HEALTH, SAFETY AND ENVIRONMENT PLAN

A Guide to
Laboratory Hazards,
Recommended Working Practices
and
Hazardous Waste Disposal

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1. Introduction

This document prepared by the Department of Chemical Engineering, Indian Institute of Technology Bombay, is a guide to the desirable practices relating to the protection of personnel health, safety and environment (HSE) which may be adopted and adhered to in connection with all laboratory-based research activities. The objective of this document is to provide all relevant information on safety and environmental disposal practices to the students, technical staff, and other concerned personnel. This is expected to help eliminate or minimize hazards that may be encountered during laboratory activities. It is anticipated that every personnel associated with the Departmental laboratory activities will strive to enhance the practices suggested here so as to ensure that potential health effects due to accidental exposure to the relevant hazards, and environmental impacts due to discharge of chemicals are either *eliminated* or *reduced to acceptable levels* as prescribed by regulatory authorities. Adherence to the best laboratory safety practices may not only be mandated, it is also in the best interest of a personnel and that of his / her co-workers.

2. HSE Policy

The Department's HSE policy may be summarized as follows:

- create and maintain a work place that is free of any hazards and environmental impacts associated with laboratory activities
- enable dissemination of all knowledge relevant to laboratory safety and waste disposal through focussed training sessions, expert lectures, posters, signage, etc.
- ensure adherence to the requisite safety and environmental (HSE) norms by all users through regular monitoring
- update the safety manual and associated HSE practices continuously
- appoint faculty co-ordinator(s) to oversee the HSE practices and ensure compliance
- discourage instances of non-compliance with suitable penalty
- publicize lessons from instances of accidental personnel exposure and environmental releases
- publicize compliance and innovative adoption of HSE practices by individual (or group of) students and technical staff

3. HSE Responsibilities:

The responsibilities in relation to adherence to safe practices within the Department would be as follows:

1. The Head of the Department would be responsible for appointing a faculty co-ordinator to oversee HSE practices, ensure compliance, and setting up HSE related committees
2. The HSE faculty co-ordinator would be responsible for continuous updating of the safety practices and the relevant documents, periodic auditing of practices in the Departmental Laboratories, and investigation of any instances of accidental personnel exposure, property damage and unacceptable environmental discharge. Other concerned and expert faculty may be co-opted in the above tasks in consultation with the Department Head.
3. The faculty-in-charge of each laboratory would be foremost responsible for overseeing and ensuring compliance with Departmental HSE norms within his/her laboratory; he/she need also enhance the practices through collection and dissemination of relevant HSE information.
4. The primary responsibility of complying with recommended HSE practices would devolve to the students and support technical staff in each laboratory.

4. The Nature of Chemical Hazards

The term hazard may be broadly defined as "anything that has a potential to cause damage to human health, property and environment". Hazards in a research laboratory may be of various forms: *mechanical, electrical, and chemical.* Examples include: *noise, rotating equipments, compressed gas cylinders, electricity, high temperature / high pressure equipments, chemicals that are toxic / flammable / corrosive / radioactive,* etc [Ref. 1]. Of these by far the most common and dominant hazard is the possible exposure to a variety chemicals that are implicated today in research in various fields of science and engineering. Many of these chemicals, especially if not properly used, may endanger health and safety, and pollute the environment, often irreversibly. Thus, a systematic assessment of the nature of personnel, property and environmental hazard posed by a chemical employed in the laboratory is necessary as part of a Department's HSE goal.

The following material attributes contribute to **toxic** heath-hazard due to possible acute, repeated or prolonged exposure [Ref. 2]:

- *toxic to human specific human organs (kidney, liver, lung, etc)*
- *toxic to human physiological systems (reproductive, nervous, blood, etc)*
- *corrosive (strong acids, bases, dehydrating agents, oxidizing agents)*
- *irritant (non-corrosive chemicals that cause reversible inflammatory effects on human tissue)*
- *cancer causing*
- *sensitizing (allergenic)*
- *radioactive*

Fire and **explosion** hazards may be classified as follows:

- *explosive*
- *oxidizing*
- *extremely flammable*
- *highly flammable*
- *flammable*

The following properties present hazard to the **environment**:

- *toxic to living organisms*
- *persistent in the environment (bio-persistent)*
- *bio-accumulative*

Also, substances and preparations that cannot be classified by using the above system may be regarded as dangerous if they have properties which are hazardous to human health, to other living organisms or if they can damage property / environment.

5. Examples of Potentially Hazardous Chemical Classes of Compounds

Of the large variety of chemicals that may potentially be used in a chemical laboratory the following classes of substances are generally regarded to pose HSE hazards [Ref 3]:

- *Acids*

- *Aldehydes*
- *Alkaline metals*
- *Amines*
- *Ammonia and Ammonium Compounds*
- *Azo and Diazo Compounds*
- *Hydrazines*
- *Carbonyls*
- *Chlorates and Perchlorates*
- *Cyanides*
- *Epoxides*
- *Ethers*
- *Halogens*
- *Hydrocarbons*
- *Hydroxides*
- *Isocyanates*
- *Mercaptans*
- *Nitro-compounds*
- *Organophosphates*
- *Peroxides and Hydroperoxides*
- *Phenols and Cresols*
- *Silanes and Chlorosilnaes*

6. HSE-relevant Properties of Chemical Substances

The hazardous nature of all chemicals is strongly grounded in their physico-chemical properties, the magnitude of which determine the degree (or intensity) of the hazard posed by them. Table 1 provides a list of such common properties of substances, which often are indicative of the level of hazard and which constitute inputs to quantitative (or semi-quantitative) assessment of hazard posed by a chemical [Refs. 3, 4, 5].

Table 1. Physico-chemical Properties defining Hazards

Appearance:	- indicate physical state (solid, liquid, gas), and colour
Odour:	- if odour is perceptible, give a brief description
Boiling point/boiling	- specify here the temperature at which the material changes from liquid to gas. If

range:	it decomposes without boiling, the temperature at which it decomposes may be given with the abbreviation `dec.'
Melting point/melting range:	- indicate the temperature at which the solid material changes to a liquid
Flash point:	- the lowest temperature at which a liquid or solid produces enough vapour to form a flammable air-vapour mixture near its surface so that it can be ignited by a spark or flame at atmospheric pressure.
pH:	- to provide an indication of acidic or alkaline (basic) properties, give the pH of the substance or preparation as supplied or that of an aqueous solution (in the latter case indicate the concentration). pH is expressed on a scale from 0 to 14, which can be divided into the following ranges: • pH 0-2 Strongly acidic • pH 3-5 Weakly acidic • pH 6-8 Neutral • pH 9-10 Weakly basic • pH 12-14 Strongly basic Substances or preparations with pH values 0-2 or 11.5-14 may be classified as corrosive.
Flammability:	- describes the ability of the material to ignite and burn readily. A liquid or solid with a flash point above 21°C but less than 55°C is flammable. - Highly flammable relates to substances or preparations with a flash point above 0°C but below 21°C, as well as to solids spontaneously flammable in air or which may readily ignite after brief contact with source of ignition and which continue to burn after removal of the source of ignition. - Extremely flammable relates to liquids which have a flash point below 0°C and a boiling point below 35°C, and to flammable gases when liquefied.
Auto-flammability:	- some materials have the feature of igniting in air in the absence of a spark or flame. The auto-ignition temperature can be found in the literature.
Explosive properties:	- specify, if appropriate, the concentrations for the lower and upper explosion limits. This is usually in volume percentage of air, for example, for xylene 1.1-7.0%, and for benzene 1.2 - 8.0%.
Oxidizing properties:	- substances which can generate and maintain heat producing chemical reaction

