Health Hazards in the Laboratory

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Health hazards encountered in laboratories involved in the conservation and restoration of museum collections and art objects may be divided into the following (somewhat overlapping) classes depending on the nature of the hazard:

1. cuts and burns
2. fire and explosions
3. asphyxiation and problems associated with dust
4. toxic hazards (including those caused by fungi)
5. radiation hazards

Many accidents may be attributed to a certain degree of carelessness on the part of the operator and, thus should be relatively easy to avoid by taking, often quite elementary, precautions. Into this category fall most hazards mentioned under 1, 2 and 3. For instance, injuries to the face and particularly to the eyes may be minimised by the wearing of safety shields or at least safety glasses. Smoking should not be allowed, particularly when inflammable or explosive solvents are being used. Burning cigarette butts should never be thrown into a sink. Electric heaters should not be used when working with ether. Unlike most other solvents, ether vapours are heavier than air and will sink to the floor where they may ignite on coming into contact with the incandescent filament of a heater situated under someone's desk. Most importantly, a great number of accidents are caused by simple inattentiveness. It must be emphasized that even the simplest laboratory operation demands the undivided attention of the operator.

Toxic hazards present a more serious problem. The chief reason is that many conservators are not trained chemists. Thus, they may not relate the name of a particular compound with its structure and therefore overlook any potential toxic properties. The name acrylonitrile (a compound used in the manufacture of plastics) does not, in itself, imply any particular dangerous properties. However, a knowledge of its structure, CH_2=CH-CN, will immediately suggest to the experienced chemist that the compound may exhibit skin irritating properties (owing to the presence of the vinyl group CH_2=CH-), cyanide-like toxicity (owing to the cyanide group CN-) as well as being inflammable (small molecule containing mainly carbon and hydrogen).

Furthermore, inexperienced workers may not realise, that certain relatively harmless substances may on mixing yield very toxic or otherwise harmful products. A few examples are:

1. Bleaching powder and its aqueous solutions (such as "Zixo") evolve poisonous chlorine gas on addition of acid (such as dilute phosphoric acid, sulphuric acid etc.). This may easily happen when waste solutions are poured down the sink.
2. Condy's crystals (potassium permanganate) when mixed with certain easily oxidisable compounds (glycerol, benzaldehyde . . .) may cause a fire or even an explosion.
3. Concentrated nitric acid, a dangerous liquid in itself, is a powerful nitrating and oxidising agent. Mixed with alcohols such as ethanol or glycerol it yields extremely explosive products such as nitroglycerine.
4. Small fires may be very effectively extinguished with carbon tetrachloride. This results in the production of highly toxic phosgene.

Before discussing individual compounds it may be useful to mention that toxic substances fall into three main classes: those causing poisoning by ingestion (clean your hands before touching food; do not mouth pipette corrosive or poisonous liquids, use a bulb pipette), skin absorption (wear gloves if required) and inhalation (ensure good ventilation; work in fume cupboards). Also, toxicity is difficult to assess quantitatively. Different people react differently to certain toxic substances. The relative toxicities of vapours and gases may be assessed from

a knowledge of their "threshold limit value" (TLV). The TLV represents conditions under which most workers after repeated exposure will suffer no adverse effects.

Individual Compounds Or Classes Of Compounds

Acids. Most mineral acids i.e. hydrochloric acid, nitric acid, phosphoric acid and particularly sulphuric acid heat up on dilution with water. In order to prevent overheating the acid is poured slowly into cold water and *not* the other way around. Hydrofluoric acid exerts a slight local anaesthetic effect on body tissues. Consequently, minor contacts with hydrofluoric acid may go unnoticed. By the time the anaesthetic effect has worn off and the affected part starts to burn, damage to the skin and underlying tissues may already be serious. Any acid spilt on the skin should be immediately washed off with a lot of water. Oxidising acids such as concentrated nitric acid or perchloric acid may react explosively with a variety of organic compounds such as alcohols, ketones and aldehydes. The use of a mixture of concentrated nitric acid and ordinary alcohol as a cleaning solution for dirty glassware is, therefore, strongly discouraged.

Organic acids are on the whole much less dangerous. Glacial acetic acid will cause severe skin burns.

Alkalies. Solutions of sodium or potassium hydroxide in water are highly caustic. Contact with the skin must be avoided. Carbonates and bicarbonates will froth uncontrollably in the presence of acid. This can give an inexperienced worker quite a fright and lead to accidents such as dropping the object in his hands, breaking glassware, etc.

