

LABORATORY SAFETY MANUAL

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1. Introduction

The aim of this manual is to provide basic information about laboratory safety for supervisors and graduate students. The laboratory has many hazards and it is essential that you are aware of these in order to keep yourself safe. You must know how to handle safely the equipment, chemicals, microorganisms and other hazards. You need to be familiar with the safe methods of storage and disposal of chemicals and microorganisms. You must know what to do in case of accidents.

You should be familiar with the contents of this safety manual, so that you are aware of the proper procedures and, if necessary, know to refer to the relevant sections for required information. Information on safety issues is available in the 'Safety' folder in the IMBS shared drive and on the IMBS web site. Information is also available on the Massey Health and Safety site at <http://hrs.massey.ac.nz/hs.php3>.

1.1 Overview of IMBS Procedures

Induction checklist

All new arrivals should complete the induction checklist. This introduces you to the Institute and basic safety procedures.

Health and safety management

Refer to the Safety folder for a description of the groups and individuals that are available to provide assistance with safety issues.

Assessing hazards

Before you work with any material or perform any procedure, you need to check whether there are any associated hazards and how to minimize the associated risks. Refer to the hazard management forms in the red folder in the laboratory. If there is no form (for example if the procedure is new for the laboratory), then you should evaluate the hazards and complete a new form for the procedure.

Use of equipment

You must complete training for any equipment in the laboratory before you use it, and be signed off in the training records. This is necessary to avoid injury to yourself or others, and to make sure you don't damage the equipment.

Chemicals

Before you handle any chemical for the first time, you must check to see whether it is hazardous and the safe methods of handling it. This information can be found on the MSDS sheets in the yellow folder in the laboratory. When you order any chemicals, check it's MSDS before it arrives in the Institute for any requirements for safe handling and storage.

Safe methods of use

Before carrying out any hazardous procedure, check for its safe method of use. Information is available in this laboratory safety manual, in the Safety folder, and in the Massey Health and Safety site.

Reporting accidents and incidents

All accidents, even minor ones, must be reported. You should fill out the accident report form and give it to the secretary (Ann Truter).

If you see a doctor and are making a claim with ACC, a copy of the claim form must be obtained from the doctor and handed in with your accident report form.

Building evacuation

In the case of fire, or major chemical accidents, the alarm will sound. You must be familiar with the evacuation procedures.

Working after hours

The after hours register must be signed for all people in the building outside regular working hours.

Working after hours imposes a particular hazard as there is likely to be no assistance available in the case of an accident. You should be familiar with the procedures to minimize the risks.

Departure checklist

You must complete the departure checklist before you leave the Institute. This lists the necessary housekeeping tasks and makes sure that the laboratory remains a safe and tidy environment for those remaining.

2. The health and safety in employment act 1992

Work conducted in laboratories, like all other work, is subject to the provisions of the Health and Safety in Employment Act 1992. This Act requires employers to take all practicable steps to ensure the safety of employees while at work (section 6 of the Act). At Massey, the employer is the Chief Executive Officer (Vice-chancellor) and all people whom the CEO delegates to employ or supervise other persons working in the University. Employees are all people employed by the CEO. In university laboratories, academic staff are both employees (of the CEO) and employers (supervisors of others). Technical staff, undergraduate and graduate students, and post-doctoral fellows are all employees (supervised by academic staff or employed by the university).

The Act describes the responsibilities of employers under the following headings.

1.1 Hazard management

See <http://hrs.massey.ac.nz/hs-hazardsys.php3>. The Act requires the employer to identify all significant hazards associated with the work done by employees. For each significant hazard identified, the employer must take the following steps, in the order prescribed, to prevent harm to employees.

- Take all practicable steps to eliminate the hazard.
- If it is not practicable to eliminate the hazard, take all practicable steps to isolate the hazard.
- If it is not practicable to eliminate or isolate the hazard, take all practicable steps to minimize the hazard, provide the employees with clothing or equipment to protect them from harm, and monitor exposure to the hazard.

This means that for undergraduate laboratory classes the laboratory supervisor must examine each experiment performed and examine all the procedures used by the technical staff who prepare materials for these classes, to identify all significant hazards in these procedures.

In research laboratories, supervisors must identify all significant hazards whenever they instruct a technician to carry out a new task. It may be considered that postgraduate students and postdoctoral assistants should undertake hazard identification and hazard control as part of their training as potential supervisors. However, it is still necessary for the supervisor to check that their hazard identification is complete, to avoid committing an offence against the Act.

In order to prevent harm from an identified hazard, the first thing to consider is whether the task can be achieved using another procedure or using different materials that would eliminate the hazard. If it is not practicable to do this, the next thing to consider is whether the task can be isolated from the employees by: doing it remotely (eg. by using a physical barrier), doing it in a totally enclosed environment (eg. in a glove box), doing it in a protected environment (eg. in a biohazard cabinet), etc.

If it is not practicable to eliminate or isolate the hazard, then it is necessary to consider how to minimise the hazard for employees, perhaps by: scaling down the procedure, substituting another chemical agent, providing protective equipment (eg. safety glasses, gloves, pipetting aids, fume cupboards, biohazard cabinet, radiation shielding, etc.) and ensuring that the employees use this protective equipment, monitoring the employees exposure to the hazard (eg. using radiation monitors, atmospheric monitoring, measurement of UV light exposure, etc.).

2.2 Information

The Act requires that employers provide their employees with information about what to do in an emergency, what hazards are likely to arise in the course of their work, what hazards they may create for others in their workplace, and where safety clothing, safety equipment and safety materials are kept.

Information about general safety for undergraduate students can be provided in laboratory manuals. This information should include: what to do in an emergency, routes available for evacuation of the laboratory and the building, where to find and use safety equipment (fire alarms, fire extinguishers, fire blankets, safety showers, spill kits, first aid kits, etc.), how and when to use personal safety equipment (gloves, safety spectacles, fume cupboards, biohazard cabinets, pipetting aids, etc.). Students should be required to read this information and this requirement could be reinforced by conducting quizzes or providing compulsory questions to be answered in their laboratory reports.

Safety information about particular hazardous procedures or materials to be used by undergraduate students should be shown prominently in the laboratory manual, immediately following their mention in the text of the experiment. The technician's manual, used to prepare for laboratory classes, should also have this information.

In each research laboratory, the Academic staff member in charge must make sure that hazard information about chemicals is available. There should be a Materials Safety Data Sheet (MSDS) for each hazardous chemical in the laboratory, filed in a Yellow folder that is placed in a prominent position. Copies of MSDS for hazardous chemicals may be downloaded from the ChemWatch database located at <http://chemwatch.massey.ac.nz>. If the MSDS sought is not in this database, there are other Internet sources, of which (2) is a good place to start.

The chemical inventory system used at Massey University, ChiM, has a data field which identifies whether a chemical in stock requires an MSDS and whether that MSDS is available from ChemWatch. Supervisors can also obtain safety information about hazardous materials and procedures from various publications, mostly located in the university library. A selection of these sources is cited in the list of references in section 9 of this manual. A more extensive list of sources is available from your workplace safety committee.

2.3 Training and supervision

The Act requires employers to ensure that every employee is adequately trained in the use of all plant, equipment, substances or organisms used in their work and in the use of protective clothing required for these procedures. It also requires the employer to ensure that the employee has, or is under the supervision of a person who has, the knowledge and experience to keep them from harm while they work.

The safety component of undergraduate laboratory training should be taught as an integral part of general laboratory instruction, rather than as a separate topic in the course. That way the practice of safety will be seen to be an integral part of laboratory work and not seen as some peripheral, and perhaps optional, activity.

Although technical staff who have recently gained qualifications, such as NZCS or BSc, have received some training in general laboratory safety, it should not be assumed that they are fully trained in all situations that might arise in the laboratory. The supervisor or academic staff member should check that they are sufficiently trained to carry out any new task that arises.

Graduate students should be trained in general working procedures for working safely in a laboratory. However, it may become necessary to carry out hazardous procedures which are novel to both student and supervisor, and perhaps to science. In these situations, the supervisor and the student together should consult the safety literature and discuss the development of safe procedures for the work and for dealing with emergencies that might arise, using the approach to hazard management required by the Act.

2.4 Duties of employees

The Act requires that employees take all practicable steps to ensure their own safety at work and to ensure that their own actions do not cause harm to others.

2.5 Other legislation

The Hazardous Substances and New Organisms (HSNO) Act 1996 provides a mechanism for the management or prevention of the harmful effects of hazardous substances and new organisms on the environment and on the health and safety of people. Any hazardous substance, new organism, or genetically modified organism can be imported, developed, field tested or released in accordance with an approval issued under the Act (section 25). Applications for approval are dealt with by the Environmental Risk Management Authority (ERMA). ERMA assesses the risk and declines or approves applications, in some instances with prescribed controls.

The Biosecurity Act 1993 is concerned with prevention of the unintentional introduction of plants, animals and micro-organisms into New Zealand. Its provisions overlap considerably those parts of the HSNO Act concerned with these kinds of material.

3. Emergency procedures

See <http://rfm.massey.ac.nz/vm/emergencyplan.pdf>.

3.1 At the sound of the alarm

When the alarm sounds everyone, except wardens and breathing apparatus teams, must leave the building immediately via the nearest exit and go to the prescribed assembly area. Do not use lifts, go by the stairs. No one shall return to the building until the chief warden declares the emergency is over.

3.2 Fire

The main objective in dealing with any fire is to quell the blaze as soon as possible to prevent it from becoming larger. The action taken will depend on the size of the fire.

3.2.1 Small Confined Fire

If the fire is a small one that is confined to a container, try to extinguish it by covering the container to deprive the fire of oxygen. A variety of materials at hand may be suitable for this purpose, such as a metal tray, a piece of wood, a damp cloth, a folded newspaper or a fire blanket.

When the fire has been extinguished, keep the container covered until it has cooled to avoid possible re-ignition.

If the fire is small but not in a container, use a portable fire extinguisher, dry sand, dry finely-divided sodium chloride or dry sodium carbonate, according to the nature of the material on fire, to extinguish the blaze. Water is best for burning wood, paper or textiles. Flammable liquids require dry powder, CO₂ or vaporising liquid type extinguishers.

None of the foregoing extinguishers should be used to extinguish burning alkali metals, alkali metal hydrides, alkali metal amides, metal alkyls or lithium aluminium hydride, which will all react violently with these extinguishing agents. Instead the fire should be smothered with dry sand or dry, finely-divided sodium chloride or dry sodium carbonate (soda ash).

3.2.2 Larger or Unconfined Fire

If it is evident that the fire will not be extinguished readily by using portable fire extinguishers or other simple means, immediately trigger the nearest emergency alarm to initiate building evacuation.

You are not required to fight a fire. If you have any doubt about your ability to deal with the fire, leave the building immediately. If, AND ONLY IF, the exit is clear and you are between the fire and the exit and there is no imminent peril, you may attempt to contain the fire using a fire extinguisher or water from a fire reel hose until the Fire Service arrives. However, at the first sign of being affected by fumes cease this activity and leave the building immediately and report to the Warden at the Emergency Base.

If someone is present who is familiar with the activities and materials used in the room where the fire is located, he should go to Emergency Base (alarm indicator board at the bottom of Tower C) and report to the Warden. This person should stand by so that he is available to advise the Fire Service, when they arrive, of any special hazards that they may encounter.

If fire extinguishers or hose reels have been used, inform Facilities Management (ext 5888) promptly so that the extinguishers can be recharged and hose reels checked.

3.2.3 Clothing Fire

Clothing fires may be extinguished using a fire blanket or by rolling the person affected on the floor. When the fire has been put out, the affected person should be taken immediately to the safety shower and deluged with water to cool overheated tissues.

When the affected areas of the body have been thoroughly cooled with water, telephone for a first aider (telephone numbers on the list of Emergency Services).

3.3 Explosion

Explosions have many causes, such as: a runaway chemical reaction, moisture-sensitive chemicals coming into contact with water, ignition of flammable gases in a confined space, over-pressurisation of a vessel, over-heating of a thermally-sensitive substance, friction on a pressure-sensitive substance, etc. The emergency action required will depend upon the type of damage caused.

3.3.1 Explosion Causing Fire

If the explosion causes a fire, those at the scene should respond as described in section 3.2.

3.3.2 Explosion Causing Injury

If the explosion has caused injury, those at the scene should quickly assess whether the casualty will suffer further harm if he remains where he has been found.

If it seems that the casualty will not suffer further harm, he should not be moved until first aid has been given.

If the casualty appears to be in danger of further harm due to his location (eg. the atmosphere is harmful, or there is danger from a spreading fire or spilled chemicals), he should be moved to a site where first aid may be given in safety. If the atmosphere is harmful, the transfer of the casualty must be done by people with lung protection. Therefore, the Breathing Apparatus Team must be summoned (telephone numbers on the list of Emergency Services for the Science building) to shift the casualty.

When the casualty is in a safe location, summon First Aiders (telephone numbers on the list of Emergency Services for the Science building) to render aid and prepare the casualty for transfer to a hospital.

The Warden should be informed (telephone extension 3511) of the site of the explosion and of any involvement of the B/A teams or First Aiders.

3.3.3 Explosion Causing Chemical Spillage

If the explosion has caused dispersal or spillage of hazardous chemicals, those at the scene should respond as described in section 3.6.

3.3.4 Explosion Causing Release of Harmful Gas

If the explosion has caused release of a harmful gas, those at the scene should respond as described in section 2.9.

3.4 First aid for injury

For all but trivial injuries summon expert medical aid. A list of emergency services, which includes the names of persons in your building who hold first aid certificates, should be provided near all telephones. If a first-aider cannot be located, a physician may be contacted for advice at the Student Health Service (ext 5533 or 2787).

For serious injury call an **ambulance by dialling 1 for an outside line then 111**. When the operator answers tell them you need an ambulance. When the ambulance response service answers give them full details of the location of the emergency (eg. Palmerston North, Massey University, Science buildings, Tower ?, level ?). The response is co-ordinated from a single call centre in the North Island and the staff may not have sufficient detailed local knowledge to send the ambulance to an incompletely described destination). Also provide your name and the number of the telephone from which you are calling (6-356-9099 and your extension number, in case the ambulance service needs to call you back) and, if possible, a description of the injuries (so that paramedical personnel may bring any specialised equipment that may be required).

Prompt action by those at the scene of an accident may prevent serious injury. If the place of the accident is dangerous, move the casualty to a safe area, if this can be done safely, before giving first aid. Never give first aid unless you are certain of the correct treatment. Get assistance from qualified first aiders.

3.4.1 Bleeding

In cases of severe bleeding try to stop the flow of blood by applying pressure to the wound for 5 to 15 minutes. Use a pad of any suitable material or apply pressure with your fingers. Pressure should not be used on scalp wounds which may have an underlying fracture. Lay the casualty down, apply a dressing to the wound and arrange for removal to hospital.

3.4.2 Burns and Scalds

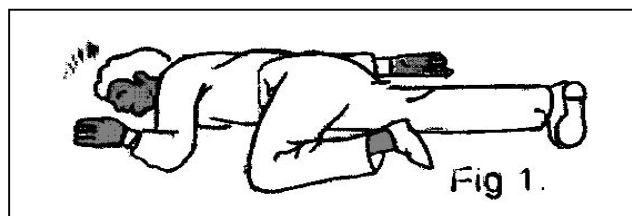
These are best treated by immediately placing the affected part in running cold water or in crushed ice. If the burns or scalds are severe, arrange for the casualty to be taken to hospital as soon as possible. In the meantime, lay the casualty down, remove anything of a restrictive nature before the affected parts swell and cover the burnt areas to minimise infection. Do not apply creams or oils to the burn.

3.4.3 Asphyxiation and Inhalation of Toxic or Narcotic Vapours

Unprotected rescuers need to check that the atmosphere is safe before moving the casualty. If it is safe, remove the casualty from the contaminated atmosphere into fresh air. If the atmosphere seems unsafe, summon members of the self-contained breathing apparatus team (see the list of emergency services).

When the casualty has been brought to a safe place, immediately check that he is breathing and check his pulse. If breathing has stopped and there is no pulse, immediately use cardiopulmonary resuscitation (CPR). If you do not know how to give CPR, summon a first aider (see the list of emergency services; see also inside the front cover of this manual for a summary of how to give CPR).

Unconscious casualties who are breathing must be placed in the recovery position (see illustration below), clothing around the neck loosened and dentures removed. Unconscious casualties must be kept under observation until he can be taken to hospital, in case they stop breathing.



You will notice the casualty is lying on his side, supported by one leg and one arm. In the case of head or ear injury, keep the injured side down.