	with other materials, especially burning flammable material.
Vapour pressure:	- describes the tendency of a material to form a vapour. It is used e.g. for estimating the inhalation or fire hazards. Vapour pressure is expressed usually at the temperature of 20°C.
Relative density:	- the density of the substance or preparation compared to the density of water (= 1). This figure indicates whether the substance floats in water or sinks (when the relative density is more than 1).
Solubility:	- indicate here the solubility in water. If the solubility is not accurately known describe with words such as: poor, moderate, miscible...
Partition coefficient:	- the ratio of the solubility of a substance or preparation in n-octanol to that in water.
Other data:	- provide here data relevant for safety aspects, such as vapour density, evaporation rate, conductivity, viscosity, etc.
LD50	- abbreviation used for the dose which kills 50% of the test population. LD50 is expressed in milligrams per kilogram of body weight of the test animal (which must be mentioned).
LC50	- abbreviation used for the exposure concentration of a toxic substance lethal to half of the test animals. LC50 is expressed in millilitres per kilogram of body weight of the test animal (which must be mentioned), exposed to the substance by inhalation during a specified period.
TLV-TWA (Threshold Limit Value - Time Weighted Average)	- time-weighted average concentration for an eight hour working day or 40 hours a week to which nearly all personnel may be repeatedly exposed without adverse effect.
TLV-STEL (Threshold Limit Value - Short Term Exposure Limit)	- concentration to which a person may be exposed for a short time (usually 15 minutes) without suffering from irritation, long-term or irreversible tissue damage or impairment likely to increase accidental injury, affect self-rescue or reduce work efficiency
TLV-C (Threshold Limit Value - Ceiling)	- concentration that should not be exceeded at all during work exposure

7. Occupational Exposure Limits (OELs)

In order to control toxic effects in workplaces the commonest strategy is to define Occupational Exposure Limits (OELs). OELs are based on the best available information from industrial experience, from experimental laboratory studies and from accidents.

Different kinds of OELs are applied in practice. The TLVs (Threshold Limit Values) which have been defined in Table 1 are published by the American Conference of Governmental Industrial Hygienists (amongst others) [http://www.acgih.org/home.htm]. They set a limit concentration below which it is believed that nearly all workers can be repeatedly exposed day after day without adverse effect [Refs. 6, 7]. Therefore, these may also be regarded as target airborne concentrations that should never be exceeded in a laboratory environment. The TLVs are regularly reviewed and corrected when new information becomes available. Annexure 1 provides the latest Occupational Exposure Limits (termed alternatively as *Workplace Exposure Limits*) set by the UK Health and Safety Executive.

Almost all countries in the world today have adopted similar table of values of OELs for regulating personnel health at workplace (industry and laboratory). For detailed information on effects of various chemicals one may access the following website of *International Program on Chemical Safety (a World Health Organization subsidiary)*: http://www.who.int/ipcs/publications/ehc/en/.

8. Criteria for Major Hazard Chemicals

Typically any assessment of the degree of hazard from a chemical is based on multiple parameters which include: values of relevant physico-chemical properties, operating conditions, available inventory etc. Of these, the property values generally provide a very critical input to hazard assessment. Thus, several international and national bodies across the world have defined criteria based on substance physico-chemical properties, primarily for classifying substances into various hazard categories. One of the widely accepted classification criteria is due to the International Labour Organization (http://www.ilo.org), which recommends the following taxonomy for hazardous substances that pose significantly high level (major) hazard:

Toxic substances:

Toxic substances are classified into hazard categories according to their acute toxicity. Classification can be done by determining the acute toxicity in animals, expressed in LD50 or in LC50 values (see table 1). In general three categories are suggested: Very Toxic (Category 1 and 2) and Toxic substances (Category 3). These are demarcated by LD50 and LC50 values as shown in Table 2.

Table 2. Classification of toxic chemicals based on LD50 and LC50

Category	LD50 absorbed orally in rat (mg/kg bodyweight)	LD50 dermal absorption in rat or rabbit (mg/kg bodyweight)	LC50 absorbed by inhalation in rat (mg/litre per 4 hours)
1	<5	<10	<0.10
2	5-25	10-50	0.1 - 0.5
3	25 - 200	50 - 400	0.5 - 2

Flammable substances:

- Gases which form flammable mixtures with air
- Highly or extremely flammable liquids with flash points lower than 21 °C
- Flammable liquids with flash points lower than 55 °C

Explosive substances:

This category includes substances which may explode when brought in contact with a source of ignition or which are more sensitive to shock and friction than *dinitrobenzene*.

9. Hazardous Material Labeling:

There are several conventions of classifying and labeling hazardous chemicals across various continents. However, in an effort to develop a uniform, global system of classification of chemicals, labels and safety data sheets, the Globally Harmonized System (GHS) was initiated by the United Nations Conference on the Environment and Development in 1992. The work was co-coordinated and managed under the auspices of the Interorganization Programme for Sound Management of Chemicals (IOMC) Coordinating Group for the Hamonization of Chemical Classification Systems (CG/HCCS). The technical focal points of completion of the work were the International Labour Organization (ILO), The Organization of Economic Cooperation and Development (OECD), and the United Nations Economic and Social Council’s Sub-Committee of Experts on Transportation of Dangerous Goods (UNSCETDG). The first version became available in 2003 in the form of the so called purple book (compared to the orange book for transportation). The GHS harmonizes most classification criteria for supply and transportation and is based on the intrinsic properties of substances.

The following table 3 provides the signs used to label different types of hazardous substances enlisted in the UN Globally Harmonized System of Classification and Labeling of Chemicals (GHS). More details on the system are available at: http://www.unece.org/trans/danger/publi/ghs/ghs_rev03/03files_e.html

Table 3 Labels Representing Various Chemical Hazard Classes

Hazardous Substance Classes	**Label**
Unstable explosives	
Flammable substances - gases - aerosols - liquids - solids	
- Oxidizing gases - Oxidizing liquids	
- Compressed gases - Liquefied gases - Refrigerated liquefied gases - Dissolved gases	
- Corrosive to metals - Skin corrosion / irritation - Serious eye damage / irritation	

Acutely Toxic Substances - oral - dermal - inhalation	
Highly Toxic Substances & Substances with Specific Organ Toxicity - oral - dermal - inhalation - hazardous to ozone layer	
- Respiratory sensitizer - Germ cell mutagenic - Carcinogenic - Effects via or on Lactation - Toxic to Reproduction - Specific Target Organ Toxicity following Single Exposure - Specific Target Organ Toxicity following Repeated Exposure - Aspiration Hazard	
Substances posing acute, long term hazard to aquatic environment	
Radioactive Substances*	

* *From US Department of Transportation*

10: Stability and Reactivity of Chemicals: Use of Interaction Matrix

During the hazard assessment of a chemical one must also scrutinize the stability of the substance and the possibility of hazardous reactions occurring under certain conditions. It is necessary to list the conditions which should be avoided, such as high or low temperatures, pressure, light and shock effects [Refs. 3, 8, and http://www.ilo.org], which may cause a dangerous reaction and if possible include a brief description of these.