Metals and Metal Salts. Salts of barium and of certain heavy metals such as copper, lead, chromium and particularly mercury are quite toxic. Vapours of metallic mercury are also very harmful. Spilt mercury (from broken thermometer bulbs) may be rendered harmless by dusting with sulphur powder. Metallic sodium reacts violently with water and must be stored under kerosene or, preferably, paraffin oil. Potassium cyanide liberates lethal hydrogen cyanide on contact with even very weak acids.

Solvents. All hydrocarbons are highly inflammable. Toxicity increases from the relatively harmless aliphatics such as hexane or kerosene to aromatics such as toluene and particularly benzene. Benzene exerts a toxic action on blood forming tissues and should, therefore, be replaced wherever possible with the less toxic toluene or xylene.

All chlorinated solvents possess harmful or potentially harmful qualities of one kind or another. Consequently, inhalation of their vapours or skin contact should be avoided. Particular care should be exercised when working with carbon tetrachloride, a rather more toxic member of this group. Incomplete burning of chlorinated hydrocarbons yields the highly toxic phosgene.

Oxygenated solvents i.e. various alcohols, ketones, ethers and esters are, apart from their inflammability, on the whole relatively safe. Notable exceptions are methyl alcohol (ingestion may cause blindness) and diethyl ether (its vapours form extremely explosive mixtures with air).

All nitrogen containing solvents such as pyridine, aniline and N, N-dimethylformamide (DMF) are highly toxic. Extreme care should be exercised in their handling; in particular skin contact as well inhalation of their vapours should be avoided at all cost.

Preservatives, Insecticides and Fungicides. As one would expect, all compounds in this category will be quite toxic. However, special care is indicated with the following:

Carbon disulphide – highly poisonous as well as inflammable and capable of forming explosive mixtures with air.

Various chlorinated insecticides (DDT, dieldrin, aldrin, chlordane) – lipid soluble, cause damage to liver and kidneys.

All phosphate esters (parathion, malathion, dichlorvos, diazinin) – parathion is particularly dangerous; poisoning may occur from skin contact, ingestion or dust inhalation.

Plastics, Curing Agents and Dyes. Most fully cured plastics are non-poisonous; at worst they may be inflammable (celluloid, perspex). Liquid resins may cause skin and eye irritation.

Hardeners for two-stage epoxy resins are often high molecular weight amines which may act as strong irritants, particularly when heated. Isocyanate hardeners for polyurethane resins are very toxic. Their vapours must not be inhaled.

Many dyes based on diazotised aromatic amines may be carcinogenic.

Fungal Hazards. Certain species of *Aspergillus*, and in particular *A. flavus* produce highly carcinogenic metabolites, the aflatoxins.

Table 1

Acids

Compound	Hazard
Hydrochloric acid	Corrosive; irritant to mucous membranes. TLV 5 ppm (7 mg/m^3 of air), 1000-2000 ppm may be lethal.
Sulphuric acid	Corrosive; mists may cause chronic bronchitis. TLV 1 mg/m^3 of air. Causes rapid destruction of

	plant and animal tissues. Heats up on mixing with water.
Hydrofluoric acid	Extremely corrosive and irritating to mucous membranes and skin. Burns may result in gangrene. TLV 3 ppm (2 mg/m^3 of air), 50-250 ppm extremely dangerous even for short exposures.
Phosphoric acid	Irritant; toxic vapours emitted on heating. Dilute solutions in water relatively safe.
Nitric acid	Corrosive; irritant to mucous membranes and skin. TLV 10 ppm (25 mg/m^3 of air). Fumes very toxic. Powerful oxidising agent.
Aqua regia	Similar to nitric acid. Emits fumes of highly toxic nitrosyl chloride.
Perchloric acid	Very corrosive; burns the eyes and skin severely. Powerful oxidising agent.
Acetic acid (conc.)	Causes skin burns; irritant to mucous membranes; may cause dermatitis and skin ulcers. Inflammable.
Formic acid	Vapour irritates all parts of the respiratory system as well as the eyes. Liquid burns the skin and causes painful eye burns.
Oxalic acid	Dust irritates respiratory system; TLV 1 mg/m^3 of air. Severe pain if swallowed.

Table 2

Alkalies

Compound	Hazard
Caustic alkalies (Hydroxides of sodium and potassium)	Highly caustic; both the solids and strong aqueous solutions cause severe burns to the eyes and skin. Must not be swallowed.
Ammonia solution	Strong ammonia irritates the eyes and skin; TLV 50 ppm (35 mg/m^3 of air). The concentrated solution (ca 35%) in water may develop during warm weather pressure in its bottle and the cap must be released with care.
Barium hydroxide	Toxic if ingested; skin contact should be avoided.
Sodium carbonate and bicarbonate	React with acids with intense frothing.