3.4.4 Electrical Injury

Do not touch a casualty who has suffered an electric shock until you are sure he has been isolated from the electrical current source. If it is not possible to switch off the electrical current at source, an attempt may be made to separate the casualty from the conductor by using any dry insulating material such as wood, rubber, folded paper, etc. and taking care that you are not standing on a conducting surface. Once the casualty is isolated, quickly check for breathing and pulse and give CPR if necessary (see inside of front cover for a summary of CPR).

Electrical burns should be treated as described under (3.4.2) above.

3.4.5 Poisonous or Corrosive Chemicals in the Mouth

If a chemical, which has entered the mouth, was not swallowed, immediately wash the mouth thoroughly with water. If the chemical was swallowed and the casualty is conscious, quickly ask him about the nature of the chemical in case he loses consciousness later. Give large quantities of water to dilute the swallowed chemical. Unconscious casualties should be placed in the recovery position and their breathing and pulse checked regularly.

Call an **ambulance (dial 1 then 111)**; see under 3.4 for details) to take the casualty to hospital as soon as possible. Any information that could be useful at the hospital, such as, the nature of the chemical, its hazardous properties, the time of ingestion, the condition of the casualty at the time of despatch to the hospital, your name and phone number, should be written down and the note fixed to the casualty's clothing.

If the hazardous properties of the chemical are not known or can not be obtained readily locally, this information may be obtained by telephoning the **National Poisons and Hazardous Chemicals Information Centre**. This service is available 24 hours of the day. Dial 1-0800-764-766 or go to their webpage <http://www.toxinz.com>; username massey (password: safetyo) or massey2 (password: green).

3.4.6 Eye injury

In the case of chemicals in the eye, wash away the chemical as quickly as possible by holding the affected side of the face under cold water, so that the water drains away from the face. Continue this for 10 minutes.

If washing is not possible, lay the casualty down, protect the uninjured eye, and gently pour water into the open affected eye to drain away the chemical.

Lightly dress the eye with sterile eye pad or clean cloth.

Never attempt to remove solids embedded in the eye since this requires expert treatment.

An eye specialist should examine all eye injuries.

3.4.7 Chemicals on the Skin or Clothing

Clothing contaminated by hazardous substances should be removed promptly and contaminated skin washed immediately with copious amounts of water (use a safety shower for extensive contamination). Further treatment will depend on the nature of the chemical. Identify the contaminating substance and consult the safety literature.

3.4.8 Broken Limbs

Unless life is endangered, immobilise the fracture before moving the casualty. Summon a first aider if you do not know how to apply bandages and splints to immobilise the broken bones. Arrange for the casualty to be taken to hospital.

3.5 Flooding

3.5.1 Flood protection

Expensive items of equipment which would be damaged by contact with water should be protected by fitted plastic covers.

Rubber hosing carrying water to and from apparatus should be fixed to inlets and outlets using wire or hose clamps, especially if water flow to the apparatus is required for long periods when the apparatus is unattended (eg. overnight).

3.5.2 Minor Flooding

If the source of the flooding was connected to a main supply, turn off the water supply at the tap.

Water on floors should be mopped up promptly to minimise leakage to lower levels in the building.

The occupants of rooms immediately below should be warned as soon as possible that leakage may occur from above.

3.5.3 Major Flooding

For major floods resulting from burst water mains, rupture of header tanks, rupture of feed pipes for reverse osmosis water, shearing of taps from pipes, etc., engineers from **Regional Facilities Management (RFM)** must be summoned (**ext 5888**) to turn off the main valve in the plant room.

Immediately after RFM have been summoned, telephone the building **Warden** (**extension 3511**), who has the names of those in charge of any equipment or process in

the region of the flood that would be affected by loss of water supply, and will inform anyone likely to be affected.

Equipment for removing flood water (vacuum sweepers, pumps, rubber blade sweeps, etc.) should be obtained from RFM (**ext 5888**). Alternatively, there is a wet/dry vacuum cleaner in the 37°C room opposite the lift in tower D, level 3

3.6 Chemical spillage

A Material Safety Data Sheet (MSDS) should be available for each hazardous substance in use in the laboratory and this should include information about how to deal with a spillage of the substance.

3.6.1 Minor Chemical Spill (low hazard or non-hazardous substances)

If the identity of the spilled material is not known, it should be identified as soon as possible to establish if it is hazardous or not.

If it can not be identified, then it must be dealt with as if it were hazardous (see below).

If the spilled material is of low hazard or non-hazardous, laboratory personnel should clean it up.

Someone should be posted, or a tape barrier installed, to prevent others from entering the affected area. Barrier tape is kept in the breathing apparatus cabinets.

Those doing the clean up must wear eye protection, protective gloves and rubber boots.

Spilled solids should be collected using a plastic dust pan and brush. Spilled liquids may be confined and absorbed using dry sand or paper towels (only if the liquid will not react with paper).

Cleaned up material must be disposed as hazardous waste.

3.6.2 Major Chemical Spill (hazardous material or a large quantity of low hazard material)

If the identity of the spilled material is not known, it should be identified as soon as possible to establish if it is hazardous or not. If it cannot be identified, then it must be dealt with as if it were hazardous.

If the spilled material is hazardous in a way which could affect the safety of others in the room, the person causing or finding the spill must verbally warn all occupants of the hazard and tell them to leave the room immediately.

If it appears that the spilled material or hazardous vapours from the spilled material could spread to other parts of the building, the nearest emergency alarm must be triggered to initiate building evacuation.

The person causing or finding the spill should go to the Emergency Base (the alarm indicator board at the bottom of Tower C, Library side) and tell the Warden the nature and location of the emergency.

If it is apparent that the spilled material and any hazardous vapours will not spread beyond the room where the spill occurred, when everyone has left the room the doors should be locked and a notice or tape barrier installed to prevent others from entering.

The person causing or finding the spill shall telephone the **Warden (Barry Evans (ext 3511))** and report the nature and location of the spill. The Warden will telephone members of the nearest Breathing Apparatus Team and tell them to go to the scene of the spill.

3.7 Spillage of radioactive material

All users of radioactive materials must either be licensed by the National Radiation Laboratory or be under the direct supervision of a licence holder. Clean up of a radioactive spill shall only be done by those persons licensed or supervised by a licence holder who have knowledge of the hazardous properties of the particular radionuclide which has been spilled. The procedure used will depend upon the radiological and physical properties of the spilled material.

The Code of Practice for the Use of Unsealed Radioactive Materials (1996) states that the procedures to be followed in the event of an emergency must be documented in a Manual of Standard Procedures (MOSP) and that all users of radioactive materials must be familiar with these procedures. The Massey University Manual of Standard Procedures for the Use of Unsealed Radioactive Materials is a separate document held by each licence holder.

The emergency procedures described below are in accord with the Code and the MOSP. The terms lower and higher energy emission referred to are in the context of the amounts and kinds of radionuclide used at Massey University and the facilities available for their use. These facilities are classified as low-level.

If a spillage of radioactive material is found by people who are not licence holders or supervised users of radioactive material, they must inform the Warden (ext **3511**) of the location of the spill.

The Institute of Molecular BioSciences licence holders in Palmerston North are:

Dr K.M. Stowell (ext 7517)

Dr M. McManus (ext 2577)

Professor B. Scott (ext 4033)

in Albany, Professor D. Lambert (ext 9673)

All incidents involving spills must be reported to the safety officer Dr N. Honey (ext 2573) and an incident form completed.

The Warden will contact a licence holder responsible for supervision of the laboratory where the spill was detected, who will initiate clean up procedures.

3.7.1 Minor Radioactive Spill (small amount of radioactivity)

Because it is difficult to detect radionuclides emitting low energy radiation using radiation monitors, it is important that the extent of the spill is identified visually as soon as it is found and the perimeter marked.

Access to the contaminated area by other people should be prevented by using a tape barrier or posting someone to stop anyone from entering the area. Barrier tape is kept in the breathing apparatus cabinets.

Those doing the clean up should wear eye protection, disposable gloves and a laboratory coat.

A suitable radioactive waste container should be brought to the site of the spill.

If the spilled material is a liquid, it should be prevented from spreading by soaking up the bulk of the liquid using paper towels held in a pair of tongs. In doing this, the surface should always be wiped towards the centre of the spill area to avoid spreading the contamination. Contaminated towels must be transferred to the waste container.

If the spilled material is a solid, it should be mopped up using tongs and a paper towel or disposable absorbent cloth which has been moistened with a liquid, if possible one that is a solvent for that material, in the same way as described for liquids.

Residual radioactive material should be removed by successively wiping with paper towels or disposable absorbent cloths moistened with an appropriate solvent and testing the surface for radioactivity.

Testing for residual radioactivity should be done using a wipe test. The dry contaminated area should be wiped with a filter paper disc held by tweezers and moistened with a suitable solvent for the spilled material. The disc should be transferred to a liquid scintillation counting vial and assayed for radioactivity. Cleaning and wipe testing should be repeated until the radioactivity has been reduced to the background level.

When clean up has been completed, the personnel involved should remove their gloves and place these in the waste container.

Before leaving the site of the spill all people involved in the clean up must wash their hands thoroughly in warm soapy water.

3.7.2 Major Radioactive Spill (large amount of radioactivity or a radionuclide with a higher energy emission)

All people at the site of the spill must be checked for personal contamination using a radiation monitor.

All uncontaminated people not involved in cleaning up the spill must leave the affected area.

Other people must be prevented from entering the site by installing a tape barrier or posting someone to stop anyone from approaching. Barrier tape is kept in the breathing apparatus cabinets.

Personnel dealing with the spill should put on protective clothing (shoe covers, laboratory coat, eye protection, disposable gloves).

A suitable radioactive waste container should be brought to the site of the spill.

The extent of the spill should be determined using a radiation monitor, the perimeter marked and access to the area restricted using a tape barrier and warning signs.

If the spilled material is a liquid, it should be prevented from spreading by soaking up the bulk of the liquid using paper towels held in a pair of tongs. In doing this the surface should always be wiped towards the centre of the spill area to avoid spreading the contamination. Contaminated towels must be transferred to the waste container.

If the spilled material is a solid, it should be mopped up using tongs and a paper towel or disposable absorbent cloth which has been moistened with a liquid, if possible one that is a solvent for that material, in the same way as described for liquids.

Residual radioactive material on contaminated surfaces should be removed by successively wiping the surface with paper towels or disposable absorbent cloths moistened with an appropriate solvent and monitoring the surface for radioactivity, until the radioactivity has been reduced to the background level.

If the foregoing procedure is not effective, the contaminated surface should be moistened to minimise the production of radioactive dust and polished with an abrasive agent to remove the contaminated layer. Abraded material should be collected, transferred to the waste container and the surface monitored as described before, repeating the treatment until the radioactivity has been reduced to the background level.

When clean up has been completed, personnel involved shall remove their shoe covers and gloves and place these in the waste container.

All those at the site of the spill must check, using a radiation monitor, that there is no radioactivity on their shoes, hands or clothing before they leave.

As soon as possible contaminated skin should be washed with warm soapy water, dried with paper towels and checked using a radiation monitor, successively, until the contamination has been removed.

3.8 Spillage of infectious material

The emergency procedure used for a spillage of infectious material depends upon which Risk Group the organism is classified in (39). Currently, infectious micro-organisms in use at Massey University are confined to Risk Groups 1 and 2. The emergency procedure described below is applicable to Risk Group 1 and 2 organisms only.

When a liquid containing micro-organisms is spilled, any emergency procedure must take into account that the spilled material divides into three components; most of the liquid collected in a single puddle, splashed liquid dispersed as many droplets or pools, and an aerosol consisting of a large number of airborne small particles and minute droplets.

3.8.1 Minor Spill (Small volume of liquid without splashing)

A minor spill can be attended to by the worker at the scene.

Put on disposable gloves and eye protection.

Promptly cover the spill with a paper towel moistened with disinfectant (a 1% solution of Virkon, a peroxy biocide, is effective for most pathogenic viruses, bacteria and fungi; mycobacteria require a 3% solution). Pour more disinfectant gently onto the towel.

After 30 minutes, remove the towel using forceps and transfer it to a biohazard bag for autoclaving.

Using forceps, swab the affected area with cotton wool soaked in disinfectant and transfer the swabs to the biohazard bag for autoclaving.

3.8.2 Minor Spill with Splashing

The workers at the scene of the spill should hold their breath and move away from the area and allow about 30 minutes for larger aerosol droplets to settle and smaller aerosol particles to be removed by the ventilation system.

Other people should be prevented from approaching the site.

The spill should be cleaned up then using the procedure described in section 3.8.1.

3.8.3 Major Spill with a larger volume of liquid with splashing, or breakage of a centrifuge tube

Verbally warn others who may be in the room of the hazard. Then leave the room immediately, holding your breath as you go.

Close all doors to the room and prevent other persons from entering by locking doors, using a tape barrier to prevent access and post warning signs.

If garments, gloves, shoes or any other apparel are suspected of being contaminated these should be removed and placed in biohazard bags before leaving the scene. Biohazard bags containing contaminated apparel must be autoclaved.

Affected people should thoroughly wash all parts of their skin that were exposed at the time of the spill.

No one shall enter the affected room until at least 30 minutes after evacuation of the room, to allow heavier aerosol particles to settle and smaller particles to be dispersed by the ventilation system.

Summon the Infectious Spill Clean Up Team (telephone numbers on the list of Emergency Services for the Science building). Inform the team of the type of micro-organism that has been spilled.

Inform the Warden (ext **3511**) of the location and nature of the emergency.

3.8.4 Spillage of Infectious Material Outside Normal Working Hours

Minor spills of infectious material which occur outside normal working hours should be dealt with as described in sections 3.8.1 and 3.8.2.

If a major spill of infectious material occurs after normal working hours, proceed as follows:

Verbally warn others who may be in the room of the hazard. Then leave the room immediately, holding your breath as you go.

Close all doors to the room and prevent other people from entering by locking doors and posting warning notices.

If garments, gloves, shoes or any other apparel are suspected of being contaminated these should be removed and placed in biohazard bags before leaving the scene. The biohazard bags must be autoclaved later.

Affected people should thoroughly wash all parts of their skin that were exposed at the time of the spill.

No one shall enter the affected room until normal working hours, when the Infectious Spill Clean Up Team will be available to undertake spill clean up.

Telephone the security service (**ext 5030**) to inform them of the situation and of the need to keep the affected room secure until normal working hours.

Leave a message so that the Warden (Engineering Services Workshop, level 1, Tower C) will be informed of the situation as soon as possible.

3.9 Release of harmful gas (other than domestic gas)

The person witnessing or causing the release must verbally warn all others in the room of the hazard and tell them to evacuate the room immediately.

If the fume cupboards are not already on they should be turned on, if it is possible to do so before leaving the room, and the doors to the room closed.

Unconfined Gas Release

If it is apparent that the gas will not be confined to the room where it was released, the nearest emergency alarm must be triggered to initiate a building evacuation. The person who witnessed or caused the gas release shall go to the Emergency Base (alarm indicator board at the bottom of Tower C, Library side) and inform the Warden of the location and nature of the emergency.

Gas Release Confined to Room

If it seems the gas will be confined to the room where it was released, a notice, tape barrier or persons should be posted at all entrances to the room to prevent anyone from entering.

The person witnessing or causing the gas release shall inform the **Warden** by telephone (**ext 3511**) of the location and nature of the gas release.

The Warden will telephone members of the nearest B/A Team and tell them to go to the site of the gas release.

3.10 Domestic gas leak

The immediate hazard of a domestic gas release is ignition of the flammable gas causing a fire or explosion. The first action must be to turn off the supply. Therefore all occupants of laboratories supplied with domestic gas should know where the main valve for each bench in their laboratory is located (usually under the bench near the junction of the bench and the service duct) so that they can isolate any leaking gas tap or pipe downstream.

3.10.1 Gas leak at a bench, supply stopped

If a gas leak occurs because of a broken bench tap or ruptured bench pipe, and it can be isolated by turning off the supply at the bench valve, do this and warn all others in the room of the hazard and tell them to leave the room immediately.

If possible, turn on the fume cupboard(s), if they are not already on, before you leave the room.

Close the doors behind you and install a notice, tape barrier or have someone wait at each entrance to prevent anyone from entering the room.

Inform the **Warden (telephone extension 3511)** of the location of the gas leak. The Warden will telephone the Works and Services section (extension 7054) to summon a gas fitter to repair the fault.

3.10.2 Gas Leak, Supply Not Stopped

If the gas leak is due to rupture of a main gas pipe upstream of a bench valve or if the supply to a leak on the bench could not be turned off, the nearest emergency alarm to initiate building evacuation.