As part of the assessment one also must identify the materials which may cause a dangerous reaction if they come into contact with the substance or preparation concerned, such as water, air, acids, bases, oxidizing agents, etc. In addition it is necessary to list materials which may be produced in dangerous quantities upon decomposition. In a laboratory environment, the information pertaining to stability and reactivity of chemicals may be conveniently documented in the form of an "interaction matrix" [Ref. 2] which (for example) is illustrated in table 4.

Table 4 Interaction Matrix

	Chemical A	Chemical B	Chemical C	Mixture X	Mixture Y	Mixture Z
Chemical A						
Chemical A						
Chemical A						
Mixture X						
Mixture Y						
Mixture Z						
Low Temperature						
High Temperature						
High Pressure						
Humidity						
Light						
Shock						

As may be evident from fig 1, the interaction matrix essentially is a means to record the consequence of *an accidental combination* of the substances and / or conditions in the *first column* and the substances enlisted in the *first row*. The number of elements in the first row and the column may be expanded as a user may feel the need for. The user may then fill in the table (i.e, the individual boxes at the juncture of each row and column) with information on the expected consequences of each combination. Such a document may then become a source of information for decisions on expected experimental programs.

11. Ingress of Chemicals into Human Body

Chemical substance cause adverse health effects by either entering the body or coming in contact with it. There are four main routes for chemical substances to enter the human body:

- *Inhalation* (breathing in)
- *Absorption* (through the skin or eyes)
- *Ingestion* (eating, swallowing)

- *Transfer across the placenta* of a pregnant woman to the unborn baby

As already introduced above, the common chemical groups that cause health risks are: dusts, fumes and gases, solvents, acids, bases, heavy metals etc. Many chemicals may be dispersed into the air to form dust, mist, fumes, gas or vapour and can then be inhaled. Skin absorption is, after inhalation, the second most common route through which exposure may take place. Handling chemical substances without proper protection exposes one to the risk of absorbing harmful amounts of chemical through the skin. This usually happens when handling the chemical in liquid form. Dust may also be absorbed through the skin if it is wetted by, for instance, sweat. The capacity of different chemical substances to penetrate the skin varies considerably. Some substances pass through it without creating any feeling [http://www.ilo.org].

The protective external layer of skin may be softened (by toluene, dilute washing soda solution, etc) thus permitting other chemicals to enter readily into the bloodstream (such as aniline, phenol, benzene, etc). Eyes may also absorb chemical substances, either from splashes or from vapours. Dangerous chemicals can enter the body through ingestion as gases, dusts, vapours, fumes, liquids or solids. Inhaled dust may be swallowed, and food or cigarettes may be contaminated by dirty hands.

Whatever the route of entry, chemicals can reach the blood stream and be distributed all over the body. In this way damage can be caused at the *site of entry* as well as to organs distant from the exposed area. Chemical exposure may also cause adverse impacts at systemic levels: such as nervous and reproductive systems [Refs. 2, 5].

12. Chemical Absorptivity of Skin

In many countries a “skin notation” is used for cautioning against skin contact in cases where the skin is significantly permeable to the chemical in question. The *stratum corneum* provides the greatest barrier against hydrophilic compounds, whereas the viable epidermis is most resistant to highly lipophilic compounds. Skin absorption depends on the physicochemical properties (e.g. octanol–water partition coefficient ($P_{o/w}$), molecular weight, electron structure and dissociation constant (pKa) of the compound, but also on interactions with other compounds. Additionally, the vehicle, occlusion, concentration, exposure pattern and the site of the skin also play a role [Refs. 2, 5].

Evaluations of hazards due to skin penetration are generally complicated due to various factors that need to be considered: type of vehicle for the chemical, size of the exposed area, applied dose, etc. The simplest, semi-quantitative assessments consider the flux (in mg/cm^2hr) derived from *in vitro* studies. Theoretically, skin absorption depends, amongst others things, on the volume of the molecule and hence on the molecular weight of a compound as well as on the hydrophobic and hydrogen bonding properties, which are often based on the Po/w [Ref. 9]. The *U.S. National Institute for Occupational Safety and Health* (NIOSH) has a free service that allows the calculation of a skin permeation coefficient (K_P) for substances: http://www.cdc.gov/niosh/topics/skin/skinPermCalc.html. Also, skin penetration data can be obtained from the EDETOX database [http://www.ncl.ac.uk/edetox/].

13. HSE Information Requirements for a Laboratory

The key information that must be collected and disseminated amongst all users in a laboratory are:

- Material Safety Data Sheets (MSDS) pertaining to all chemicals used in a laboratory; these are generally available from manufacturers of chemicals and provide safety-related information for a chemical. This broadly includes: hazards, safe exposure levels, over-exposure symptoms, safe handling practices, waste disposal methods, etc. MSDS of many chemicals are also freely available on the internet
- Interaction Matrices containing information on stability and reactivity of various chemicals (may be abstracted from MSDSs)
- Documents containing detailed information on safety practices to be followed for all other classes of substance under usage: biological, radioactive, nanomaterials, etc. Information on these materials may be sourced and consolidated from all possible sources.
- Relevant Laboratory Standards recommended by regulatory agencies and other apex bodies (for example: OSHA *Laboratory Standard (US)* and its Appendices available at the OSHA website under the regulation number “1910.1450”: [http://www.osha.gov/pls/oshaweb/searchresults.relevance?p_text=29%20CFR%201910.1450]
- Consolidated information on safe handling and disposal information on all chemicals for ready reference (to be prepared from MSDSs and any other source, and made available in both hard and online formats)
- Consolidated information on management of accidental spills / release of hazardous chemicals and other forms of abnormal situations that may potentially cause harm to

personnel / environment (information may be obtained from MSDSs and other relevant sources)

For developing documents on the best practices in a customized manner at the laboratory level, the user of this manual is also advised to refer to the comprehensive compendium of safety and waste-disposal information related to all forms of laboratory hazards (including chemicals / biohazardous materials / radioactive substances, etc) available at: http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf.

