosives

An explosive on detonation, undergoes a rapid chemical change with the production of a large gas volume relative to the volume of explosive. It is this rapidly

expanding pressure wave that produces the devastating destruction characteristic of explosives. Explosives include: explosive substances, pyrotechnic substances and explosive articles. The explosive class of dangerous goods is divided into 6 divisions. These sub-classes do not include those explosives that are too hazardous to transport, or substances that are not intrinsically explosive, but can form an explosive atmosphere of gas, vapour, or dust<sup>5</sup>.

- Division 1.1 Substances that have a mass explosion hazard.
- Division 1.2 Substances and articles that have a projection hazard, but not a mass explosion hazard.
- Division 1.3 Substances or articles that have a fire hazard and either a minor blast hazard or minor projection hazard, or both, but not a mass explosion hazard.
- Division 1.4 Substances and articles that present no significant hazard. The effect would be confined to the package and no projection of fragments of size or range is expected.
- Division 1.5 Very insensitive substances that have a mass explosion hazard. These substances have a low probability of initiation or of transition from burning to detonation under normal conditions of transport.
- Division 1.6 Extremely insensitive articles that do not have a mass explosion hazard.

## **Class 2 – Gases**

Gases pose a hazard because of their ability to diffuse over a large volume to exert a flammable, asphyxiating, toxic or oxidizing effect. A gas is defined as a dangerous good if at 50 °C it has a vapour pressure greater than 300 kPa, or it is completely gaseous at 20 °C at standard pressure (101.3 kPa).

This is further divided into four sub-classes:

- Division 2.1 Flammable gases (hydrogen, methane, acetylene)
- Division 2.2 Non-flammable, non-toxic gases (e.g. nitrogen, compressed air, helium, argon)
- Division 2.2 Oxidising gases: oxygen and nitrous oxide (Subsidiary Risk 5.1)
- Division 2.3 Toxic gases (carbon monoxide, chlorine, etc.)

### **Class 3 – Flammable liquids**

Flammable liquids are capable of being ignited and burned. They may also be mixtures of liquids, containing solids in solution or suspension (e.g. paints). Ignition of the flammable liquid and production of fire is a major hazard. The flammable liquids (Class 3) are considered a higher risk than flammable solids (Class 4) which we will discuss below. This is because of generally higher vapor pressure exhibited by liquid compounds, ability of the liquid to flow under gravity and collect at low points or flow into drains and waterways<sup>5</sup>.

### **Class 4 – Flammable solids**

Flammable solids, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction. They can also be a powder or paste. An added danger can be from toxic combustion products. E.g. metal powders, naphthalene.

#### ***Division 4.1*** Flammable solids

Self-reactive and related substances are liable to undergo a strong exothermic reaction. e.g. aliphatic azo- compounds, organic azides. Desensitized explosives are substances that may explode if not diluted sufficiently. e.g. ammonium picrate, wetted; dinitrophenol, wetted; barium azide, wetted; nitrocellulose with alcohol.

#### ***Division 4.2*** Substances liable to undergo spontaneous combustion

This division is comprised of substances that are liable to get spontaneously heated under normal conditions encountered in transport; or heated up in contact with air, and catch fire due to such heating. e.g. white phosphorus.

#### ***Division 4.3*** Substances that in contact with water emit flammable gases

These are substances that, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities. e.g. sodium metal.

### **Class 5 – Oxidising substances**

Oxidizing substances and organic peroxides pose a hazard because of their ability to chemically oxidize matter, including living tissue. Strong oxidizers can greatly enhance the flammability of material with the production of heat, fire, and dangerous reaction products<sup>5</sup>.

#### ***Division 5.1*** Oxidizing substances

Although these substances are not necessarily combustible, they may readily liberate oxygen; or be the cause of, or contribute to the combustion of, other materials (eg. hydrogen peroxide, copper chlorate and fluorine).

### **Division 5.2** Organic peroxides

All organic peroxides contain -O-O- structure. They are thermally unstable substances that may undergo exothermic, self-accelerating decomposition and most substances of this class are combustible. Examples of organic peroxides are dibenzoyl peroxide, peracetic acid and perbenzoic acid.

## **Class 6 – Toxic and infectious substances**

These are hazardous because of their chemical toxicity or biological infectivity to people, animals or the environment. The words “toxic” and “poisonous” are synonyms.

### **Division 6.1** Toxic substances

These are substances that if swallowed, inhaled or come into contact with the skin are liable to cause death, serious injury, or to harm human health.

### **Division 6.2** Infectious substances

Infectious substances are materials known, or reasonably expected, to contain pathogens. Pathogens are defined as microorganisms including bacteria, viruses, parasites, fungi, or are genetically modified microorganisms that are known, or reasonably believed, to cause disease in humans or animals. Genetically Modified Microorganisms which do not meet the criteria of an infectious substance should be considered for classification in Class 9.

## **Class 7 – Radioactive substances**

The substances which spontaneously emit ionizing radiation are considered under this category.

## **Class 8 – Corrosives**

Class 8 dangerous goods are corrosive substances that, by chemical action, will cause severe damage when in contact with living tissue, or in the case of leakage, will damage or destroy other materials.

## **Class 9 – Miscellaneous**

These are substances and articles that during transport present a danger not covered in other classes. This class includes substances that are transported or offered for transport at temperatures at or above 100 °C (liquid state) or in a solid state at or above 240 °C. Some examples of Class 9 dangerous goods are dry ice and strong magnets.

## **Basic Guidelines for Working with Hazardous Materials**

Before starting any work in the lab, personnel should be familiar with the procedures, equipment's, chemicals and hazards of the chemicals being used. Personnel who are unfamiliar with the hazardous material or a new procedure should consult their supervisor.

### **Working with Allergens and Embryotoxins**

A wide variety of substances such as diazomethane, chromium, nickel, dichromates, formaldehyde, isocyanates, and certain phenols can elicit skin and lung hypersensitivity. Because of this variety and the varying response of individuals, suitable gloves should be used whenever there is potential for contact with chemicals that may cause skin irritation.

Embryotoxins are substances that cause adverse effects on the developing fetus in pregnant women. These include benzene, heavy metals, carbon tetrachloride, chloroform, azo dyes, propylene glycol, xylene, formaldehyde, nitrous oxide and toluene.

Many substances, some as common as sodium chloride, have been shown to be embryotoxic to animals at some exposure level, but usually this is at a considerably higher level than is encountered in the course of normal laboratory work. However, some substances do require special controls due to embryotoxic properties.

### **Working with Substances of Chronic or Acute Toxicity**

The standard precautions will provide laboratory workers with good protection from most toxic substances. In addition, records that include amounts of material used and names of workers involved should be kept as part of the laboratory notebook record of the project. To minimize hazards from accidental breakage of apparatus or spills of toxic substances in the fume hood, containers of such substances should be stored in pans or trays made of polyethylene or other chemically resistant material and apparatus should be mounted above or on trays of the same type of material.

## References and Further Reading

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