The person setting off the alarm should go to Emergency Base (alarm indicator board at the bottom of Tower C, Library side) and tell the Warden the cause and location of the emergency.

The Warden will telephone the Works and Services section to summon a gas fitter urgently to turn off the main gas supply valves for the building.

3.11 Earthquake

See <http://rfm.massey.ac.nz/vm/emergencyplan.pdf>

Earthquakes are potentially the most destructive events that could affect the Science building. A worst case scenario for a major earthquake could be that the building was near maximum occupancy at the time, all services were disrupted, parts of the building had collapsed, there were gas and water leakages, mixing of interactive chemicals had started fires and generated toxic atmospheres, fire had ignited a gas explosion, there was spillage of radioactive material, infectious agents were released and a major aftershock occurred within an hour of the primary event.

However, it is probable that most earthquakes experienced will be of low magnitude. Nevertheless, because of the nature of work done in the Science building, a low magnitude earthquake could cause considerable minor damage and disruption. There are a number of simple preventive measures that can be taken to mitigate these effects.

3.11.1 Mitigation of the effects of Earthquakes prior to the event

Corridors must be kept clear of furniture, cabinets, lockers, etc. unless approved. Approved items must be permanently fixed to walls.

Heavy items must not be stored on high shelves.

Shelving in laboratories and store rooms should be fitted with rims to prevent bottles and equipment from being shaken off.

Bottles of hazardous liquids must be stored in low level cupboards in laboratories and not on open shelves, benches or in high cupboards.

Cupboard door latches should be inspected regularly and faulty ones reset for security.

Compressed gas cylinders must be fixed to permanent fittings by strong restraints, preferably at two levels to prevent the cylinder from slipping out of the restraint when shaken.

Where possible, large items of equipment should be fixed to walls or the floor to prevent toppling or lateral movement.

Upright refrigerators and freezers with magnetic door catches should be fitted with mechanical latches.

Containers of chemicals liable to undergo hazardous reactions upon mixing must be stored in separate compartments.

3.11.2 Low Magnitude Earthquake

When the tremor has stopped the occupants of each research laboratory, the supervisors of teaching laboratories and the persons in charge of chemical stores should quickly search their workplace for any damage caused by the earthquake.

Any damage found should be assessed for its potential to cause harm.

If the damage has generated a hazard and it seems likely the hazard could spread and cause harm elsewhere, the nearest alarm should be activated so that the building is evacuated.

The person who identified the hazard should go to the Emergency Base (alarm indicator board at the bottom of Tower C) and inform the Warden of the nature and location of the emergency.

If damage has generated a hazard but it is evident the hazard will be local, then action should be taken that is appropriate for the kind of hazard, described elsewhere in this document.

3.11.3 High Magnitude Earthquake

The primary objective after a major earthquake will be to locate everyone in the building and arrange their evacuation safely.

After a major earthquake all able-bodied people should attempt to search the floor of their workplace for injured colleagues, with due care for any hazards that may have been created and the possibility of aftershocks.

Record the names and locations of any casualties you find in writing. Also record any hazardous situations you may witness during your search.

If you are a qualified first aider, you may give first aid to casualties you find.

If you are not qualified to give first aid, you should attempt to leave the building and report to a building Warden (see below).

If there are no casualties on your floor, you should attempt to leave the building.

If all possible exits from the building have been damaged to the extent that it is not possible to leave and your building has a strengthened central core (usually including the lift shafts), you should retreat and seek shelter in the central core while you await rescue by the emergency services.

Everyone who is able to leave the building should go to the Emergency Base (alarm indicator board at the bottom of Tower C) and give all information about casualties he has found or hazardous situations he has seen to a Warden.

3.12 Intruders

People may enter the building for a variety of illegal purposes, but most likely for theft of valuables, or equipment and chemicals for the manufacture of illicit drugs. As much as possible, these items should be kept secure to prevent and deter such activity. If strangers are seen in the building acting illegally or are suspected to be there for that purpose, the following procedure should be followed.

3.12.1 Strangers acting suspiciously

If strangers in the building are acting suspiciously, they may be accosted in a non-confrontational manner by asking them 'Can I help you?' or 'Are you looking for someone?'

If the answer is not satisfactory, you may ask them politely for some identification. Persons who are not regular occupants of the building but are there for legitimate reasons should carry identification from Massey University or whatever other organisation they come from.

If satisfactory identification can not be provided and you are not convinced that they are there with good reason, telephone the **Security Officer (extension 5030 or 1 0263 000373)** to activate their pager) or the **Community Constable (extension 5042)** for assistance. After normal working hours telephone 5030 to contact a security guard.

In the meantime try to arrange for someone to keep the suspect under surveillance until help arrives.

3.12.2 People acting illegally

If strangers are seen to be acting illegally, do not try to accost them.

Try to arrange for someone to keep those acting illegally under observation.

Telephone the **Security Officer (ext 5030 or 1 0263 000373)** to activate their pager) or the **Community Constable (ext 5042)** for assistance and after normal working hours telephone 5030 to contact a security guard.

3.13 Bomb threat

See <http://hrs.massey.ac.nz/hs-procs.php3>

A bomb threat will usually be made by telephone but may be delivered in person or through a third party. The main objective for the recipient is to collect as much information about the situation as possible from the threatener and then initiate building evacuation as soon as possible.

Try to remain calm.

Do not be dismissive, all threats must be treated as genuine until it is definitely established that the threat is empty.

Do not be confrontational, the threatener may be of disturbed mind and act irrationally when confronted.

Collect as much information about the bomb, its location, the timing of its detonation and any characteristics of the threatener as possible. Try to record all the information you have received in writing.

As soon as possible after the threat has been delivered, trigger the nearest alarm to initiate building evacuation.

Go to Emergency Base (alarm indicator board at the bottom of Tower C) and inform the Warden of the nature of the emergency. If a Warden is not available, contact the **University Security Officer (ext 5030 or 1 0263 000373)** to activate their pager) and inform the officer of the situation.

4. Hazards and precautions when using chemicals

Since the precautions described for using hazardous chemicals and infectious materials are for classes of chemicals and infectious microorganisms in general, the safety literature must be consulted for a full understanding of any safety measures required for a particular chemical or organism.

Before using any chemical, users must check whether the chemical has any hazardous properties and take appropriate measures to ensure that the chemical is used in a safe manner. Some general aspects of the safe handling of chemicals are considered here. Information about the hazards of specific chemicals must be obtained from the MSDS for that chemical or sought in the safety literature (2-9, 11). Information on safe methods of use is available on the IMBS safety sites

Now that the University is employing a contractor for the disposal of hazardous chemical wastes, it is necessary to meet the requirements of The Transport Act (1962 and amendments) and NZS 5433 (30). These requirements include the classification, labelling and documentation of all hazardous chemical wastes and the segregation of wastes according to class during transport. The labelling and documentation required is described in section 4.8.2. Class numbers are given for each group of hazardous chemicals described in this manual. Definitions of the classes and the subdivisions within classes are described fully in the Appendix to the manual.

4.1 Flammable solvents

These are the class 3, Flammable liquids: packaging groups I, II and III (10, 11, 12). The hazard of a chemical varies, depending on its flash point, boiling point, ignition temperature and flammable limits. For definitions, see appendix 11.1. The information for some common laboratory chemicals is shown on the next page.

4.1.1 Carrying solvents from store to the laboratory

Solvents are normally issued from the store in 2.5 litre Winchester pattern bottles. These bottles must be carried in the bottle carriers available from the store and must not be carried in the hands. Empty carriers should be returned to the store.



4.1.2 Quantity kept in the laboratory

The quantity of flammable solvents stored in the laboratory must be kept to a minimum. Amounts must not exceed 50 litres of Class 3 packaging groups I and II or 100 litres of Class 3 packaging group III, per 50 m² of floor area. The safest place to keep flammable solvents is in the store. Any flammable solvents surplus to your immediate requirements should be returned to the store.

Chemical	NFPA Class	Flash Point	Boiling Point	Ignition Temperature	Flammable Limit (Percent by volume)	
		(°C)	(°C)	(°C)	Lower	Upper
Acetaldehyde	IA	-37.8	21.1	175.0	4.0	60.0
Acetone	IB	-17.8	56.7	465.0	2.6	12.8
Benzene	IB	-11.1	80.0	560.0	1.3	7.1
Carbon disulfide	IB	-30.0	46.1	80.0	1.3	50.0
Cyclohexane	IB	-20.0	81.7	245.0	1.3	8.0
Diethyl ether	IA	-45.0	35.0	160.0	1.9	36.0
Ethyl alcohol	IB	12.8	78.3	365.0	3.3	19.0
<i>n</i> -Heptane	IB	-3.9	98.3	215.0	1.05	6.7
<i>n</i> -Hexane	IB	-21.7	68.9	225.0	1.1	7.5
Isopropyl alcohol	IB	11.7	82.8	398.9	2.0	12.0
Methyl alcohol	IB	11.1	64.9	385.0	6.7	36.0
Methyl ethyl ketone	IB	-6.1	80.0	515.6	1.8	10.0
Pentane	IA	-40.0	36.1	260.0	1.5	7.8
Styrene	IB	32.2	146.1	490.0	1.1	6.1
Toluene	IB	4.4	110.6	480.0	1.2	7.1
<i>p</i> -Xylene	IC	27.2	138.3	530.0	1.1	7.0

4.1.3 Storage in the Laboratory

Bottles of flammable solvent kept in the laboratory must be stored in cabinets, not on the bench and not on the floor where they may be accidentally knocked over. The quantity of flammable solvents stored in any cabinet must not exceed 36 litres. (37)

4.1.4 Segregation of Chemicals

Flammable solvents should not be stored together with strong oxidising agents (nitric, perchloric or chromic acids, hydrogen peroxide, etc.). (1, p 259-261), (37) Accidental mixing of these two classes of substances is a common cause of fires.

4.1.5 Chemical Incompatibilities

Class 3.1 Flammable Liquids are incompatible with HSNO Classes 1, 2, 3.2, 4 and 5. Some examples are given below.

Chemical	Is Incompatible With
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Acetone	Concentrated nitric and sulfuric acid mixtures
Alkali and alkaline earth (e.g. powdered aluminium or magnesium, calcium, lithium, sodium, potassium)	Water, carbon tetrachloride or other chlorinated metals hydrocarbons, carbon dioxide, halogens
Ammonia (anhydrous)	Mercury (e.g. in manometers), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrates, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	See Chlorine
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Everything
Hydrocarbons (e.g. butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, sodium peroxide, halogens
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, combustible materials
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia,
Nitrates	Sulfuric acid

Chemical	Is Incompatible With
Nitric acid (concentrated)	Acetic acid, aniline, chromic acids, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, any heavy metals
Nitrates	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen, flammable liquids, solids, or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Phosphorus pentoxide	Water
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
(see also chlorates)	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartartic acid, ammonium compounds, fulmunic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals, such as sodium, lithium)
Tellurides	Reducing agents

4.1.6 Control of Ignition Sources

Take special care when using solvents which have a low flash point. Some commonly used solvents in this category and their flash points (°C) are:

acetone	-18°	ethyl acetate	-4°
benzene	-11°	hexane	-23°
carbon disulphide	-30°	methanol	+10°
diethyl ether	-45°	tetrahydrofuran	-17°
ethanol	+12°	toluene	+4°

Make sure that there are no ignition sources nearby before using such solvents. Potential ignition sources include bunsen burners, any equipment in operation having a series wound electric motor (vacuum pumps, mechanical and magnetic stirrers, rotary evaporators, heat guns), an exposed electrically-heated element (heating mantles, heat guns, dryers), thermostat controls (thermostat water baths, ovens, hot plates, refrigerators, heating mantles) or electric switches. Whenever possible, flammable solvents in open containers should be used in a fume cupboard.

4.1.7 Safe Practice

Distillations and reactions involving flammable solvents should not be allowed to proceed unattended. If you must leave, ask a colleague to keep watch while you are absent.

4.1.8 Solvents in Refrigerators

Flammable solvents should only be stored in refrigerators which have been made safe for this purpose. These have been modified by mounting the thermostatic controls externally and removing the interior light, at the time of their purchase. Any refrigerators which have not been modified in this way are not safe for storing flammable solvents and should be labelled "NO FLAMMABLE SOLVENTS". All flammable solvents stored in a refrigerator must be in a container which has a securely closed, leak-proof cap.

4.1.9 Peroxide-forming Solvents

Solvents containing ether, acetal, isopropyl, allyl, vinyl or diene groups and bearing a susceptible hydrogen atom, can form unstable peroxides on exposure to light and air. Susceptible solvents should be tested for the presence of peroxides before use and the peroxides removed by an appropriate procedure.

The simplest procedure for the detection of peroxides is the iodide test. Add 0.5-1.0 mL of the liquid to be tested to an equal volume of glacial acetic acid. Then add about 0.1 g of sodium iodide crystals. The appearance of a yellow to brown colour indicates the possible presence of peroxides (the test should always be compared with a blank).

A more sensitive method for peroxide detection is the ferrous thiocyanate test. A small volume of the liquid to be tested is mixed with an equal volume of ferrothiocyanate reagent (9 g $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ is dissolved in 50 mL 6M HCl and treated with 0.5 g granulated zinc and 5 g sodium thiocyanate. After the initial red colour fades, a further 12 g sodium thiocyanate is added and the liquid decanted from the zinc into a clean bottle). The appearance of a red colour indicates the possible presence of peroxides.

A variety of methods can be used to remove peroxides from susceptible solvents. The simplest is to pass the liquid down a short column of activated alumina. Since some peroxides are adsorbed but not destroyed by alumina, the alumina should be treated with a dilute acid solution of potassium iodide or ferrous sulphate to destroy the adsorbed peroxides before disposal.

Further information about detection and removal of peroxides can be found in (1, p 271-274), (13), (14, p 118-121 and 242-244).

Even when peroxides have been removed, distillation of peroxide-forming solvents should be stopped before the volume of liquid remaining in the still pot is less than 10% of the initial volume, since peroxides may form during distillation and concentrate in the distillation residue. Never distil to a dry residue since peroxides are thermally sensitive and may explode violently if heated excessively.

Common Peroxide Forming Chemicals

List A: Severe Peroxide Hazard on Storage with Exposure to Air

Discard within 3 months

Diisopropyl ether (isopropyl ether)	Potassium amide
Divinylacetylene (DVA)	Sodium amide (sodamide)
Potassium metal	Vinylidene chloride (1, 1-di-chloroethylene)

List B: Peroxide Hazard on Concentration

*Do not distill or evaporate without first testing for the presence of peroxides.
Discard or test for peroxides after 6 months*

Acetaldehyde diethyl acetal (acetal)	Ethylene glycol dimethyl ether (glyme)
Cumene (isopropyl benzene)	Ethylene glycol ether acetates
Cyclohexene	Ethylene glycol monoethers (cellosolves)
Cyclopentene	Furan
Decalin (decahydronaphthalene)	Methylacetylene
Diacetylene (butadiene)	Methylcyclopentane
Diethyl ether (ether)	Tetrahydrofuran(THF)
Diethylene glycol dimethyl ether (diglyme)	Tetralin (tetrahydronaphthalene)
Dioxane	Vinyl ethers

List C: Hazard of Rapid Polymerization Initiated by Internally Formed Peroxides

*Normal Liquids
Discard or test for peroxides after 6 months*

Chloroprene (2-chloro-1, 3-butadiene)	Vinyl acetate
Styrene	Vinylpyridine

*Normal Gases
Discard after 12 months*

Butadiene	Vinylacetylene (MVA)
Tetrafluoroethylene (TFE)	Vinyl chloride

4.1.10 Drying Solvents with Sodium

Since sodium reacts violently with water, care should be exercised when using sodium wire to dry solvents. If the solvent is grossly wet it should be pre-dried with some other less reactive siccativ to remove the bulk of the water. Then residual water can be scavenged by decanting the predried solvent from the primary siccativ and adding sodium wire. Never attempt to dry halogenated hydrocarbon solvents with sodium since it reacts violently with these substances.

Residual sodium wire, in the die or adhering to the press used to make the wire, should be destroyed with ethanol. Bottles which have contained solvents that have been dried using sodium wire in situ must be cleaned of all residual sodium before they are returned to the store. Never use potassium to dry solvents. Waste potassium must not be destroyed by treatment with ethanol since the reaction is too violent. Use the much less reactive tertiary-butanol to destroy waste potassium.