14. Information on Carcinogenic Compounds

The International Agency for Research on Cancer (IARC) is internationally recognized for evaluation of compounds, complex mixtures with a carcinogenic potential. For the current state of the science of classification and evaluation see Annexure 2. The IARC evaluations rank the compounds and complex mixtures into five groups. Select examples of workplace carcinogens are enlisted below:

- ***Group 1:*** Carcinogenic to humans, which are based mainly on studies in humans. This group comprised 28 definite occupational carcinogens, including asbestos, crystalline silica, wood dust, arsenic and arsenic compounds, beryllium, cadmium and cadmium compounds, hexavalent chromium compounds, nickel compounds, benzene, vinyl chloride monomer, 4-aminobiphenyl, benzidine, 2-naphthylamine, ethylene oxide, 1,3-butadiene (recently reclassified to Group 1, cf. below), and coal tars and pitches.
- ***Group 2A:*** Probably carcinogenic to humans, which are based on sufficient evidences from animal studies. This group comprised 27 probably occupational carcinogens, including benzo[a]pyrene, tetrachloroethylene, trichloroethylene, acrylamide, epichlorohydrin, benzidine-based dyes, diethyl sulphate, and formaldehyde.
- ***Group 2B:*** Possibly carcinogenic to humans, which are based on a combination of effects in humans, animals and other evidences. This group comprised more than 100 occupational exposures, including antimony trioxide, cobalt and cobalt compounds, lead and inorganic lead compounds, naphthalene, acrylonitrile, ethyl acrylate, isoprene, styrene, toluene diisocyanate, acetaldehyde, acetamide, chloroform, 1,2-dichloroethane, dichloromethane, some aromatic amine dyes, some azo dyes (including trypan blue), butylated hydroxyanisole (BHA), catechol, 1,4-dioxane, and hydrazine.
- ***Group 3:*** Not classifiable as to its carcinogenicity to humans due to limitations in the data set.

- ***Group 4:*** Probably not carcinogenic to humans, which are based on a combination of effects in epidemiologic and animal studies together with other evidences.

For more details on classifications and the various categories and examples of carcinogenic compounds see article in Annexure 3. The summary and overall evaluations by IARC are available from the home web of the *International Programme on Chemical Safety* [http://www.inchem.org/pages/cicads.html and http://www.inchem.org/pages/icsc.htmlDf]. Another comprehensive list with documentations of carcinogenic compounds is available from the *U.S. Department of Health and Human Services* through the home web of the National Toxicology Program [http://ntp.niehs.nih.gov/ntp/roc/toc11.htm]. The list is published biennially and distinguishes between compounds "known to be human carcinogens", which is based on epidemiological studies, and compounds "reasonably anticipated to be human carcinogens", which is based on human and/or animal studies as well as on other relevant data. The lists are useful as a first choice of information about potential carcinogenic effects.

15. Biohazards and Related Safety Measures

The World Health Organization (WHO) divides the *Biohazardous Substances* class into two categories: **Category A**: Infectious; and **Category B**: Samples (virus cultures, pathology specimens, used intravenous needles). The procedures for handling of all such materials, intermediates, products and waste, and the attendant protective equipment in laboratories engaged in biological research require special attention. The pertinent safety information and hazard assessment procedures, standard laboratory practices must be identified, maintained and disseminated in the form of a manual by the concerned faculty-in-charge. As indicated in section XIV, a wide-ranging compilation of biosafety and waste-disposal information is available at:

http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf.

Select critical requirements with respect to biosafety are summarized below:

- Training of all personnel on standard procedures, techniques and safety practices to be adopted in microbial research
- Identifying the level of hazard posed by each biological material handled in the laboratory (by use of standard classification schemes recommended by regulatory agencies)

- Restricting access to all experimental apparatuses in use / display of appropriate bio-hazard signage
- Use of appropriate safety equipment (bio-safety cabinets) and appropriately designed apparatus for preventing release of biological materials during processing
- Use of specialized personal protection equipment during laboratory activities (face protection, gloves, respirators, coats, etc)
- Use of any special immunization procedures that may be required for personnel working in the laboratory
- Adherence to strict sterilization / decontamination procedures for laboratory equipment and exposed surfaces
- Decontamination of bio-wastes prior to disposal
- Development of emergency procedures to be adopted in the event of accidental spillage of biological materials
- Avoidance of intake of food in the laboratory

16. Safety in Nanomaterials Research

Engineered nanomaterials are those that are intentionally created (in contrast with natural or incidentally formed) and possess dimensions <100 nanometers. This definition excludes biomolecules (proteins, nucleic acids, and carbohydrates). Like most other laboratory chemicals nanoparticles may enter the human body through inhalation, skin exposure and ingestion. The specific hazards associated with most nanomaterials are yet to be identified in a systematic manner. Limited safety information available on such materials suggests that nano-sized particles are likely to be relatively more toxic than larger sized particulate matter. Owing to their reduced size and hence higher specific surface area, such materials have been found to be more reactive than higher sized particulate matter. Also, for the same reason nanomaterials are expected to be far more penetrable into the human body and hence can find their way to the body fluids (blood) and to specific organs more readily. Thus, if the material is toxic on its own, a higher level of toxic response is anticipated. Also, the nanoparticulate forms of some materials show unusually high reactivity, especially for fire, explosion, and in catalytic reactions.

In spite of the uncertainties on the nanomaterial hazards it is believed that the same general technical hazard control measures which are usually adopted for most chemicals may also be applied effectively for nanoscale materials. The *Oak Ridge Institute for Science and Education* (ORISE) a U.S. Department of Energy institute which focuses on scientific initiatives to research health risks from occupational hazards, prescribes, amongst other, the following work practices for nanomaterials:

- Transfer engineered nanomaterials samples between workstations (such as exhaust hoods, glove boxes, furnaces) in closed, labeled containers, e.g., marked "Zip-Lock" bags.
- Take reasonable precautions to minimize the likelihood of skin contact with engineered nanoparticles or nanoparticle-containing materials likely to release nanoparticles (nanostructures).
- If engineered nanoparticle powders must be handled without the use of exhaust ventilation (i.e., laboratory exhaust hood, local exhaust) or enclosures (i.e., glove-box), evaluate hazards and implement alternative work practice controls to control potential contamination and exposure hazards.
- Wear appropriate PPE on a precautionary basis whenever the failure of a single control, including an engineered control, could entail a significant risk of exposure to researchers or support personnel. Alternatively, ensure that engineered controls (e.g., laboratory chemical hoods) are equipped with performance monitors that will notify users if equipment malfunctions.
- Keep potentially contaminated clothing and PPE in the laboratory or change out area to prevent engineered nanoparticles from being transported into common areas.
- Consider any material that has come into contact with dispersible, engineered nanoparticles (that has not been decontaminated) as belonging to a nanomaterial-bearing waste stream. This includes PPE, wipes, blotters and other disposable laboratory materials used during research activities. Do not put material from nanomaterial-bearing waste streams into to the regular trash or down the drain.
- Evaluate surface contamination or decontaminate equipment used to manufacture or handle nanoparticles before disposing of or reusing it. Treat wastes (cleaning solutions, rinse waters, rags, PPE) resulting from decontamination as nanomaterial-bearing waste.