Table 3

Metals and metal salts

Compound	Hazard
Cyanides of potassium and sodium	Liberate hydrocyanic acid in acidic media (even moist air). Death is due to asphyxiation. Causes "cyanide rash"; chronic poisoning manifests itself with headaches, loss of appetite and irritation of upper respiratory tract.
Salts of barium	All toxic (except sulphate) when ingested.
Salts of copper	Dust irritates mucous membranes and the eyes; toxic when ingested.
Chromates and dichromates	Dust irritates respiratory tract and the eyes. Frequent exposure of skin to dust can cause ulceration; long-continued absorption can cause liver and kidney disease and even cancer.
Mercury	Very toxic vapour; TLV 0.1 mg/m^3 of air. Produces acute as well as chronic poisoning.
Mercury compounds	Mostly very toxic, both by skin absorption as well as ingestion. Chronic effects include nervous disturbances.
Lead compounds	Inhalation of dust or ingestion may cause severe internal injuries.

Table 4

Solvents

Compound	Hazard
Petroleum hydrocarbons (hexane, kerosene)	Inflammable; may form explosive mixtures with air. Some cause dermatitis.
Tetralin	Irritant; narcotic in high concentration; causes cataracts and kidney damage in animals. Inflammable.
Benzene, toluene and homologues	Inflammable. Strong local irritants (particularly benzene). Toxic action on blood forming tissues may cause death. Bleeding in urinary tract. TLV for benzene 25 ppm.
Chlorinated solvents	Narcotic action; kidney and liver damage. Dermatitis. Toxic phosgene produced on burning.

Alcohols	
Methanol	Action on nervous system via stomach tissues may result in blindness.
Ethanol	Irritant of mucous membranes.
Glycol	Inhalation of vapours or ingestion may cause liver and kidney damage.
Esters, ketones, ethers	Inflammable; narcotics. Diethyl ether forms very explosive mixtures with air. Usually contains explosive peroxides, hence exercise care when distilling large volumes of ether.
Nitrogenous solvents	
Pyridine	Vapour irritates respiratory system. Affects central nervous system if ingested; may cause death. Highly inflammable.
Aniline	Inhalation of vapours causes headaches and even convulsions. Avoid contact with skin.

Table 5

Preservatives, Pesticides and Fungicides

Compound	Hazard
Formaldehyde solutions (formalin)	Powerful irritant; if swallowed causes vomiting and diarrhoea followed by collapse. TLV 5 ppm.
Sulphur dioxide	Causes irritation and inflammation of the conjunctiva; throat and nose irritant. TLV 5 ppm, 400-500 ppm may be lethal.
Carbon disulphide	Repeated inhalation of the vapour may cause severe damage to central nervous system, including failure of vision, mental disturbance and paralysis. Causes liver, kidney and heart damage. Powerful anaesthetic. Highly inflammable and explosive.
D.D.T.	Cumulative poisons. May cause anaemia.
p-Dichlorobenzene	Liver damage
Dieldrin, aldrin, chlordane, etc.	Ingestion, inhalation of dust and skin contact should be avoided. May damage kidneys and liver. Acute poisoning may result in respiratory failure.
Parathion, malathion, dichlorvos, etc.	Visual disturbances, respiratory difficulty. Inhalation, ingestion or skin contact should be avoided. Cases of coma and cardiac failure have been reported.
o-Phenylphenol and its sodium salt.	Affects central nervous system, may cause liver, kidney, pancreas and spleen damage.
Pentachlorophenol and its sodium salt	Acute poisoning results in liver and kidney damage. More toxic than o-phenylphenol.
Salicylanilide and its sodium salt	Toxicity related to that of aniline. May cause malignant bladder growths.

Table 6

Synthetic resins

Type of resin	Hazard
Phenol/ formaldehyde,cured	Slightly inflammable
Urea/ formaldehyde, cured	
Melamine/ formaldehyde, cured	
As above but liquid	May cause irritation to the eyes and skin.
Polyethylene	Inflammable
Celluloid	Inflammable
Polyvinyl acetate and acrylic emulsions	Residual monomers may cause irritation to the skin, eyes and mucous membranes.
Epoxy resins (araldite type)	Hardeners are usually fairly strong irritants, particularly when heated.
P.V.C.	Emits hydrogen chloride on burning.
Rubber cements and adhesives	Inflammable owing to solvents present.
Perspex	Highly inflammable; depolymerized on heating to the highly inflammable methyl methacrylate.
Polyurethane	Isocyanate hardeners are extremely toxic. Their vapours must not be inhaled.