4.1.11 Solvent Residues

Flammable solvents that are not miscible with water must not be disposed in drains. These waste solvents should be put in Winchester pattern bottles which are fitted with screw caps that have liners to prevent leakage during transport. Different kinds of waste solvents must be collected in separate bottles. However, regard should be given to the possibility of unwanted reactions occurring between dissolved solids in different batches of the same waste solvent. If this is possible, the waste solvent should be separated from the reactive solids, using a rotary evaporator, before adding it to the waste bottle.

The procedures and documentation required for sending bottles of waste solvent for disposal are described in section 8.8.2.

Small quantities of water-miscible flammable solvents may be disposed in fume hood drains together with large volumes of diluent water.

4.2 Highly reactive and explosive chemicals

These are the class 1, Explosives (divisions 1-5), class 5.1, Oxidisers, and class 5.2, Organic peroxides.

Any compound possessing one of the functional groups listed below should be regarded as being potentially highly reactive. Compounds with more than one of these groups are particularly suspect since their effect on the stability of the compound may be more than additive. Compounds having groups with acid (-COOH), base (-NH₂, -CHO), oxidising or reducing characteristics, in addition to the sensitive groups listed below, will have enhanced reactivity and reduced stability.

Compounds having those functional groups in the list which are capable of forming inorganic salts are often very sensitive to impact and friction in the salt form. Reactions performed with these classes of compounds should be conducted in a manner that anticipates a possible explosion. Reactions should be done behind an adequate safety screen and on as small a scale as is possible. Substances in these classes should be kept apart from other chemicals that will sustain fire.

Care must be taken to prevent accidental mixing of strong oxidising agents, such as chromates, hydrogen peroxide, nitric acid, nitrates, chlorates, perchlorates, permanganates, persulphates, halogens and halogenating agents with organic fuels, as these will result in violent reactions and explosions (1, p 305-319). Perchloric acid is particularly notorious and anyone using this reagent is urged to consult the safety literature (1, p 276-277 and 308-319).



GROUP	STRUCTURE
acetylide	- C = C - metal
amine oxide	- N ⁺ - O ⁻
azide	- N = N ⁺ = N ⁻
chlorate, bromate, iodate	- ClO ₃ , -BrO ₃ , -IO ₃
epoxy	$\begin{array}{c} \text{---C---C---} \\ \quad \diagdown \quad / \\ \quad \quad \text{O} \end{array}$
ethyleneimine	$\begin{array}{c} \text{---C---C---} \\ \quad \diagdown \quad / \\ \quad \quad \text{N} \\ \quad \quad \\ \quad \quad \text{H} \end{array}$
diazo	- N = N -
diazonium	(- N = N) ⁺ X ⁻
fulminate	-O = N - C
N-haloamine	$\begin{array}{c} \text{Cl} \\ \diagup \\ \text{---N} \\ \diagdown \\ \text{X} \end{array}$
hydroperoxide	- O - O - H
hypohalite	- O - X
nitrate	- O - NO ₂
nitrite	- O - NO
nitro	- NO ₂
nitroso	- NO
ozonide	$\begin{array}{c} \text{---O---O---} \\ \quad \diagdown \quad / \\ \quad \quad \text{O} \end{array}$
peracid	$\begin{array}{c} \text{---C---O---O---H} \\ \\ \text{O} \end{array}$
perchlorate	- ClO ₄
peroxide	- O - O -

Partial List of Oxidizers

Increase Rate of Combustion	
Aluminium nitrate	Perchloric acid 60% or less
Ammonium persulfate	Potassium chlorate
Barium chlorate	Potassium dichromate
Barium peroxide	Potassium nitrate
Calcium chlorate	Potassium persulfate
Calcium nitrate	Silver nitrate
Calcium peroxide	Silver nitrite
Cupric nitrate	Sodium perborate
Hydrogen peroxide	Sodium perchlorate
Lead nitrate	Sodium persulfate
Lithium hypochlorite	Strontium chlorate
Lithium peroxide	Strontium nitrate
Magnesium nitrate	Strontium nitrite
Magnesium perchlorate	Thorium nitrite
Magnesium peroxide	Uranium nitrate
Nickel nitrate	Zinc chlorate
Nitric acid 70% or less	Zinc peroxide
Cause Spontaneous Ignition	
Calcium hypochlorite	Sodium chlorite (>40%)
Chromic acid	Sodium peroxide
Hydrogen peroxide (27.5-52%)	Sodium permanganate
Nitric acid	Trichloroisocyanuric acid
Potassium bromate	Sodium dichloroisocyanurate
Potassium permanganate	
Decompose with Catalyst or Heat	
Ammonium dichromate	Perchloric acid (60-72.5%)
Hydrogen peroxide (52-91%)	Potassium dichloroisocyanurate
Calcium hypochlorite (>50%)	Sodium dichloroisocyanurate
Cause Explosive Reaction when exposed to Catalyst, Heat, Shock, or Friction	
Ammonium perchlorate	Perchloric acid
Ammonium permanganate	Potassium superoxide

4.3 Toxic chemicals

[Class 6.1, Poisons : Packaging groups I, II and III]

The extensive biological testing of recent times has led to an increasing awareness of the potential toxic hazards of chemicals in the work place. A number of chemicals in common use, which previously had not been regarded as hazardous, are now considered to be dangerous and their use is restricted to situations where the atmospheric concentration can be kept below prescribed limits (15). It is essential to consult the recent safety literature for hazardous properties of even commonly used chemicals.

The kind of protection required for the safe handling of a toxic chemical will depend upon the degree of its toxicity and the potential routes of exposure.



One indicator of the degree of toxicity which has been used is the acute dose of the chemical which causes death of 50% of the test animals (LD_{50}). This amount is usually quoted together with the species of test animal and the route of exposure (inhalation, ingestion, skin, etc.). For a number of reasons, which will not be considered here, this value is a crude indicator for deciding what control measures are needed to protect the worker.

Better indicators of the magnitude of the hazard presented by toxic chemicals are the **Workplace Exposure Standards (WES)** in New Zealand [comparable indicators are Threshold Limit Values (TLV), used in the USA, Occupational Exposure Standards (OES) in the UK and Maximum Allowable Concentration (MAC) in the EU]. These values are the concentrations of hazardous chemicals to which most workers may be exposed without ill effect over different time periods.

Three versions of **WES** are used:

- (i) **WES-TWA**, the eight hour time-weighted average exposure standard (based on a 40 hour work week),
- (ii) **WES-STEL**, the maximum short term exposure limit (15 minute exposure average),
- (iii) **WES-C**, a ceiling concentration that must not be exceeded during any part of the working day..

WES values are usually expressed in parts per million (ppm), or mg m^{-3} .

Some **WES** values have been obtained from human morbidity studies. Most of the available data has come from animal experimentation, either directly by measuring **WES** or indirectly by equating **WES** with $LD_{10} \times 10^{-3}$ (LD_{10} is the single dose of chemical causing death of 10% of the test animals). For a large number of chemicals WES values have not been determined.

The considerable differences in the susceptibilities of different species of animal to a toxic chemical should be taken into account when deciding what protective measures are required for safe work with that chemical (use protective measures which ensure that the level of exposure is less than 20 - 50% of WES). WES values provide a measurable standard for the workplace which can be monitored to see if the control measures used are adequate for the protection required.

Work with moderately toxic to toxic volatile chemicals should be done in fume cupboards and protective gloves should be worn. Depending upon the quantity to be used, a totally enclosed glove box may be required for work with highly toxic chemicals. Work with extremely toxic chemicals should be avoided if possible; anyone contemplating the use of such chemicals must consult their Workplace Safety Committee before proceeding.

A toxic chemical of particular concern is mercury, because of the ease with which it is spilled, the ready dispersal of droplets that occurs when it falls onto a hard surface and the difficulty of cleaning it up (1, p 324-329). Mercury vapour is toxic and the metal can be absorbed through the skin. The evaporation rate of mercury is $0.8 \text{ mg m}^{-2} \text{ h}^{-1}$ at room temperature, and the equilibrium vapour pressure is 13.2 mg m^{-3} , while the WES is 0.05 mg m^{-3} . The general room ventilation in laboratories probably ensures that the atmospheric concentration arising from unrecovered, spilled mercury is kept well below the WES. However, adding to the atmospheric burden of mercury should be avoided.

Work with exposed mercury should be done in a fume cupboard and performed over trays to catch spills. The trays could be lined with siliconised release paper which has been reported to be effective in preventing the dispersal of dropped mercury (16).

If mercury is spilled, pools and droplets which can be seen may be recovered by vacuum collection through a narrow orifice into a buchner flask trap which is connected to a water aspirator pump. Residual mercury which cannot be collected by this means may be collected by covering it with a 1:1 mixture of zinc dust and sawdust for an extended period. The zinc forms a solid amalgam with mercury vapor that is evolved. Subsequently the zinc-sawdust mixture is swept up and put in a sealed plastic bag for disposal (17). Alternatively, there are mercury spill kits available in ScD3.02, telephone extension 5015 (Paul Hocquard's office) for small spills such as the breaking of a mercury filled thermometer.

4.4 Corrosive chemicals

These are chemicals (class 8) which cause destruction of body tissues by direct chemical action. Since most corrosive chemicals are also toxic to varying degrees, they may have secondary systemic effects besides local destructive ones. Strong mineral acids, strong alkalis, acid chlorides, organic acids, some halogenated aliphatic carboxylic acids, some acid anhydrides, bromine, phosphorus, alkali metals and phenol are some commonly used classes of chemical which are corrosive.



Corrosive liquids must never be pipetted by mouth. A variety of manually operated pipettes or aids which can be fitted to glass pipettes and obviate the need to pipette by mouth are available commercially. Perfectly serviceable aids for pipetting can be constructed from plastic syringes and short lengths of heavy wall rubber or plastic tubing to fit the end of a glass pipette.

It is essential to wear eye protection at all times when working with corrosive chemicals. Persons handling bulk quantities of corrosive liquids should wear face shields, long plastic coats, rubber boots and gloves. It is also prudent to check the operation of the nearest emergency shower before starting to work with bulk quantities of corrosive chemicals.

Corrosive gases and mists present a severe hazard since their inhalation, dissolution in lung fluids and ready transfer from there to the rest of the body via the blood, can expose other internal organs to their destructive effects. Always use substances of this type in a fume cupboard.

Corrosive solids may seem to be a lesser hazard because of their physical state. However, many are readily soluble in water or are readily hydrated by atmospheric moisture. Upon contact with skin these corrosive solids can be converted to corrosive liquids by dissolution in dermal moisture and can spread over a wider area of skin.

Hydrogen fluoride is worthy of special mention because of its combination of hazardous properties (1, p 329-333), (19). It is both highly toxic (WES 3 ppm) and powerfully corrosive. Lesions arising from HF burns are slow to heal, due to the toxicity of fluoride ions, and often lead to permanent loss of tissue. Skin contaminated by HF must be washed immediately with cool water for at least 15 minutes. Further treatments have been recommended to immobilise fluoride ions absorbed by the tissues (18, 19), and are briefly given below. It would be prudent to assemble any medication required for these treatments at the workplace before using HF.

If any user has skin contact with an HF spill the procedure is to wash the contaminated area thoroughly and remove contaminated clothing. Copious water should be used and washing is probably not advantageous beyond 5 minutes duration.

Every care must be taken to not spread acid to anyone who assists the casualty.

Then the casualty or helper should rub calcium gluconate cream generously on the exposed area. The casualty should be taken urgently to the student health clinic, to receive subcutaneously injected calcium gluconate and, if required, pain relief, before transfer to hospital.

Student Health holds supplies of calcium gluconate cream and calcium gluconate. There is also some held in IVABS in the equine hospital as well as in the farm service clinic.

Partial List of Corrosive Chemicals

Acids

Nitric	Perchloric
Sulfuric	Periodic
Phosphoric	Hydrofluoric
Hydrochloric	Chloroacetic
Acetic	Cresylic
Chromic	

Bases

Sodium hydroxide	Potassium carbonate
Potassium hydroxide	Calcium hydroxide
Ammonium hydroxide	Trisodium phosphate
Calcium Oxide	Barium hydroxide
Sodium Carbonate	Barium carbonate

Others

Bromine	Glutaraldehyde
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4.5 Carcinogens, mutagens and teratogens



Carcinogenic chemicals are substances that induce uncontrolled tumorous growth in animal tissues. Mutagens are substances that cause irreversible changes in chromosomal DNA. Teratogens are agents that cause malformations of the embryo during pregnancy.

Most, but not all, carcinogens are also mutagens and teratogens. It is important to be familiar with the types of chemicals which belong to these classes. Often carcinogens are not immediately harmful. The period from the time of exposure to the time of induction of tumorous growth can be long and latencies greater than 15 years have been recorded. The proportion of chemicals which have been screened for human carcinogenicity is small, so it is prudent to handle chemicals of similar structure, which have not been tested for mutagenicity, as if they were potential carcinogens.

Some types of carcinogenic compounds together with specific examples are listed below (1, p 240-255), (21).

Class	Examples
Alkylating agents (direct electrophiles)	bis-Chloromethyl ether Dimethyl sulphate Epichlorohydrin Ethylene oxide 2-Methyl aziridine 1,3-Propane sultone Propiolactone
N-nitroso compounds	N-nitroso, N-methyl nitroguanidine (MNNG) N-nitroso, N-methyl p-toluene sulphonamide N-nitroso, N-methyl urea
Compounds which can be metabolised to N-nitroso derivatives	The lower N-alkylamines N-alkylated hydrazines Methyl phenyl triazole
Aromatic amines and related compounds	4 Aminobiphenyl Benzidine Dimethyl aminoazobenzene (butter yellow) Ethidium bromide 2-Naphthylamine
Aromatic nitro compounds	4-Nitroquinoline N-oxide
Fungal toxins	Aflatoxins Citrinin Griseofulvin Patulin Sterigmatocystin
Polycyclic aromatic hydrocarbons	3-Methylcholanthrene 7,12-Dimethyl benz[a]anthracene
Haloalkanes Polychlorinated biphenyls	Carbon tetrachloride DDT Heptachlor Lindane Vinyl chloride
Oestrogens	Diethylstilboestrol
Certain metals and metal ions	Chromium (VI) Arsenic (V) Nickel (II)
Miscellaneous carcinogens	Asbestos Benzene Butadiene Hexamethylphosphoramide (HMPA)

Not all compounds of a particular class are carcinogens. For example, 2-naphthylamine is a highly potent carcinogen but pure 1-naphthylamine is non-carcinogenic (however, 2-naphthylamine is usually a contaminant of impure 1-naphthylamine). Potency of carcinogens ranges over about 6 orders of magnitude. Therefore it is essential to consult the safety literature to determine the magnitude of the hazard posed by a particular carcinogen (20-23).

The risk associated with exposure to a carcinogen will depend upon its potency, physical state, the quantity in use and the duration of exposure. Thus the risk of inducing a cancer for a one time exposure to a low potency carcinogen in solution would be quite low.

The precautions required when using these types of substance are the same as those used for toxic substances (see Section 4.3), with due regard for the degree of hazard.

The identification of teratogens has received relatively little attention. One listing (24) divides these chemicals into two categories. One is teratogens, recognised to be teratogenic in humans, and the other is suspect teratogens, only shown to be teratogenic for animals but suspected of being human teratogens. A partial list of the commoner chemicals in these categories is given below.

Female laboratory workers who believe they may have become pregnant or who plan pregnancy and are using or are about to use a teratogenic chemical should arrange to do other work, not involving teratogens, until it has been established by testing that impregnation has not occurred. The embryo is at greatest risk from these agents during the period 15 days to 2 months after ovum fertilisation.

Teratogens	Suspect teratogens
Alkyl mercury compounds	Cadmium and compounds
2,2'-Dichloro, N-methyl diethylamine	Carbon disulphide
Diethylstilboestrol	Carbon monoxide
Iodoacetic acid	1,2 Dibromo, 3 chloropropane
Lead	Dimethylformamide
N-Methyl, N-nitroso urea	Ethylcarbamate (urethan)
N-Methyl, N-nitroso nitroguanidine (MNNG)	Ethylene thiourea
N-Methylformamide	Formamide
Tellurium and compounds	Alkyl hydrazides
Thalidomide	Lithium chloride
	Nitrogen dioxide
	Phthalimides
	Polychlorinated biphenyls
	Selenium
	Vinyl chloride

4.6 Cryogenics

Liquefiable gases, which are used in laboratories for cooling (boiling points less than about -75°C), are known collectively as cryogenics (Class 2, Gases : Divisions 1-3). Cryogenics are hazardous in several ways (1, p 348-356) (25).