For more relevant information and guidance on preferred HSE practices for nanoscale materials the user may refer to the following document (from the US Department of Energy, Nanoscale Science Research Centres) on *Approaches to Nanomaterials ES&H* (NSRC, Revision 3a, May 2008) available at: http://orise.orau.gov/ihos/Nanotechnology/files/NSRCMay12.pdf

17. Human Physiological Responses to Toxic Substances

The human body needs very small quantities of chemicals that are poisonous in large doses. This applies, for example, to some heavy metals, such as copper, magnesium and manganese. The adverse effect is strongly related to the dose. The effects may be immediate or delayed, and they may be reversible or irreversible toxic effects [Ref. 1, 2, 5; and http://www.ilo.org]. The worst possible effect is fatality.

- *Local/systemic toxicity:* There are two main ways in which chemicals may exert their effects. Local effects occur at the area of the body which has been in contact with the chemical. Examples include external tissue injuries from acids or lung injuries from inhaled reactive gases. Systemic effects occur after the chemical has been absorbed and distributed from the entry point to other parts of the body. Most substances produce systemic effects, but some substances may cause *both* types of effects. An example is tetraethyl lead, which is a gasoline additive and produces skin effects at the contact site. It may also be absorbed and transported into the body causing adverse effects on the central nervous system and on other organs.

- *Target organs:* The degree of the toxic effect is not the same in all organs. Usually there are one or two organs which show the major toxic effect. These are referred as target organs of toxicity of the particular substance. The central nervous system is the target organ of toxicity most frequently involved in systemic effects. The blood circulation system, liver, kidneys, lungs and skin follow in frequency of systemic effects. Some substances attack muscle and bones. Both the male and female reproductive systems are susceptible to adverse and often debilitating impacts from many substances.

Skin. The largest organ in the human body (~1.5-2 m^2 in area) provides a protective cover to the body organs but can allow permeation of chemicals if the load is excessive. Many substances can infiltrate through the skin and find its way to the hematological system, for example phenol, which may even lead to fatality in the event of heavy exposure. Most common forms of skin disorders that may occur due to chemical contact are: eczemas, irritation and local inflammation. This condition can be either a non-allergic or allergic reaction to exposure to chemical substances. Examples of common contact allergens are several colorants and dyes, nickel, chromium, cobalt and their salts, organomercuric compounds, acrylate and methacrylate monomers, rubber additives and pesticides. Chemical skin injury may also be influenced by extreme levels of humidity and heat.

Lung. The lung is the major route through which toxic substances in the workplace enter the body. It is also the first organ to be affected by dusts, metal fumes, solvent vapours and corrosive gases. Allergic reactions may be caused by substances such as cotton dust, toluene diisocyanate (TDI, used in the manufacture of polyurethane plastics), and methylisocyanate (MIC, used in production of carbaryl insecticide). Allergic reactions may result from exposure to bacteria or fungi. When dust particles of size lower than 0.1μm are inhaled the lungs are unable to exhale them. They become embedded in the lung leading to a condition called *pneumoconiosis*. Pneumoconiosis is mainly a problem for human beings exposed to the dust of silica (quartz) and asbestos, and is the commonest non-malignant occupational lung disease throughout the world. Other substances, such as formaldehyde, sulphur dioxide, nitrogen oxides and acid mists may cause irritation and reduce the breathing capacity [Refs. 2, 5].

Nervous System. Several types of substances act as neurotoxins. The nervous system is sensitive to the hazardous effects of organic solvents, such as carbon disulphide. Some heavy metals also affect the nervous system; examples include lead, mercury and manganese. Several organophosphate insecticides (malathion, parathion) and other chemicals such as acrylamide hinder chemical neurotransmitter function in the nervous system, leading to weakness, paralysis and sometimes death [Ref. 2].

Blood. The blood circulation system may also be adversely affected by solvents. For example, benzene affects the bone marrow; the first sign is mutation in the lymphocytes. Pure as well as compounds of lead, carbon monoxide, and cyanides, may overcome enzyme activities involved in the production of hemoglobin in red blood cells. Chronic lead poisoning, for example, may result in anaemia, a condition in which the ability of the blood to distribute oxygen through the body is impaired.

Liver. The main function of liver is to break down unwanted substances in the blood. Solvents such as carbon tetrachloride, chloroform, nitrosamines and vinyl chloride, as well as alcohol, are hazardous to the liver. Such substances are termed hepatotoxins.

Kidneys. Kidneys help excrete waste substances that the blood transports from various organs of the body. This helps: (i) ensure that the body fluids contain an adequate blend of various necessary salts; (ii) maintain the blood pH constant. Solvents such as carbon tetrachloride, other halogenated hydrocarbons, may irritate and can severely damage kidney function. Turpentine in large quantities is also harmful to the kidneys: `painter's kidney' is a known condition related to occupational exposure. Other well-known kidney- damaging substances (otherwise termed nephrotoxins) are lead and cadmium [http:www.ilo.org].

Reproductive system. Several classes of compounds are also known to produce disorders of the reproductive system and impair birth functions. Examples include thalidomide, formamide, tetracycline, etc.

Allergic reactions. An allergic reaction (or sensitization) may appear after repetitive contact with a substance. Once the sensitization has been produced, even very low doses can provoke a reaction. Allergies can range from minor skin irritation to very severe or even fatal reactions. The pattern of sensitization varies according to the organism exposed to an allergen. In humans, the skin and the eyes are the most common areas of allergic response.

Interactive effects of chemicals on human body. The effect manifested by combination of chemicals (and mixtures) is known to be varied [http://www.ilo.org]. In some cases the effect may be additive (1+1=2). Organophosphate pesticides (for example, dialiphos, naled and parathion) exhibit such additivity of effects.

In other cases the combined effect of chemicals may exceed that of the individual ones (e.g., 1+1=4).It has been found that the risk of developing lung cancer after exposure to asbestos fibres is forty times greater for a smoker than for a non-smoker. In the domain of solvents, trichloroethylene and styrene manifest similar behaviour.

When two substances negate each other’s effect (1+1=0), it may provide an indication as to an antidote (as say for a poison).

In still other instances, a relatively risk-free substance may aggravate the effect of another (e.g., 0+1=3). Isopropanol and carbon tetrachloride have this kind of mutual effect. Isopropanol, at concentrations which are not harmful to the liver, increases the liver damage caused by carbon tetrachloride.

18. Chemical Hazard Control: Technical Measures

There are a variety of technical measures that can be used to prevent chemical hazards at source and / or reduce personnel exposure [Ref. 1 & 2; also http://www.ilo.org].