Skin contact with cryogenic liquids, or low temperature gases evolving from them, can produce injuries similar to burns. Skin contacting vessels or metal objects cooled by cryogenics may freeze fast to the metal and a layer of flesh may be removed when an attempt is made to separate the affected part from the cold metal.

Eye protection and insulating gloves should be worn when cryogenics are transferred between vessels or when handling objects which have been cooled in a cryogen.

Cryogenic liquids and solids must not be kept in closed containers since the vessel may not withstand the pressure generated by the gas evolved as the cryogen warms (the ratio of the volume of gas formed per unit volume of liquefied gas is about 840 for oxygen and about 680 for nitrogen).

Dry ice (solidified CO₂) and liquid nitrogen must not be kept in enclosed, unventilated walk-in spaces, such as cold rooms, since evaporation of the cryogen may generate an asphyxiant atmosphere by lowering the proportion of oxygen (normal oxygen composition of air is 20.9%; air becomes asphyxiant when the oxygen composition falls below 19.5%).

Vessels which are open to the air must not be cooled with liquid nitrogen (b.p. -196°C) since atmospheric oxygen (b.p. -183°C) will condense in the vessel. Liquid oxygen has a concentration which is about 4,000 times that of oxygen in air. Oxidation reactions initiated in the presence of liquid oxygen proceed at greatly enhanced rates. Instead, open vessels or cold traps on vacuum lines may be cooled using liquid air. However, nitrogen evaporates more rapidly than oxygen from liquid air so that the liquid remaining gradually enriches with oxygen. Liquid air in this state can be recognised by the appearance of a blue tint. It should be kept from contact with fuels and allowed to evaporate in a fume cupboard.

Avoid pouring cryogenic liquids from glass dewar vessels, as they are prone to collapse when the narrow turn at the top of the vessels is subjected to thermal stress.

4.7 Chemical spills and disposal of chemical wastes

4.7.1 Spillage

Before commencing work with any hazardous chemical, the MSDS or other safety literature must be consulted to ascertain how to deal with a spillage of that chemical (3, 4, 8, 31). Any equipment or inactivating reagents required to deal with a spill should be assembled nearby **before starting to use that chemical**.

A general procedure which can be used to clean-up spilt hazardous liquids is to use dry sand to dam and absorb the liquid, then scoop the sand into a plastic bucket using a plastic dust pan and transfer the bucket to a fume cupboard. When the absorbed hazardous liquid has been transferred to a fume cupboard, the safety literature can be consulted to find a method that can be used for its final disposal and this can be performed in the controlled environment of the cupboard (32).

4.7.2 Disposal of chemical wastes

The safety literature must be consulted before disposal of any unwanted hazardous chemicals (3, 8, 15, 31, 33, 34).

Often water soluble hazardous chemical wastes can be disposed most readily in a fume cupboard drain together with a **large** volume of diluent water. Strongly acid or alkaline substances should be neutralised prior to disposal in this way. Also avoid mixing different kinds of waste prior to disposal and take care that different kinds of waste are not allowed to mix in the plumbing, except in highly diluted form, to prevent unanticipated violent reactions. In all cases dilution must be sufficient to lower the concentration in the waste water leaving the campus below the environmentally acceptable limit for that chemical.

Chemical destruction may be another laboratory disposal option for highly reactive or highly toxic waste materials, if suitable procedures are available (13, chap. 10), (35).

All chemical wastes which can not be disposed in the laboratory by dilution or destruction must be disposed off site by chemical waste disposal contractors. For this method of disposal there is a single site (the chemical stores) where chemical wastes are accumulated for collection by the contractor. To comply with the Code of Practice for Transport of Hazardous Substances on Land (NZS 5433: 1988) (30), all chemical wastes delivered to the chemical stores must be packaged, labelled, and accompanied by a completed hazardous substances declaration (see appendix F of the Code for a copy of the declaration form). The labels must show for each chemical in a package:

- the name,
- the classification number (see the Appendix to the manual),
- the UN number (the MSDS should show this number; a complete list is available in reference 38)
- the approximate proportions of the constituents in mixtures
- the name and Institute of the disposer (for University accounting purposes).

When collecting chemical wastes for disposal, it is essential not to mix hazardous wastes from different classes or packaging groups.

An exception to the above procedure is **ethidium bromide-contaminated wastes**. This type of waste must be disposed separately from all other types of waste. Gels stained with ethidium bromide must be disposed in the special discard buckets kept in room 2.08 of Science Tower D. Destain and other solutions contaminated with ethidium bromide must be disposed into the special flasks kept in the same room.

Chemical waste which can not be identified will be accepted for disposal but, because the nature and magnitude of any hazard it has is unknown, it will be classified in the extreme hazard category. Since there will be a considerable additional charge by the contractor for handling and disposing unidentified chemical wastes, measures should be taken to avoid losing identities of waste materials and stored chemicals.

Waste chemicals for off site disposal which do not meet the requirements described above will not be accepted by the chemical stores.

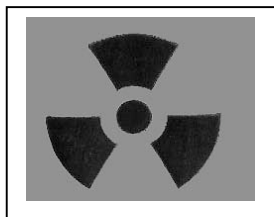
4.7.3 Removal of residues from apparatus before washing

Non-technical staff cannot be expected to know the hazards possessed by any chemicals. Therefore, it is essential that chemical residues are removed from apparatus before sending it to glassware washing facilities. Staff employed in these facilities should be instructed to return apparatus containing such residues, uncleaned, to the user.

4.7.4 Clearing Laboratory Benches Before Leaving

Laboratory workers who leave the Institute must clear their bench of all chemicals before they leave. Surplus proprietary chemicals should be returned to the chemical store. Made-up chemicals and reagents must be disposed. Known and unidentified materials must be disposed using appropriate safe procedures (see section 3.8.2).

5. Safe use of radioactive materials



The most recognizable symbol for a radiological hazard is the trifoil. Most radiation symbols are magenta on a yellow background but may also be black on a yellow or white background. Rope, ribbon, or tape with yellow and magenta bands may be used as a barrier to a radiological hazard.

In New Zealand, the use of radioactive materials is governed the Radiation Protection Act, 1965 and Radiation Protection Regulations, 1982. This is administered by the National Radiation Laboratory. The Act directs that no person shall use or acquire radioactive materials unless they are a holder of a licence issued by the National Radiation Laboratory, or they are a person acting under the supervision or instruction of a licence holder.

One licence holder has been delegated the tasks of administering use of the common radioactive waste storage and disposal facilities on campus and of liaising with the Executive Safety Committee about radiation safety matters. Currently this person is Dr. J Cockrem, Institute of Veterinary, Animal and Biomedical Sciences (telephone 4483).

An introduction to radiation and the measurement of radiation dosage is given in Appendix 11.2

5.1 Protection from Radiation

There are three main principles of radiation protection: **time**, **distance** and **shielding**. If you **decrease the time** you spend in a radiation field, you will **reduce your radiation exposure**. Radiation exposure increases approximately linearly with time.

Increasing your distance from a radiation source will **reduce your radiation exposure**. The radiation exposure from a point source will fall off as the inverse square of the distance from the source. Therefore, if the exposure from a source is 4 rem/hour 1 foot from the source, the exposure twice as far (2 feet) from the source will be $(\frac{1}{2})^2$ or $\frac{1}{4}$ of 4 rem/hour, or 1 rem/hour.

Finally, **increasing the amount of shielding** between you and a radiation source will **reduce your radiation exposure**. The amount that your exposure will be decreased depends on the amount and type of shielding used. It is important to use the appropriate kind of shielding material for the type of radiation you are trying to shield.

It is important to know when it is appropriate to use shielding materials and the correct types of shielding to use.

For the quantities typically in use at Massey, shielding is *not* required for ^3H (tritium), ^{14}C or ^{35}S . However, higher energy beta emitters such as ^{32}P , may require shielding when larger activities of the radioisotope are present in the lab.

Beta particles should be shielded with low Z materials such as plexiglass/perspex or wood, not with a high Z material such as lead. If a high Z material is used, the beta particles could interact with the shielding and produce X-rays through the process of bremsstrahlung.

In some cases with high activities of high energy beta emitters, a low Z shield is used as a primary shield and is surrounded by a high Z material. However, this technique of shielding against beta particles first, then against x-rays, is seldom, if ever, necessary at Massey.

Unlike beta particles, high Z materials such as lead are used to shield gamma rays. However, for the quantities of gamma emitters (such as ^{125}I) typically in use at Massey, shielding is *not* usually needed, except when storing large quantities in a fume hood.

5.2 Code of Safe Practice

The National Radiation Laboratory has written a Code of Safe Practice for the Use of Unsealed Radioactive Materials (26), which must be consulted before commencing any work with radioactive materials (copies of the Code may be obtained from the National Radiation Laboratory). All work with radioactive materials must conform to this Code. The upper limits of the amounts of radionuclide that might be used in a particular class of laboratory are given in appendix 2 of the Code. The facilities currently available on this campus are those of either a class A or a class B laboratory. Only laboratories set aside solely for work with radioactive chemicals belong to class B.

5.3 Standard Procedures for Commonly used Isotopes

The Code of Safe Practice requires that, whenever the radioactivity of any unsealed radioactive material exceeds the A limit in appendix 2 of the Code, a Manual of Standard Procedures shall be prepared to describe all standard methods used locally for routine safe handling of that radioactive material. Copies of the standard procedures for the use of the common radioactive waste disposal and storage facilities at Massey University are available from Dr. J Cockrem (ext 4483).

5.3.1 Using tritium

Tritium (^3H) emits low energy (about 0.019 MeV) beta particles. *Shielding is not needed*, as the beta particles don't travel very far and are stopped by the outer protective layer of your skin. One of the major problems with tritium occurs during storage, as tritium in some chemical forms tends to "creep." That is, tritium thought to be in properly sealed containers can migrate, so that tritium contamination of entire refrigerators, ventilation systems, etc. occurs. Therefore, tritiated water should not be stored in refrigerators or freezers.

5.3.2 Using ^{14}C and ^{35}S

^{14}C and ^{35}S are beta-emitting radioisotopes with energies of about 0.16 and 0.17 MeV, respectively. *Shielding is not needed* for the quantities typically used in labs at Massey University because of these relatively low beta energies. It is because of the low beta energies that contamination surveys cannot be performed by direct monitoring with a Geiger counter. Instead, “swipe” samples should be taken and counted in a liquid scintillation counter. However, when performing spot checks of your gloves and work area, direct monitoring with a Geiger counter is an acceptable means of contamination control.

5.3.3 Using ^{32}P

^{32}P is a beta emitting radioisotope with a maximum energy of 1.71 MeV. As beta particles travel approximately 12 feet per MeV in air, this means that a ^{32}P beta particle can travel up to about 21 feet.

Larger quantities (several millicuries or more) of ^{32}P should be shielded. As ^{32}P is a beta emitter, use a low Z material for shielding, such as plexiglass (pespex) or wood. In some situations, such as waste storage, wood may be preferred as it is less expensive than plexiglass.

Lead shielding should *not* be used because of the possibility of generating X-rays via the bremsstrahlung process.

5.3.4 Using carrier-free ^{125}I

^{125}I is a gamma emitter. Although the gamma rays emitted by ^{125}I are not particularly energetic (its highest energy gamma is about 0.035 MeV), ^{125}I is of concern because of its volatility when it is not bound (also known as carrier-free).

Therefore, special precautions should be taken when using carrier-free ^{125}I :

Iodinations should be performed quickly in a working fume hood to prevent iodine from escaping into the laboratory air.

When finished with the iodination, immediately reduce (from iodine to iodide) all fractions, liquid waste and residual iodine on equipment with sodium metabisulfite or thiosulfate.

If there are items contaminated with iodine that cannot be reduced, store them in a fume hood inside a sealed bag containing activated charcoal. This is also the recommended method of storing unused ^{125}I .

5.4 Purchase and Record Keeping

All orders to purchase radioactive materials must be made on the appropriate order form that must be signed by a licensee. Order forms are available from Robert Cleaver (ext 2589, room ScD 4.07, email R.Cleaver@massey.ac.nz). Completed forms must be returned to him for processing of the order.

5.5 Disposal of Radioactive Wastes

The procedures for disposal of radioactive wastes at the common university facilities are described in the Manual of Standard Procedures.

Radioactive waste must be stored properly to prevent the spread of radioactive contamination and so it is not mistaken for non-radioactive trash. Each container of radioactive waste *must be labeled* with the words “Caution Radioactive Materials” and bear the three-bladed symbol for radiation.

Although radioactive waste usually only contains minute amounts of radioactive material, it still must be kept in a controlled area. That is, radioactive waste *cannot be stored in an unsecured room or hallway*.

Radioactive waste is classified into four types: **solid radioactive waste**, **liquid radioactive waste**, **radioactive “sharps”** and **radioactive carcass waste**. Each type of radioactive waste should further be segregated in the lab into specific categories of radioactive waste, and should be treated differently.

Solid radioactive waste should be segregated into at least three different categories in the lab:

Glass and plastic that cannot be decontaminated easily. Most glass and plastic can be decontaminated by soaking in detergent. As glass and plastic items tend to increase waste volume, it is in the campus’ best interests to reduce such waste as much as possible.

Paper, gloves and other compressible items. These are items that cannot be decontaminated and do not consume much volume.

Short-lived waste of any form (glass, plastic, paper, gloves, etc.). This is waste with radioisotopes of half-lives less than 90 days, such as ^{32}P , ^{125}I and ^{35}S . In fact, further separation of radioisotopes which have similar half-lives would make waste treatment easier for the campus.

Solid radioactive waste containers should be lined with **clear plastic bags at least 4 mm thick**. This makes it easier for staff to identify contents and the bags will not tear as easily as thinner bags would.

It is important not to put liquids into the solid radioactive waste. Accumulation of liquid in the solid waste stream can lead to some unpleasant products.

Liquid radioactive waste must be segregated into two different categories, as each is treated differently.

Organic liquid radioactive waste is liquid waste that contains less than 10% water by volume. A typical component of organic liquid radioactive waste is liquid scintillation cocktail that is based on organic solvents such as toluene or benzene.

Organic liquid radioactive waste **must** be stored in approved containers. The containers must be contained within a larger container that is capable of retaining all the liquid in case of leaks.

Solids must be filtered out of the wastes.

The pH of the waste must be approximately neutral, that is, it must be adjusted to between pH 6.8 and 8.0.

This category of waste must be returned to stores for proper disposal.

Aqueous liquid radioactive waste can be disposed into the sewer system. However, there are *very* strict regulations on the activities and concentrations involved. Therefore, *prior approval from a Licence Holder is always required* before disposal.

Radioactive “sharps” are items such as Pasteur pipettes, syringes, hypodermic needles.

Most glass items, such as test tubes and vials, can be decontaminated and should *not* be disposed as radioactive sharps, unless they cannot be decontaminated.

Do not dispose of radioactive sharps in non-radioactive sharps containers.

5.6 Spillage and clean up

Workplaces where unsealed radioactive materials are used should be monitored routinely, before, during and at the end of the work period, so that inadvertent spillage of radioactive material does not go unnoticed.

See Section 3.7 under Emergency Procedures for the procedure to follow to clean up a spillage of radioactive material. All significant spillages of radioactive material must be reported promptly to the supervising licensee and an accident report form completed.

When cleaning a radioactive spill, **avoid spreading radioactive contamination**. Place absorbent material around the edges of the spill to keep it from spreading. Wipe from the outside of the spill towards the center, using only one side of the absorbent material for each stroke. Rubbing back and forth or in circles will only tend to spread the radioactive contamination further.

Make sure to dispose of the materials you used to clean the spill properly.

Radioactively contaminated wipes should be placed into containers for solid radioactive waste; radioactively contaminated rinse water should be disposed of in a sink designated for radioactive use.

5.6.1 Intermediate sized spills

Confine the contamination: Place absorbent material around any spilled liquid to prevent it from spreading

Prevent the spread of contamination: Use a survey instrument, such as a Geiger counter, to check yourself for radioactive contamination before leaving the contaminated area. Make especially sure to check your hands and the soles of your shoes. Remove contaminated clothing before leaving the contaminated area.

Restrict access to the spill area: Inform others in the immediate area. Post warning notices, if necessary

If a volatile material is involved, increase ventilation: Open windows and turn on fume hoods

If the material involved is dry, decrease ventilation: Close windows and doors

If contamination has become widespread outside of the lab, eg., several hallways or floors of a building, you may need to contact campus police to control access to the affected areas.

Don't try to decontaminate the spill unless the situation threatens to become much worse. Decontamination can usually wait until after the Radiation Safety Section has had time to assess the situation and recommend appropriate decontamination measures.