- ***Substitution:*** An effective control method for any hazardous chemical is substitution; a hazardous chemical is substituted with a less hazardous one. This is preferred especially if highly hazardous substances such as carcinogens are implicated, or those which may seriously impair human physiological systems. However, one must ensure that the substitute substance allows the elimination of the hazard posed by the previous substance.
- ***Engineering control (Closed system)****:* If the option for substitution is not available easily, the personnel must be safeguarded against any exposure. A usually effective measure is to enclose the hazardous process or chemical. For example one must use sealed pipes to transfer toxic or highly flammable solvents and other liquids (especially the volatile ones) instead of pouring them in the open air. Exposures to vapours and gases need also be controlled and minimized if hazards are implicated in their use.
- ***Local exhaust ventilation:*** It may not always be possible to isolate experimental activities involving hazardous materials. In such a case solution must be sought through adequately designed local exhaust ventilation, which usually helps remove the contaminants at the source. A local exhaust ventilation system consists of a fume hood, ducts or pipes, a system to collect and separate the pollutants from the clean air, and an efficient fan to create the necessary suction force. Hazardous gases, fumes and dust collected from the vented air should, however, be treated before disposal. Inspection, proper maintenance, regular cleaning and changing of filters are essential to protect to protection against hazardous contaminants.
- ***General ventilation****:* Where it is difficult or impossible to prevent hazardous chemicals, fumes, dusts, mists or particles from entering the laboratory air at the source, general dilution ventilation can be installed so that the maximum airborne

pollutant concentration does not exceed the TLV (see section VI) for the substance. At its best it should consist of an inflow of clean air and an outflow of exhaust forced by fans at placed at the right places. It can also be used with other preventive measures.

- ***Housekeeping:*** When working with dangerous chemicals, proper housekeeping is essential. Storage areas / stacks / cupboards must be well organized and kept in order. Maintenance of premises and equipment should also be planned. These tasks should be dedicated to persons/laboratory work groups. Periodic testing and repairing faulty equipment must also be ensured. The efficiency of housekeeping should be monitored with a suitable periodicity; this should involve the faculty-in-charge / students / staff associated with a laboratory.

19. Exposure Control through Personal Protection

Exposure control involves a wide variety of defensive measures to be taken during the use of hazardous substances in order to minimize worker exposure [Ref. 1 & 2; also http://www.ilo.org]. However, it may be emphasized that engineering measures (see section XIX) should always be the primary measure, to be reinforced by deployment of personal protection equipment (PPE). The choice of the type of PPE should be commensurate with the type of likely exposure (inhalation, contact, etc) and designed to provide effective protection against exposure. Examples are summarized below:

- *Respiratory protection*: specify adequate masks and the filter type
- *Eye protection*: specify the type of protective equipment, such as safety glasses, safety goggles, face shield
- *Hand protection*: specify the type and material of gloves to be worn when handling the substance or preparation. An example of the importance of choosing the right material is that polyvinyl alcohol (PVA) provides good protection against toluene diisocyanate but offers poor resistance to trichloroethylene.
- *Skin protection*: specify the type and quality of equipment required, such as an apron, boots or full protective suit. Indicate also the specific hygiene measures, such as eating or smoking prohibition during handling, or washing methods.

- Additional protection / mitigation from emergency situations: specify safety showers, eyewash stations, fire extinguishers, etc.

20. Chemical Hazard Identification and Management

The foregoing sections have introduced the various classes of hazardous chemicals, their hazard criteria, effects they exert on human health, and the technical measures that one may adopt in order to contain and / or mitigate the associated danger in working with them. Thus it may be appropriate to summarize the entire process of hazard identification and management by means of layered or step-by-step scheme. Such a *decision tree* is presented in fig. 1. It is expected to provide a structured approach to selection and admittance of a chemical for use in laboratory research.

21. Safe Laboratory Practices: General Recommendations

- Establish and follow safe chemical storage procedures for your laboratory
- While working outside normal hours ensure that information about your presence in the laboratory is available to another person
- Avoid all skin contact with toxic and corrosive chemicals through minimum usage and use of personal protective equipments
- Ensure good housekeeping, adequate spacing between experimental setups
- While handling flammables ensure that no ignition sources are available in the vicinity; in case highly flammable substances are in use consider use of sensors to detect leakages if reasonable amount of inventories are available
- Ensure all chemical containers are labelled (along with a date of purchase) according to relevant industry guidelines
- Use appropriate signage to indicate highly hazardous chemicals and wastes
- Use signage to demarcate work areas subject to non-chemical hazards such as noise, temperature, radioactivity, microwave exposure, etc.
- Document any known hazardous properties of new chemicals, nanomaterials, toxins, etc
- While using a chemical ensure that information on other chemicals which are incompatible with the former
- Segregate and avoid simultaneous use of all incompatible chemicals
- Maintain adequate number and type of personal protection equipment and first-aid kit

- Maintain adequate type of equipment and devices to manage accidental spills and releases of hazardous chemicals
- Investigate all ‘abnormal occurrences’ that lead to (or potentially may have led to) impact on a laboratory personnel / external environment
- Document lessons from abnormal occurrences and publicize them to prevent recurrence
- Ensure that there is an emergency exit in the laboratory and always keep it clear
- Take special precautions to secure all high pressure gas storage cylinders against accidental slippage and fall

22. Management of Chemical and Bio-wastes

Hazardous wastes of all forms generated during laboratory activities must be identified and managed in a manner to ensure acceptable personnel exposure and environmental disposal as specified by regulatory bodies [http://www.cpcb.nic.in/Hazardous_waste.php]. Some recommended practices are as follows [Ref. 10; and http://www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf]:

- Laboratory activities should be consciously planned to help minimize generation of wastes, particularly those which are hazardous
- All students / staff handling wastes need be fully informed of the associated hazards
- Safe practices for handling, storage, labelling and disposal of hazardous materials must be identified and documented and displayed prominently in each laboratory
- The maximum quantity of hazardous waste that may be stored at any time for disposal must be regulated by the laboratory with due reference to any standard that may be available
- The maximum time of storage of hazardous wastes must be fixed and adhered to in order to ensure timely disposal
- While storing hazardous wastes special caution and effort must exercised for identifying container materials compatible with the waste
- In the instances when no adequate treatment / disposal facilities are available at the laboratory level it is essential to label and store wastes in a safe manner and identify contractors to whom the materials may be transferred for treatment and disposal