5.6.2 Large Spills

The health and safety of personnel is absolutely the FIRST priority over contamination concerns.

If the situation involves the possibility of high level radiation exposures or airborne radioactivity, it is important to: Evacuate the area immediately to reduce personnel exposure. Upon reaching a safe area, rid yourself of any contamination as soon as possible. Keep other personnel away from the affected area

If there is no possibility of high level exposure or airborne radioactivity, and it is safe for personnel to remain in the area: Confine the spill, if possible, by placing absorbent material around the edges of the spill. Avoid spreading the contamination outside the affected area (no tracking!). Restrict access to the contaminated area to personnel.

Do not attempt to decontaminate the area unless the situation threatens to become much worse. The Radiation Safety Officer will suggest decontamination measures when an analysis of the situation is completed.

5.7 Storage

Radioactive materials must be stored in containers that have conspicuous labels showing the type of radionuclide and the amount of radioactivity. If the storage site is remote from the work location and the amount of radioactivity exceeds the upper limit in appendix 2 of the Code, then the storage place shall be locked. Stock quantities of radioactive materials that have a penetrating radiation (e.g. ^{32}P) should be stored in a well-shielded place; the kind of shielding required will depend upon the nature of the radiation (27-29).

5.8 Radiation Monitoring

Unnecessary exposure to radiation should be avoided and workplaces should be monitored to ensure safe practices.

Put on the appropriate personal protective equipment, such as gloves, a labcoat, etc.

Make sure that the Geiger counter is functioning correctly by following the following steps:

- a. *Turn on the unit and perform a battery test.* Depending on the type of instrument, the battery test will either be a choice on the rate selection knob or a switch on the instrument face. Some sort of indicator (on analog instruments, a needle should move) will let you know whether or not the battery has sufficient charge. If the battery is low, make sure you change the batteries before proceeding.
- b. *Turn the instrument to its most sensitive setting (on the ratemeter this is usually the "X1" position) and note the reading you get for background radiation.* This reading should be in counts per minute (cpm).
- c. *Test the probe by holding a "check source" up to it and checking the reading against previous readings ..* If the probe does not respond correctly, do not use it for the survey. Contact the Radiation Safety Section for advice

Switch selector on the Geiger counter to its most sensitive multiplier, which is usually the "X1" scale.

Hold the probe so that its counting window is about 1 cm from the surface to be surveyed.

When surveying the surface, move the probe over the surface at a rate of about 1 cm/second. If you move much faster than that, the probe can pass too quickly for contamination on the surface to be detected.

If you are trying to detect the presence of alpha or beta particle contamination, do not cover the probe window (we often see probes covered with parafilm or plastic wrap to reduce contamination of the probe). Alpha and lower energy beta particles cannot penetrate the cover over the probe, so any particles present would not be detected!

5.9 Exposure Rate

Survey meters, some with Geiger-Mueller (GM) detectors, read out radiation exposure in rates. This is exposure over a period of time. If a person were standing in a dose rate of 1 R/hour and stands there for 1 hour his exposure would be 1 R.

If you know the exposure rate, you can reduce how much radiation you receive. For example, if the dose rate meter were reading 1 R/hour and you only want to receive 0.250 R, you would limit your time to 15 minutes in the area.

A website for calculating the amount of radiation emitted by an isotope is <http://www.riskman.unsw.edu.au/ohs/decay.htm>

5.10 Radiation Biohazards

Estimates suggest that the average person receives over 150 mrem of radiation exposure per annum. Half of the people who receive a dose of 400-450 rads (about 3000 times greater) over a 30-day period die from the exposure within a period of weeks. A dose of 100 rads generally makes people very sick; a dose of 5000 rads usually will kill someone within hours. (For comparison, adult cockroaches can withstand doses of 100,000 rads, and some viruses can survive doses of millions of rads.)

6. Microbiological safety

6.1 Risk levels and containment requirements

In working with microorganisms, it would be prudent to regard all species as potential pathogens and to use appropriate work practices. However, to assist with the provision of appropriate safety facilities, pathogenic organisms have been classified into groups according to the degree of hazard they present. The joint Australia/New Zealand standard (39) divides infective microorganisms into four Risk Groups. Four Containment Levels specify the laboratory facilities required for work with microorganisms in these Risk Groups.



Before beginning work with any microorganism new to your workplace, it is essential to determine in which Risk Group this organism belongs. IMBS only has facilities that meet the requirements of Containment Levels 1 and 2 (PC1, PC2).

6.2 Hygiene

Attention to good personal hygiene is fundamental to safety in the microbiological laboratory. Work surfaces may become contaminated as a result of unrecognised spillage or due to the settling of aerosol borne organisms. In these instances even careful workers may become contaminated on the hands and contract an infection by hand to mouth or hand to eye transfer of infective organisms. Therefore, a conscious effort is required to resist the natural tendency for such movements when working with harmful microorganisms. Other practices that should be avoided or followed at all times in the laboratory are described below.

Do not eat or drink in laboratories. (Use the common room or cafeterias.)

Do not store food for personal consumption in laboratory refrigerators.

Always wash your hands when leaving the laboratory, for any reason. Use disposable paper towels, not communal towels, to dry your hands.

Use disposable tissues, not personal handkerchiefs for nasal drip.

Do not pipette by mouth. Use a pipetting device.

Do not moisten labels with your tongue. Use self-adhesive labels whenever possible.

Keep your personal belongings away from potentially contaminated work places. Use lockers away from the laboratory area to store personal effects.

Do not store protective clothing in the same place as street clothing. There should be a place to leave protective clothing in the laboratory where it is used.

Do not wear protective clothing outside the workplace, for example when you go the toilet, to the common room, to the library, etc..

Cover all cuts, abrasions and other lesions, which may provide points of entry for pathogens, with impervious dressings. Wash your hands in disinfectant and wear gloves as an extra protection against possible infection via these routes.

6.3 Safe work practices

The results of a large number of studies of reported laboratory-acquired infections of workers handling infective microorganisms in microbiological laboratories (40) attest to the potential hazards of this kind of work. A significant feature of the findings of these studies was that only 20% of the infections could be attributed to an exact source. That is, 80% of the infections were not the result of overt accidents, but were occurring during the performance of routine procedures. These findings underline the need to follow safe work practices.

Some safe work practices when handling infective microorganisms are described below. These practices take into account the known routes of infection; through the mouth, through the skin, through the eyes, through the lungs. Safe work practices for using other non-microbiological hazardous materials commonly used in microbiology laboratories are also described.

When working with infectious material, always wear a **laboratory coat** (protects skin and personal clothing against splashing), **safety glasses** (protect eyes against splashing), **footwear** with closed uppers (protect skin against falling drops) and **gloves** (protect hands against splashing and collection of microorganisms from contaminated work surfaces).

Decontaminate work surfaces by wiping down with a 1% Virkon solution before and after use, or daily.

Clean and **tidy work spaces** regularly to remove dust and used apparatus. Organise a cleaning roster for communal areas.

Set aside a space, separate from the workplace, for **writing up reports** and note books to prevent contamination of reading and writing materials.

Include disinfectant (e.g. Aqua Stabil) in the water of **water baths** used to warm infectious materials.

Always **label** cultures of infective organisms, showing the date, the name of the organism and the name of the owner. Cultures should be kept in a dedicated storage place (cold room, refrigerator, warm room) and not on work benches.

Work in ways that minimise microbial **aerosol formation**. Several commonly used microbiological procedures are capable of generating aerosols and should be performed in ways which minimise this:

- Wire **bacteriological loops** should have an enclosed loop with a diameter of 2-3 mm (so that a stable film of liquid is collected and not an unstable drop) and a shank no longer than 6 cm (to minimise vibration of the wire). Disposable, sterile, plastic loops are desirable alternatives to wire loops if they can be used instead.
- After flame sterilisation, always allow the **loop** to cool before inserting it into a culture.
- When using a loop to **transfer infective samples to slides** for staining and microscopic examination, use slow movements when spreading the material on the slide and when withdrawing the loop. If possible, do this in a biohazard cabinet.
- When using **pipetting devices** to transfer infective material, operate the plunger slowly for intake and delivery of the liquid. Uncontrolled release of a depressed plunger will generate an aerosol inside the tip and pipette. Rapid depression of the plunger will cause dispersal of aerosol droplets at the point of the tip. It is good practice to touch the tip to the surface of the liquid or to the wall of the receiving vessel, at a large angle, during sample delivery. This both minimises aerosol production and improves the accuracy with which the measured volume is delivered. Used tips must be discarded into disinfectant solution.
- Great care is required in **centrifuging** infectious materials. Any material released in the centrifuge during operation will be broken up into very fine droplets by impact with the rotor or wall of the centrifuge and dispersed into the laboratory by the air stream created by the moving rotor. Sealed tubes, sealed buckets or sealed rotors should be used. Tubes should be inspected for faults before use and must be carefully balanced to avoid rotor failure during operation. Sealed buckets, tubes or rotors should be filled and opened in a biohazard cabinet. After each time the equipment is autoclaved, the seals should be inspected and replaced if deterioration is evident.
- **Opening closed vessels** containing infectious materials can generate aerosols. Water expelled from contracting agar and collecting on the lids of inverted **Petri dishes** may carry microorganisms from the culture. When the lid is removed the film of liquid between the lid and the dish is broken generating an infectious aerosol. When **cotton wool plugs** are used to close vessels it is important to handle the vessels in a way that prevents the contents from wetting the plug, since withdrawal of wet plugs generates an aerosol. Care is required not to allow the contents of **screw-capped bottles** to reach the cap since liquid will be retained at the junction of the cap seal and the vessel wall and will generate an aerosol when the cap is removed. Rapid removal of the lids of petri dishes containing cultures of sporulating fungi will cause sufficient draught to disperse **fungal spores** as airborne particles. **Opening ampoules** containing freeze-dried infectious material requires special care. The ampoule should be scratched at a point above the inner cotton wool plug and a red-hot glass rod applied to the scratch to crack the glass. The ampoule should then be wrapped in alcohol-

soaked cotton wool and the tip broken off and placed in a disinfectant. These procedures should be done in a biohazard cabinet.

- The act of **pouring liquids**, e.g. from centrifuge tubes, can generate an infectious aerosol, even if the liquid is being poured into disinfectant. An additional hazard is that drops of liquid are often retained at the lip of the vessel and run down the outside when the vessel is returned to an upright position.
- **Shaking of cultures for aeration, blending and homogenising** are all procedures that generate aerosols. Blenders and homogenisers used with infectious material must be equipped with seals at the lid and around the blade drive shaft. The operations should be done in a biohazard cabinet. Opening the vessels used for these purposes will form an aerosol from liquid retained at the closure. Shaking cultures for aeration produces aerosols that persist for a period after shaking has been stopped. The culture flasks should either, be allowed to stand for a long period to allow the airborne particles to settle before opening, or they should be opened in a biohazard cabinet.
- **Ultrasonic disruptors** must be used in a biohazard cabinet when disrupting infectious microorganisms, since the cavitation at the surface of the probe that causes cell disruption, also generates an aerosol.

A large proportion of reported laboratory-acquired infections have resulted from the use of **syringes and needles**. Therefore syringes should not be used when the task can be done using a pipetting device instead. If syringes have to be used:

- Gloves must be worn when using syringes. To avoid leakage past the plunger, only syringes with a close fitting plunger should be used. To prevent accidental release of the needle, only use syringes with a Luer-Lok fitting to retain the needle.
- When using a syringe to withdraw infectious material through the rubber septum of a vaccine bottle always cover the needle and cap with cotton wool soaked with disinfectant.
- If it is necessary to adjust the volume of liquid in the syringe or to displace air from above the liquid, insert the needle into a small bottle containing cotton wool soaked in disinfectant to do this.
- Always discharge the contents of a syringe through a needle slowly since rapid discharge will generate an aerosol at the needle tip. Do not place used needles on the bench, always discard them directly after use into sharps waste containers for decontamination. Always be careful to avoid 'needle-stick' injuries.

If **infectious material** has to be **transported** from one laboratory bench to another or from one laboratory to another, the primary container should be put into a secondary leak-proof container to contain any accidental spillage that might occur during the transfer. There are special packaging requirements for infectious materials that are transported via public thoroughfares (39).

6.4 Sterilisation

Only those who are properly trained shall operate an autoclave. The following matters should be attended to for safe operation of an autoclave.

Media and equipment to be sterilised by autoclaving shall be received and collected at a separate place from that used to receive material and equipment for decontamination by autoclaving.

No material containing inflammable volatile liquids or materials that will emit toxic vapours or containing highly reactive chemicals shall be sterilised in an autoclave.

Anyone loading or unloading an autoclave should wear a laboratory coat, a facemask and heat-insulating gloves.

At the end of the sterilisation cycle, sufficient time should be allowed for the loads to cool before removing them from the autoclave, particularly for containers of large volumes of liquid which may take a long time to cool to below 100°C. Liquid that is moved before the vessels have cooled sufficiently may boil over violently.

Small items or materials liable to deteriorate as a result of prolonged exposure to elevated temperatures may be sterilised using domestic pressure cookers. Ensure that the vessel has sufficient water (usually about 300 mL) to provide steam for the duration of the cycle. The same remarks made about cooling time for autoclaves apply to pressure cookers also. (See section 9.10.1)

6.5 Decontamination

There are three methods available for the decontamination of laboratory equipment and wastes; autoclaving, chemical disinfection and incineration. The method of choice will depend upon the nature and size of the material needing decontamination. Chemical disinfection may not kill all the organisms in contaminated material. Whenever possible autoclaving is preferable. If not the first method used then it should be the final method used. Properly done, autoclaving will sterilise (kill all the organisms in) contaminated material.

6.5.1 Decontamination by autoclaving

Section 6.4 should be consulted for information about the safe use of autoclaves. This section describes additional procedures that must be used for materials needing decontamination.

Whenever possible, all materials to be decontaminated by autoclaving should be placed in stainless steel decontamination bins and the lid vents closed.

Materials liable to melt or spill or otherwise not retain their contents during autoclaving (such as plastic Petri dishes, cultures in tubes and narrow based bottles, used slides and Pasteur pipettes) must be put in autoclavable plastic bags inside the decontamination

bins. The mouths of the bags must be turned back over the rim of the bin, to allow steam to penetrate the load.

No material containing inflammable volatile liquids or materials that will emit toxic vapours or containing highly reactive chemicals shall be sterilised in an autoclave. In particular, Virkon and hypochlorite solutions should not be autoclaved since they emit corrosive vapours. Equipment that has been disinfected in these solutions must be separated from the disinfectant before autoclaving (see section 5.9 for the procedure for disposal of used disinfectant).

If you are likely to generate material for decontamination with properties which might be a hazard if autoclaved, you should consult staff who operate the autoclave about safe procedures, before commencing the work.

Decontamination bins for autoclaving must not be taken into the 'clean' kitchen area but shall be left only in the 'dirty' room (Science Tower D 2.10).

All decontamination bins left for autoclaving shall be labelled using the tags provided (loop the tag over the sliding vent handle). The label shall show the name of the owner of the material to be autoclaved and the room number of the laboratory it came from.

6.5.2 Decontamination by chemical disinfection

Chemical disinfection is often a convenient first treatment for articles contaminated by infective microorganisms. However, the **effectiveness** of this treatment may be dependent upon a large number of variables (duration of contact, temperature, pH, the presence of organic matter, the shape and size of the articles, the presence of substances catalysing decomposition of the disinfectant), not all under the control of the user. Consequently, chemical disinfection should never be the final method of decontamination.

Further, there is variability in the **susceptibility of different organisms** to chemical disinfectants. If a pathogen new to the laboratory is about to be used, the literature (40, 41) should be consulted before work begins to determine whether the chemical disinfectant in common use in the laboratory will be effective against the organism.

Discard jars for chemical disinfectants should be about 1 litre capacity and made of autoclavable polypropylene. Ideally the same size jar should be used throughout the institution so that a standard quantity of concentrated disinfectant and diluent water is required to replenish the disinfectant. The following procedures should be adopted when using this equipment.

The jars should be emptied once weekly and empty jars autoclaved so that surviving organisms do not grow.

Used disinfectant from discard jars should not be autoclaved since these agents (e.g. Virkon and hypochlorite) produce corrosive vapours in the autoclave. Used disinfectant should be poured down a drain without splashing. The drain used should be one that

feeds directly to the main drain without passing intervening drains that are open to the laboratory.

Articles taken from discard jars should be autoclaved for complete sterilisation.