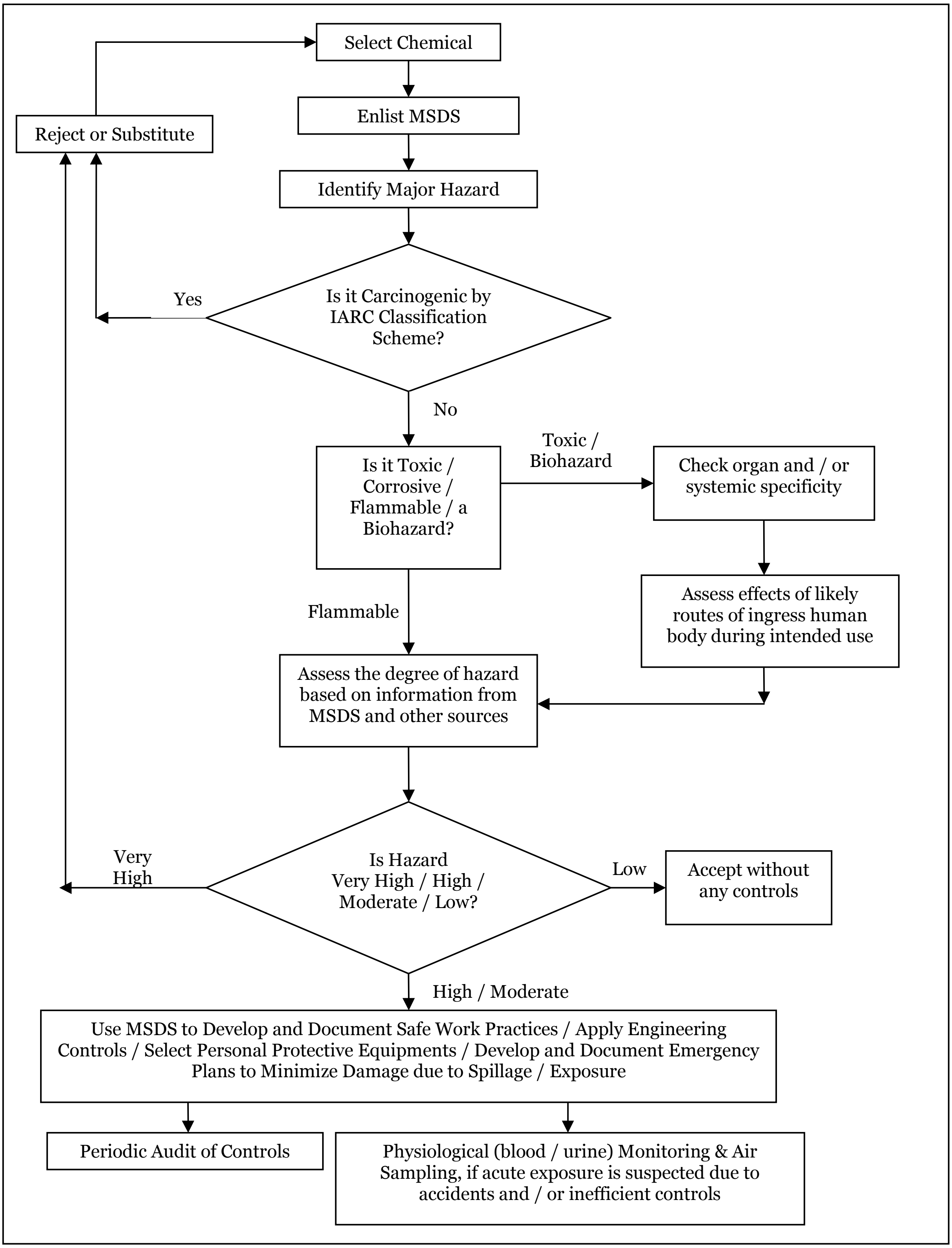

Fig. 1 Schema for Chemical Hazard Identification and Management

- Highly hazardous wastes such as radioactive materials must be handled and disposed off in accordance to guidelines from concerned regulatory bodies
- Special disposal methods must be resorted to wastes generated in bio-laboratories, including broken glassware which may be contaminated hazardous bio-materials
- Wastes whose chemical nature is not known may need specialized disposal procedures and in all such instances expert advise must be sought and documented for any future use
- All laboratories must display a prominent signage containing a list of unused or waste materials that may be permissible for disposal into sinks; these may include: very weak acids and base ($5 < pH < 12$), sugars, amino-acids, soaps / detergents, buffer solutions, metal-free solutions, disinfected bio-matter, etc.
- Disposal of all other forms of unused / waste chemicals / wastewater into laboratory sinks should be strictly controlled and avoided

23. Electrical Safety

A typical laboratory may house a large number of appliances that pose electrical hazards. Examples include: power supplies, microwave devices, ovens, stirrers, heating mantles (in say, distillation apparatus), pumps, compressors, sonicators, etc. In addition, some laboratories may need to house equipments that require high voltage / power for operation. Also devices which embody capacitors are hazardous as they may allow storage of high levels of electrical energy which may discharge accidentally. All electrical devices need to be maintained and operated following safe practices; in absence of either precautions such equipments may pose serious hazards to an user, which in the worst case may prove fatal.

The major hazards associated with electricity are electrical shock and fire. In a flammable atmosphere electrical equipment discharges cause fires and/or explosions. On the human body, the severity and effects of an electrical shock depends critically the magnitude of current, the duration of exposure to the shock. Since water is a good conductor, the effects are intensified if a contact with an electrically energized source is made with a wet skin. Electrical shocks may have minor to major consequences: a shiver to severe burns, and in the extreme case a cardiac arrest. The table 5 below shows the range of response that the human body to current.

Table 5 Current Intensity and Human Response

Current (milli-amperes)	Response
1	Perceptible magnitude
5	Experience of mild shock (not painful)
6 – 30	Feeling of pain
30 – 150	Severe muscular convulsion, Extreme pain, Respiratory seizure,
1000 - 5000	Ventricular fibrillation
> 10000	Cardiac failure, severe burns, probable fatality

Typical measures to control laboratory electrical hazards are:

- Ensure all electrical equipments are appropriately grounded; provided with suitable insulation, and guarded so as to avoid direct contact; conduct periodic checks to ensure the integrity of such measures
- Ensure adequate signage to indicate the location of main power supply which must be deactivated in case of any emergency
- In case it is needed to handle equipments that are connected to electrical power source, avoid contact through wet skin
- Use personnel protection such as non-conducting gloves and shoes when handling electrical equipments that are energized
- Be sure to disconnect the power source before repairing / removing electrical equipment
- Avoid using both hands while at work with electrical equipments, as bridge formed by using both hands increases the chance of respiratory shock
- In case of accidental receipt of electrical shock by a person, first switch off /disconnect the power source before touching the person or any part of the electrical system which relayed the shock

- In case of accidental spillage of a chemical onto an electrical equipment disconnect the electrical supply source prior to any cleanup
- In cold rooms condensation may increase the chance of electrical shock due to most conditions; hence it is desirable to minimize the use of electrical equipment in such rooms
- Modifications to existing electrical service in a laboratory or building must be subject to expert consultation and conform to standards
- Ensure that power loss doest not create hazardous situations in a laboratory
- Personnel handling high voltage/current equipment must be adequately trained on the prospective hazards

For additional information see "Chemical, Fire and Electrical Safety Document" from WHO available at: http://whqlibdoc.who.int/publications/2004/9241546506_partVI.pdf

24. HSE System Implementation and Audit

The present document provides a broad introduction to select critical HSE information and guidelines to be followed within each laboratory. The Department encourages active participation from the student and support laboratory staff to employ the guidelines in order to prepare further specific documents outlined in section 14. The appointed HSE committee member along with the faculty convener will provide due support and guidance for such efforts through provision of suitable formats for maintenance of all information online.

However, the HSE committee will also perform periodic audits of compliance of HSE norms and guidelines by each laboratory, in terms of the documentation and internal dissemination of all relevant HSE information, adoption of safe practices on laboratory work, housekeeping and waste disposal on a continual basis.