Do not add large volumes of liquids (e.g. supernatant liquids from centrifuge tubes) to dilute disinfectant solution. Instead put the standard volume of neat disinfectant into the jar, pour in the liquid for disinfection and adjust the volume to the usual standard volume by addition of water.

Chemical disinfectants are also used for routine **decontamination of work surfaces** (see section 6.3) and for clean up of spills of infectious material (see section 3.8).

6.5.3 Decontamination by incineration

Incineration is not a method of decontamination available on campus. Therefore all other methods should be considered first. In some instances the mass and impenetrability of material needing decontamination precludes autoclaving or chemical disinfection and incineration is the only option. Special arrangements will be required to do this. The need for incineration of wastes should be identified before the work begins so that there is time to arrange the procedure beforehand.

6.6 Spillage of infectious material

See section 3.8 for the emergency procedure for dealing with spillage of infectious material.

6.7 Precautions for handling human body fluids and tissues

Anyone contemplating work with human body tissues or fluids must obtain permission from the Institute Safety Committee before this work can begin. All of these materials should be treated as potential sources of infection by hepatitis viruses or the human immunodeficiency virus (HIV). Hepatitis B is the most dangerous of these organisms, being extremely infectious, much more so than HIV.

The following procedures and precautions should be adopted whenever working with human tissues and body fluids.

Research and teaching laboratories where human body fluids and tissues are used must have written procedural rules for handling these materials safely and for cleaning up spillage. Only those who have been instructed and trained in these procedures may work with this kind of material.

Those intending to work extensively with human body fluids or tissues should be tested for antibodies to hepatitis B. If they do not have immunity, they should be immunised with hepatitis B vaccine. This should be arranged well before the work begins to allow

sufficient time for the vaccination program to be completed and for serological testing to establish that immunity has been conferred.

Since it has been found that the hepatitis B virus can gain entry to the body through slight or unapparent cuts and grazes, gloves must be worn when working with human body fluids and tissues. Apparent cuts or grazes on the hands and other areas of the skin should be covered with impervious dressings.

A plastic apron should be worn over ordinary protective clothing when working with human body fluids. The apron should be autoclaved after a single use.

If there is a possibility that the face might be splashed by blood or other potentially infective fluids, a face shield should be worn.

All the safe work practices described in section 6.3 for, pipetting, opening closed vessels, pouring, centrifuging, transferring samples to slides, using syringes and needles and transport, must be followed when working with human body fluids and tissues.

If skin lesions are contaminated, or a puncture wound is sustained from a needle contaminated by human body fluids or tissues, the affected area must be treated immediately by washing with soap and water. If the eyes or mouth have been splashed, wash immediately with water.

After these emergency actions have been taken, report the incident to your supervisor and complete an accident report form. If the affected person has been vaccinated against hepatitis B, a booster dose should be considered. If the affected person has not been vaccinated and it is known that the contaminating material is hepatitis surface antigen B positive, they should consult their physician promptly and passive immunisation with hepatitis B immunoglobulin followed by active immunisation with hepatitis B vaccine should be considered.

Disinfection and clean up of spilled body fluids or tissues should be performed as described in section 2.8. Suitable disinfectants are 1% Virkon or freshly prepared sodium hypochlorite solution containing 10g / kg free chlorine (10,000 ppm).

6.8 Genetically modified organisms

No one shall work with genetically modified organisms (GMOs) at Massey University without obtaining permission from the university Genetic Technology Committee (GTC Secretary, Research Services, Geography Building, ext 5945). The Massey University GTC has delegated authority from the Environmental Risk Management Authority (ERMA) to grant approval for work with low risk GMOs. Application forms are available from the IMBS secretariat (ext 5450).

Approval for work with GMOs in higher risk categories must be sought from ERMA directly. All work with GMOs shall be in accordance with the guidelines set out in the Code of Practice (1994) published by the Advisory Committee on Novel Genetic Techniques.

6.9 Disposal of microbiological wastes

All contaminated microbiological wastes must be decontaminated before disposal.

Autopipette tips with a maximum volume of 1 mL or less are not recycled. Contaminated tips must be discarded into 1% Virkon solution. After a suitable time in Virkon (overnight), disinfected tips must be separated from the disinfectant and autoclaved. Autoclaved tips can then be discarded as domestic waste. Virkon solutions must not be autoclaved since they produce corrosive vapours in the autoclave. Used Virkon solution should be disposed by pouring down a drain without splashing.

The large 5 mL autopipette tips are recycled. Contaminated tips must be discarded into fresh 1% sodium hypochlorite solution (Virkon stains the tips). After a suitable time, separate the disinfected tips from the disinfectant and autoclave, preferably in a pressure cooker to minimise exposure of the tips to heat, which gradually distorts their shape and affects the tightness of fit to the pipette. Hypochlorite solutions must not be autoclaved since they produce corrosive vapours in the autoclave. Used hypochlorite solution should be disposed by pouring down a drain without splashing.

After dealing with any spilled infectious material (section 3.8), contaminated broken glassware should be put in 1% Virkon solution and left overnight. After separation from the disinfectant, the glass must be autoclaved. Autoclaved broken glass and uncontaminated broken glass must be discarded only in the metal waste bins reserved for this material. Do not discard broken glass into the domestic waste bins that are emptied by the cleaners.

Used needles, scalpel blades and other sharp items must be disposed in sharp-safe containers, available from the Purchasing and Stores Officer (Mr. P. Hocquard). Contact Mr. Hocquard for disposal of filled sharps containers.

6.10 General microbiological laboratory equipment

Equipment that is used mostly only in microbiological/biological laboratories is considered here. Safe use of equipment in more general use is considered in section 7.

6.10.1 Pressure Cookers

The minimum quantity of water required for 15 minutes of sterilisation is 300 mL. A further 130 mL of water must be added for each additional 15 minutes or part of 15 minutes sterilising time.

Put in the material to be sterilised, using a perforated stand to keep it above the water level if it needs to be kept dry. Ensure that any foil, paper, cotton wool, etc., that may be used, is secured so that it will not come free during sterilisation and block the steam outlets of the pressure cooker.

Put on the lid, lining up the marks on the lid and the cooker vessel. Press the lid down and rotate it to the left until the handles are aligned.

With the vent in the lid open, heat the cooker (gas ring) on high heat until steam escapes from the vent. Fit the appropriate pressure release weight (see table below) to the vent by pushing it down until it clicks into place. Do not wait too long after steam begins to be expelled before fitting the weight since sufficient water may be lost that the cooker boils dry before the sterilisation time has elapsed.

When the desired pressure is attained steam will be heard escaping from the valve. Turn down the heat to just maintain steam flow from the valve.

When the required time has elapsed, turn off the heat and allow the cooker to cool to less than 100°C (this may take 10-15 minutes, depending on the contents). To test that this has occurred, ease the valve weight up slightly. If no steam escapes, the temperature has fallen below boiling point. Remove the weight and open the lid carefully.

It is possible to cool the cooker rapidly by running cold water over the outside of the vessel, taking care water does not run over the vent or safety plug. However this method should not be used when liquids are being sterilised since the cooker may be sufficiently cooled but the liquid may still be above 100°C and may boil violently when the valve weight is removed.

Pressure	Boiling temperature
5 lbs/in ² (34.5 kPa)	108°C
10 lbs/in ² (68.9 kPa)	115°C
15 lbs/in ² (103.4 kPa)	121°C

6.10.2 Microwave Ovens

Never heat metal objects in a microwave oven.

Loosen the lids of all closed vessels before heating to avoid generation of dangerous overpressures.

6.10.3 Biohazard Cabinets

Biohazard cabinets are intended to protect the operator against inhaling aerosols. They do not protect the operator from contact with spillage or other accidental release. Therefore hands and arms need to be protected when using this equipment. The following practices should be adopted for the safe use of biohazard cabinets.

After switching the cabinet on and before using it, check the airflow indicator (if one is fitted) to ensure that the air extraction is satisfactory.

Limit the amount of equipment in the cabinet to that required for the task at hand. Each item in the cabinet causes turbulence in the airflow and affects the efficiency with which aerosols are extracted through the HEPA (High Efficiency Particulate Air) filter.

Position the work as far from the front of the cabinet as possible. Eddies caused by airflow around the worker can collect aerosols generated near the front of the cabinet and carry them back to the worker's breathing zone.

When an aerosol generating task has been completed wait a minute or two before withdrawing your arms from the cabinet to avoid causing an outflow of contaminated air in the eddies caused by arm movement.

When the task has been completed allow the cabinet to continue running for several minutes before removing your work materials and fitting the front cover.

Do not use Bunsen burners in a biohazard cabinet since the heat distorts the airflow. If the burner goes out, gas may accumulate in the cabinet and exhaust ducting creating an inflammable air/gas mixture which may be ignited.

Do not use a biohazard cabinet for work with volatile flammable, corrosive or otherwise reactive liquids. These substances may cause degradation of the materials used to seal HEPA filters into the exhaust duct and allow infective organisms to leak from the cabinet.

Decontamination of biohazard cabinets should be done after spillage of infectious material, before maintenance, before changing the HEPA filter, and before testing. This should be done by fumigation with formaldehyde. Only trained technical staff shall do biohazard cabinet fumigation.

6.10.4 Checklist for a PC2 laboratory

Construction Equipment

Component	Compliance	Additional Notes/Description
Doors	Closed	Standard operating practice and type (i.e. self closing)
Gown Hooks	Near door	Proximity to door, indication of use...
Washbasins	Near door	Type of washbasin, location. Is it elbow/foot operated?
Surfaces (Bench tops, floors)	Impermeable	Made of.... State of repair....
Emergency Equipment	Drench shower Eyewash station	Type, location, floor drainage, etc.
Autoclave	Easily accessible Inspected annually	Location, maintenance schedule and last inspection date
Biosafety Cabinet		Type, maintenance schedule and last inspection date

Procedures

Criteria	Compliance	Description of Procedure
Mouth pipetting, eating drinking, applying cosmetics, etc.	Prohibited	Observations - i.e. coffee cups, personal items, food stored in refrigerators
Protective clothing	Gowns worn Enclosed footwear worn Gloves worn	Observations - gowns provided/worn, type of footwear
Exiting the facility	Remove gowns Remove gloves Wash hands	
Labelling of stored GM materials	Stored materials labelled Materials identified Dated Non-lickable stickers	What areas were checked i.e. fridges, cupboards, benches.... What type of label was used? What information recorded?
PC2 Procedures	All work in the facility using PC2 procedure	
Disposal of microbiological waste	Autoclaved	Description including mode of transport, mechanism used to ensure penetration of steam....
Movement of biological materials from facility	Double contained with closed, unbreakable outer container	
Decontamination of surfaces and equipment	Chemical solution	What chemical? How is it used?
Activities creating aerosols	Done in Biosafety Cabinet	Description of procedure
Decontamination of Biosafety Cabinet	Fumigation	Description of procedure, observation of materials required.....
Identification of cultures	Labelled Dated Stored correctly	Describe procedure including type of labelling used, where the cultures were stored.....

7. Other materials and laboratory equipment

7.1 Compressed gases

These are the Class 2, Gases (divisions 1-3). Cylinders containing compressed gas are used every day on campus without incident, but these gas cylinders may easily be a hazard if they are mishandled. Filled compressed gas cylinders are repositories of a large amount of energy and should be handled accordingly. Cylinder construction is a compromise between the need to contain the energy and to minimise cylinder weight for ease of mobility. (1, p 282-285), (13, ch 8)

We have all heard stories about gas cylinders in which the valve was broken and the cylinder took off bounding around the room, sometimes even breaking brick walls. We should also not forget the explosive and toxic potential of some of the common gases and cylinder sizes found in our laboratories and shops. For example, if a 9 _ 51" cylinder filled with pressurized butane gas were to accidentally release its contents, it would make a noxious, extremely flammable cloud 200 cubic feet in volume. Even a lecture bottle, a 2 _ 12" cylinder, can release 30 cubic feet of butane.

7.1.1 Safe handling of gas cylinders.

Check to see cylinder valves are protected with protective caps. Leave caps on until the gas is about to be used.

Clear cylinder valves of any dust or dirt before attaching proper regulators. Some regulators are only for specific gases and should not be interchanged. Do not force connection fittings and never tamper with safety devices in cylinder valves or regulators.

Store cylinders in a well-ventilated area away from all sources of heat or flames. Do not store flammable gases next to exit or oxygen cylinders

Always wear eye protection whenever using equipment pressurised by gases or liquids.

All gas cylinders must be secured by means of chains fixed to permanent fittings. Large gas cylinders used upright should be secured in two places to prevent them slipping out during an earthquake. If it is necessary to use a cylinder in a place where there is no permanent chain, proprietary stands or straps that clamp onto the bench should be used to hold the cylinder.

Cylinders should be transported only on the hand trolleys designed for this purpose. Cylinders on trolleys must be constrained by the straps or chains provided. Before moving cylinders fitted with regulators the cylinder valve must be closed.

Before fitting a regulator to a compressed gas cylinder, check that it is the correct type for the gas. This can be done by asking the mechanical workshop staff, (Ext 3511) or contacting BOC safety Ph. 0800 723 378 Grease or oil must never be used on the cylinder valve and union or on the regulator that is fitted to the cylinder.

Always check that the union seats are free of dust or other particulate matter before fitting the regulator. Only use the correct spanners to tighten regulator unions. The main valve on modern cylinders has a hand wheel control. Older cylinders require the use of a cylinder key to turn the main valve spindle. Only use the proper cylinder key to open these valves. Never tighten leaking connections under pressure. Turn the cylinder main valve off and allow the system to vent to atmospheric pressure before attempting to repair the leaking connection.

Ensure contents of cylinders are properly identified. Don't accept unidentified cylinders and don't rely on colour codes; read the label. Don't destroy or remove identification tags or labels.

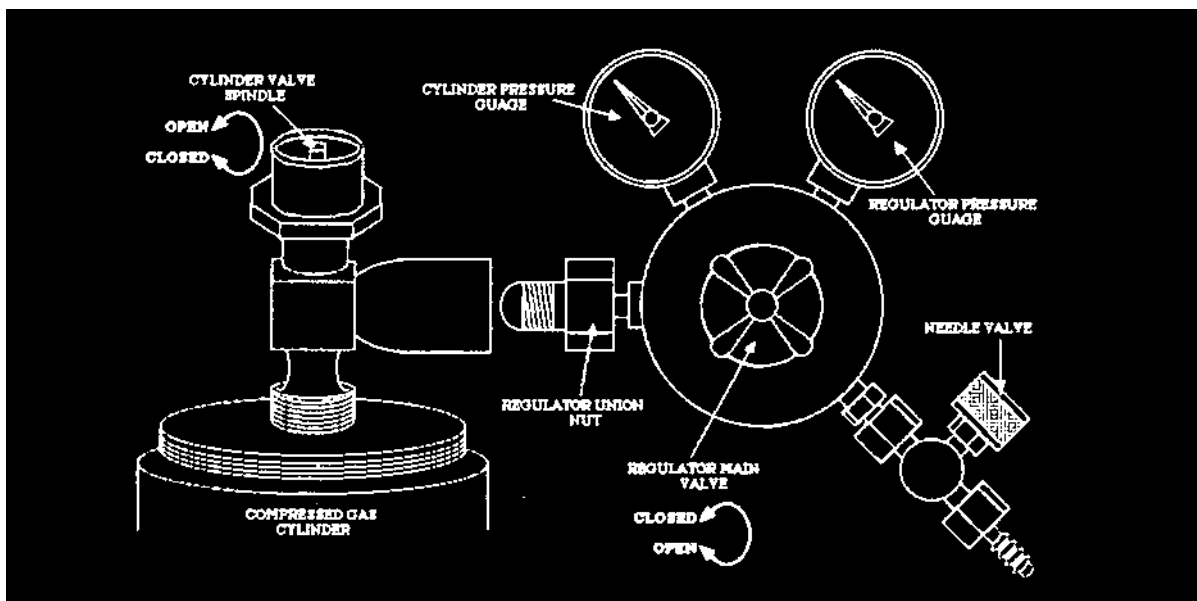
Before returning cylinder, close the valve and replace the protective cap. Separate empty and full cylinders during storage. Mark empty cylinders "EMPTY" or "MT".

Know the safety and first-aid requirements for gases being used. Review Safety Bulletins, MSDS sheets, and read the warning labels. These can be found on the website https://pgw100.portal.gases.boc.com/scripts/wgate/zcpwp_b2c/

Regulators used on cylinders containing flammable gases should be fitted with flashback arrestors, to prevent accidental ignition of the gas at the cylinder outlet.