The framework of the audit process will be made available to all users, but it is expected that all concerned personnel will strive to enhance the HSE system beyond primary compliance. Wherever deficiencies are detected through audit, the appointed HSE committee will recommend measures to ensure conformity with the norms. At the same time wherever innovative HSE approaches are adopted, the committee may recommend special recognition of the effort in suitable terms.

25. Conclusions

The present document aims to be an introductory guide to the various safety practices essential to laboratory activities. Its purpose is to offer an overview of the subject so as to help create an appreciation of potential hazards within the laboratory environment and so enable their elimination or mitigation. The user is urged to actively refer to the various literature and websites enlisted here as well as others. Since the materials used in each laboratory is likely to be different from those used in another, it is the responsibility of the user in each laboratory to establish and update the essential safety and waste disposal information, and render them available in a form that may be accessed and utilized with ease and promptitude.

The Department of Chemical Engineering at IIT Bombay holds the view that awareness of hazards, and compliance with the best safety and waste disposal practices is *integral* to the accomplishment of laboratory research. It is also an *ethical* imperative. The discipline of occupational health and safety is a rapidly expanding field and all those who work in a laboratory environment need to accept the task of *pro-actively* seeking and documenting all relevant information and implementing practical measures to establish and sustain a safe working milieu.

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Appendix: Examples of Hazardous Chemicals from Various Classes

Hazardous Material Classification due to US Department of Transportation

DOT Hazard Class	Definition	Examples	Hazards	Storage
Class 1 *Explosive/Shock Sensitive*	Thermodynamically unstable material, may explode when brought in contact with a source of ignition (or which are more sensitive to shock and friction than *dinitrobenzene)*	picric acid, 2,4-dinitro-phenol, organic azides	Explosion caused by shock or chemical reaction.	Follow manufacturer's recommendation. Discard before expiration date. Store minimum quantities.
Class 2: Gases				
Flammable Gas	Gas with a flash point less than 140° F.	carbon monoxide, hydrogen, oxygen, acetylene	Ignites easily, burns rapidly.	Store away from ignition sources and oxidizers. Secure with a double chain to prevent falling. Store oxygen away from flammable gases. Check connections regularly to avoid leaking.
Non-Flammable Gas (including compressed gas)	Non-flammable, purified gas in a pressurized tank.	nitrogen, carbon dioxide, neon	toxic atmosphere, oxygen displacement	Store upright, secure with a double chain to prevent falling. Check connections regularly to avoid leaking.
Poisonous Gases:	Gases liable to cause death or serious injury to human health if inhaled	fluorine, chlorine, hydrogen cyanide	toxic atmosphere, oxygen displacement	Store upright, secure with a double chain to prevent falling. Check connections regularly to avoid leaking.
Class 3 *Flammable Liquid*	Liquid with a flash point less 140° F.	diethyl ether, carbon disulfide, methanol, acetone, acetaldehyde	Ignites easily, burns rapidly.	Store in flammable storage cabinet, away from ignition sources and oxidizers. Quantities should not exceed 10 gallons.

Class 4 *Flammable Solid*	Solid that burns readily.	sodium, calcium, potassium, calcium carbide, nitrocellulose, magnesium, aluminum alkyls, white phosphorus	Ignites easily, burns rapidly.	Store in flammable storage cabinet, away from ignition source and oxidizers.
Class 5.1 *Oxidizer*	Agents that react with reducible material to initiate or promote combustion.	nitric acid, bromine, calcium hypochlorite, ammonium nitrate, hydrogen peroxide, potassium permanganate	Fire or explosion.	Store away from organics and flammables. Do not store directly on wooden shelves or paper. Store chlorine separately from acids.
Class 5.2 *Organic Peroxide*	Any organic compound that forms unstable peroxides when exposed to air.	diethyl ether, benzoyl peroxides, cumene hydroperoxide	Explosion resulting from formation of concentrated peroxide crystals.	Dispose before expiration date. If there is no marked expiration date, label with receipt date and maintain for no more than 1 year or 6 months after opening.
Class 6.1 *Poison /* *Toxic /* *Highly Toxic*	Chemicals that cause damage to target organs (liver, lungs, reproductive system, etc.) if inhaled, ingested, or absorbed through the skin. **Toxic** chemicals have an LD50 of 50 - 500 mg/kg, single oral dose for rats. **Highly toxic** chemicals have an LD50 of < 50 mg/kg, single oral dose for rats	chloroform, chromic acid, phenol, acetonitrile, potassium cyanide, mercuric chloride, pesticides, methylene chloride	Acute or toxic effects that may be local, systemic, or both.	Store in a secure, sealed container below shoulder level. Use only in designated areas. Store away from incompatibles.
Class 6.1 *Bio-hazardous substances*	Material of biological origin that could be infectious / pathological etc	Bacterial /virus cultures, pathology specimens, used intravenous needles	Acute or toxic effects that may be local, systemic, or both	Store in a secure, sealed containers / cabinets
Class 7: *Radioactive*	substances or a combination of substances which emit ionizing radiation	uranium, plutonium	Exposure may lead to genetic effects	Follow norms recommended by relevant regulatory bodies
Class 8: Corrosive	substances that can dissolve organic tissue or severely corrode certain metals			
Organic Acids	Compound with pH of 1-7, containing carbon.	phenol, acetic acid	Tissue damage, violent reaction with strong bases.	Segregate from mineral acids, oxidizing acids and bases.

Inorganic Acids	Compound with pH of 1-7, not containing carbon.	hydrochloric acid, sulfuric acid, boric acid	Tissue damage, violent reaction with strong bases.	Segregate from organic acids, oxidizing acids and bases.
Caustics	Compound with pH of 7-14.	sodium hydroxide, potassium hydroxide	Tissue damage, violent reactions with strong acids.	Segregate from mineral acids, organic acids, and oxidizing acids.
Class 9: Miscellaneous				
Water Reactive	Reacts violently when exposed to water producing heat or toxic gases.	sodium metal, acid anhydrides, metal anhydrides	Explosion, fire, toxic atmosphere	Store away from water, including sprinkler heads, sinks and drains, per manufacturers' instructions.
Pyrophoric	Ignites spontaneously in air.	Phosphorus, lithium	Fire	Store under inert atmosphere per manufacturers instructions.
Carcinogen	Chemicals that cause cancer in humans or animals models.	formaldehyde, benzene	Carcinogenesis	Store in a secure, sealed container below shoulder level. Use in only designated areas with approved controls. Store away from incompatibles.
Cryogen	Liquefied or solidified gases at low temperatures.	liquid nitrogen, dry ice	Tissue damage (frost bite), oxygen displacement, tank rupture	Store in approved containers. Store in well ventilated areas. (Do not store dry ice in cold rooms.) Design transfer lines such that liquids cannot be trapped in a non-ventilated part of the system.
Sensitizer	Substances that can cause an allergic reaction of the skin or respiratory system.	glutaraldehyde, isocyanates	Allergic reaction	Store in secure container taking into account other hazards associated with the substance.
Controlled Substances	Substances specifically controlled by law	narcotics	Theft	Store in a secure, locked location. Maintain a current inventory.