Do not locate compressed gas cylinders near heat sources. The increase in pressure due to heating may exceed the design specification of the cylinder.

Do not allow gas to be released from compressed gas cylinders in enclosed walk-in spaces, such as cold rooms. Release of cylinder gas into these spaces may lower the proportion of oxygen in the atmosphere to dangerous levels (normal proportion is 20.9% oxygen; any proportion less than 19.5% is dangerous).



7.1.2 Using the gas cylinder

Ensure the regulator main valve is closed by rotating the spindle anticlockwise until it moves freely. Close any flow-controlling needle valve fitted to the regulator by rotating the knob clockwise.

Using the hand wheel or cylinder key, slowly open the cylinder main valve (anticlockwise). The cylinder gauge on the regulator should register the gas pressure in the cylinder.

Open the regulator valve by rotating the spindle clockwise until the desired working pressure registers on the regulator pressure gauge.

Open the needle valve by rotating the knob anticlockwise, until the required gas flow rate is obtained.

When compressed gases are passed from cylinders into liquids, a trap of sufficient size to contain all of the liquid being gassed must be included in the gas line between the cylinder and the liquid to prevent liquid from sucking back into the regulator and cylinder.

7.1.3 Turning off the gas supply

Close the needle valve by rotating the knob clockwise.

Turn the regulator valve spindle anticlockwise until it rotates freely.

Close the cylinder valve using the cylinder key (clockwise) or hand wheel.

7.1.4 Removing the regulator from the cylinder

Disconnect any apparatus connected to the needle valve.

Check that the cylinder main valve is closed.

Open the needle valve (rotate anticlockwise) and then open the regulator valve. Check that both the cylinder and regulator pressure gauges show no pressure (regulator completely vented). Rotate spindle clockwise to allow gas in the regulator to vent to atmosphere

Using the proper spanner, disconnect the regulator from the cylinder.

7.2 Fume cupboards and laboratory ventilation

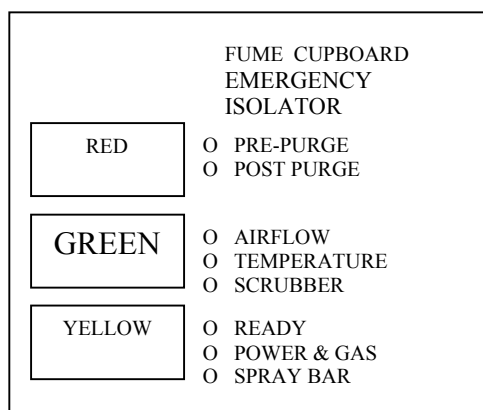
The fume cupboard is one of the most important safety devices available to the laboratory worker (1, p 147-170), (4, p 193-212). Whenever possible, fume cupboards should be used for any operations involving volatile flammable, toxic or corrosive chemicals. In order to get maximum use of these facilities, users should remove their equipment and clean up as soon as possible after their work is finished to allow access for other potential users.

Fume cupboards work most efficiently when obstruction of the flow of air from the face of the cupboard to the exhaust duct is minimal. Therefore the contents of the cupboard should be limited to that equipment which is immediately required for the work in hand.

One fume cupboard in a laboratory may have to be set aside for the storage of highly noxious chemicals requiring continuous ventilation. Potentially hazardous work should not be done in this fume cupboard.

The worker standing at the fume cupboard is a major obstruction to the airflow. The worker's body generates eddies in the air stream flowing into the fume cupboard. These eddies can collect vapours from within the cupboard and carry these vapours back to the breathing zone from which the worker inhales air. To minimise the possibility of inhaling hazardous vapours generated in this way, it would be prudent to position the work as close as possible to the back of the cupboard, out of reach of any eddies, and to have the sash in the lowest convenient position.

Usually general laboratory ventilation has been designed to work in conjunction with the fume cupboards, the laboratory airflow being directed across the room toward the cupboards. Therefore self-closing laboratory doors should not be propped open since this may generate draughts that are counter to the designed airflow and lower the efficiency with which air is exchanged throughout the laboratory.



7.2.1 Operation of fume cupboard

Start up: Press the green button. The fan and light will turn on. The Temperature LED will be green. The controller waits 7 seconds for airflow.

- Pre-purge:** The Airflow LED turns green. The Pre-purge LED will be amber for 50 seconds, then flash for another 10 seconds, before going out.
- Ready:** The Ready LED turns green.
- Active:** Press the yellow button. The Power & Gas LED turns green. The fume cupboard is now operational- power and gas can be used.
- Shut Down:** Press the red button. Power and Gas turn off automatically. The Power & Gas LED goes out.
- Post-Purge:** The fan and light continue to operate. The Post-Purge LED will be amber for 15 minutes, then flash for another 5 minutes, before going out. The light and fan turn off automatically.
- Re-Start:** Press the green button to return from post-purge to pre-purge.

7.2.2 Fault Alarms

If the Power is cut, then restored, the fan will automatically turn on for 20 minutes, then turn off. An alarm will sound for 30 seconds then turn off. The LEDs will keep flashing. Press the red button to reset the controller and stop the fan. Press the green button for normal start up.

If the Airflow get low, an alarm will sound, and the Airflow LED will flash. Press the red button to mute the alarm. The fume cupboard will go into normal post-purge, but the Airflow LED will be red. Check out what caused the alarm. Get it fixed before using the fume cupboard again.

If the temperature inside the fume cupboard gets high, the Temperature LED will flash green as a warning. Turn down the heat inside the fume cupboard. If the temperature inside the fume cupboard gets higher, an alarm will sound, and the Temperature LED will flash. Press the red button to mute the alarm. The fume cupboard will go into normal post-purge, but the Temperature LED will be red. Check out what caused the alarm and get it fixed before using the fume cupboard again. The temperature sensor works even when the fume cupboard is turned off. Press the red button to mute the alarm.

7.3 Glassware

Cuts sustained when handling glassware account for the largest proportion of injuries occurring in laboratories. Before using glass apparatus make it a practise to inspect it for cracks or deep scratches, which could be the cause of mechanical failure under stress. Do not use apparatus with chipped edges that can cause cuts. Defective glassware should be sent to the glass workshop for repair. The ends of cut tubing should be smoothed by fire polishing before use. (1, p 365-369)

Glass is a material of low ductility at room temperatures. Therefore it is liable to failure when subjected to tensile stresses. However glass will withstand compression stresses quite well. Therefore large pieces of glassware should be handled in a way that is in accord with these properties. When pouring liquids from large beakers or flasks they should not be held by the sides or necks alone (tensile stressing) but should be supported at the base (compression stressing) as well, so that tensile stressing is minimised.

7.4 Glassware under vacuum

Wear safety glasses whenever working with glass apparatus under vacuum. Whenever possible place the apparatus behind a shield of some type, eg. vacuum desiccators should be placed in safety cages before evacuation. It should be noted that the forces acting on a piece of glassware evacuated by a water aspirator are only slightly less than those acting on the same piece under a high vacuum.

Glassware for vacuum work should be inspected carefully before use and any with hair-line cracks or deep scratches should not be used. Only use round bottom flasks on rotary evaporators.

When using cold traps with evacuated glassware, care should be taken to ensure that the cryogen does not completely evaporate from the trap. Warming and evaporation of the contents of the trap may cause a sudden increase in pressure and rupture of the apparatus. At the end of vacuum work the system should be vented to atmospheric pressure before the cryogen is removed from the cold trap to avoid the same hazard.

7.5 Ultraviolet light

7.5.1 Exposure Standards

Occupational ultraviolet (UV) exposure standards have been proclaimed in the USA and these standards have been adopted in the UK (36). In these standards the UV spectrum has been divided into three regions: near UV (or UV-A) 315-400 nm, mid UV (or UV-B) 280-315 nm, far UV (or UV-C) 100-280 nm. Light of wavelengths less than 200 nm is strongly absorbed in air.

For UV-A the maximum permissible exposure (MPE) has been set at 1000 W cm^{-2} for periods of exposure greater than 1000 seconds. For UV-B and UV-C the MPE value depends upon the wavelength of the light. For example, for an 8-hour exposure, MPE at 300 nm is 100 J m^{-2} , at 254 nm it is 60 J m^{-2} and at 270 nm, the most harmful wavelength, it is 30 J m^{-2} .

7.5.2 Assessment of hazard

There are several different types of UV source on this campus, including those in: UV lamps used for detection of substances on chromatograms, photochemical reactors, germicidal lamps, trans-illuminators. The distribution of radiant flux over the UV spectrum may differ markedly with type of source. The location of the source may affect the potential exposure of a user, which may occur directly or indirectly by reflectance from surrounding surfaces. Consequently the effective radiant flux from a UV source can be properly assessed only by direct measurement. If a meter for measuring UV flux from a source is not available, it would be prudent to take all convenient measures to avoid or minimise UV exposure from that source.

Some indication of the magnitude of the hazard presented by UV sources can be obtained from data supplied by the manufacturer of a popular UV-illuminated cabinet used to view chromatograms. The measured irradiance from the 254 nm source at the floor of the cabinet was $590 \text{ } \mu\text{W cm}^{-2}$. According to the US standard, the MPE for such a source is less than 10 seconds per day.

7.5.3 Protection Against UV Illumination

Eye protection is a primary defensive measure since these organs are particularly sensitive to UV radiation. Keratoconjunctivitis is solely related to irradiation by UV-B or UV-C. However, there is evidence suggesting that chronic exposure to UV-A is a contributory factor in the formation of cataracts.

Goggles or wrap-around spectacles with special lenses that are opaque to radiation of wavelengths less than 400 nm are commercially available. Polycarbonate safety glasses, commonly used in chemistry laboratories, cease transmission at wavelengths less than 380 nm. Shields of Perspex completely remove UV-B and UV-C, but the transmission cut-off is about 360 nm so that protection from UV-A is only partial.

Skin protection can be achieved by wearing PVC gloves and a long sleeved laboratory coat. However, some coat materials, such as nylon, are relatively UV transparent.

The illuminated window of trans-illuminators, commonly used to detect the presence of UV-absorbing bands in electrophoresis gels, should be viewed only with a polycarbonate fence surrounding the window when the lamp is on.

7.6 Electrical apparatus

Electrical apparatus must be tested in accordance with AS/N2S 3760 (2003). See <http://hrs.massey.ac.nz/docs/ElectricalSafety200312.pdf>.

The flexible leads on electrical equipment should be inspected routinely before use and at the first signs of wear or cracking it should be taken to the Electronic Services workshop for replacement or repair. Only the qualified persons in the workshop should repair faulty electrical apparatus.

Always beware of situations where electrical fittings might be splashed by water or otherwise come into contact with water.

Some apparatus may require the use of isolating transformers. Never connect more than one piece of electrical equipment at a time to an isolating transformer.

Electrical equipment which has been used in a cold room and is brought out into a laboratory for use at ambient temperature must be allowed to stand at room temperature for at least 24 hours before use, to allow condensed water to evaporate from the circuitry.

7.7 Laboratory machinery

7.7.1 Danger from Moving Parts

Never remove guards or inactivate safety devices on laboratory machinery. Never put hands into machinery unless it has been turned off and all moving parts have stopped. Beware of the possibility of loose clothing or long hair becoming caught in moving parts.

7.7.2 Centrifuges

If you are using a centrifuge for the first time, it is essential to ask the person in charge of the machine how to use it. Different models of centrifuge may not be compatible with all the rotors available. Rotors may have been de-rated and should not be used at the g forces originally specified. There may be special local requirements for the operation of the centrifuge. Apart from being dangerous, accidents resulting from misuse of high-speed centrifuges are likely to be very expensive to repair.

Before each use, centrifuge rotors for all types of service should be inspected for cracks or corrosion that could portend stress failure. It should be policy to replace fixed-angle aluminium alloy rotors, which are frequently used at intermediate g forces, after about 6-7 years, especially when corrosion is evident. This type of rotor particularly is liable to suffer corrosion and should be cleaned in warm water after use, using a bristle brush to dislodge any solids compacted in the tube holes, and placed upside down to dry. Tube adaptors should not be left in these rotors as corrosive agents may accumulate beneath them.

A log of operations must be kept for rotors undergoing service at high g forces and the manufacturer's recommendations for de-rating or retirement should be followed strictly.

Before each use, centrifuge tubes should be inspected for cracks and faulty ones discarded. Check that the tubes are the correct ones for the rotor. Filled tubes must be carefully balanced before placing them in the rotor.

Always check that the rotor has been properly seated on and fixed to the drive shaft. When the rotor has a lid this must be attached to the rotor before use. When a rotor is to be used immediately after a previous run, it should be inspected for liquid that might have spilled in the previous run, which could cause rotor imbalance.

Before starting the centrifuge, check that the correct speed has been set on the speed control dial. Then check that this speed does not exceed the maximum recommended speed for that rotor. **Do not centrifuge rotors at greater than the recommended maximum speed.**

After starting the centrifuge, stay by the machine until the rotor has reached operating speed. If it is apparent that the rotor is unbalanced, turn the centrifuge off at the main power switch and move away.

When using bench top centrifuges with swinging bucket rotors, the bucket, trunnion carrier and centrifuge tube combined should be balanced against its counterpart, since the buckets and trunnion carriers may not all be the same weight.

Only operate the centrifuge with the chamber lid closed. Do not open the chamber lid until the rotor has stopped. Never attempt to slow the rotor by hand.

7.8 Sonicators

Ultrasonic disintegrators emit radiation at frequencies largely beyond the range of frequencies detectable by the human ear. Although inaudible, such ultrasound has been found to be damaging to the ear. Measurements of the intensity of this ultrasound made near ultrasonic probes gave values that were in the harmful range of intensities. Therefore, when the sonicator is provided with a sound attenuating enclosure, it should always be operated with the enclosure door closed. If the probe must be used outside an enclosure, earmuffs with an appropriate attenuation factor must be worn.

7.9 Personal computers

The personal computer has become an indispensable item of equipment for the laboratory worker. An all too common condition associated with the use of computers is occupational overuse syndrome (OOS). This can occur from the repeated exertion of muscular forces for short periods, such as occur when using computer keyboards or clicking the computer mouse, or whenever muscles are held tense for long periods, such as occur when seated incorrectly at the workstation.

If you need to work with a computer for an extended time, the prevention strategy for avoiding OOS is to reduce both the tension in muscles and the time for which muscle tension is held. Adopt a safe working posture. Use a properly designed computer workstation. Use micro pauses from keyboard work of about 20 seconds every 5 minutes and longer breaks of about 2 minutes every 20 minutes. Take morning and afternoon tea breaks, and lunch breaks.

7.10 Hand-operated pipettes

The hazard of accidental ingestion associated with the use of mouth pipettes can be avoided by using hand-operated pipettes. However, if used repetitively for extended periods without pauses, the muscular movements required by the hands to operate these pipettes can lead to the development of OOS in the hands. Therefore it is essential to follow the regime of pauses described in section 7.9 to avoid the possible development of this painful and debilitating condition.

8. Miscellaneous safety matters

8.1 Working out of regular hours or alone

Work involving highly toxic or highly reactive compounds, large volumes of flammable solvents, infectious micro-organisms or other hazardous procedures should not be done outside normal working hours (7:00 a.m. to 7:00 p.m., Monday to Friday) when assistance may not be available in the event of an accident. When conducting hazardous experiments during normal hours you should inform a colleague of the nature of your work, so that they may check at intervals to see that nothing untoward has happened.

8.2 Looking after hazardous procedures

Potentially hazardous experiments should not be left unattended. Should it be necessary to leave a hazardous experiment, arrange for a colleague to watch it while you are away, giving them instructions about what to do if the procedure becomes uncontrolled. Post warning signs stating the nature of the hazard so that colleagues will not unwittingly expose themselves to danger and be sure to remove the warnings when the hazard no longer exists.

8.3 Overnight laboratory procedures

Whenever possible your work should be organised to avoid the having chemical reactions, continuous extractions, distillations, etc. go overnight.

If overnight operations are unavoidable, particular attention should be given to ensuring that the process will be as safe as possible. The process should be conducted using fail-safe equipment (over temperature cutouts, water flow cutouts, etc.). Allowance should be made for the possibility of temporary power failures (boiling aids may not function when boiling resumes and bumping may occur) and of changes in water pressure (rubber hosing carrying water to condensers should be in good condition and secured with wire or hose clamps to both the condenser and the tap). The process should be inspected during the night in order to minimise the time that any malfunction goes undetected.

All overnight procedures must be identified by posting a notice beside the apparatus which shows the name of the person conducting the process and a telephone number where they can be contacted in the event that malfunction is observed to occur. In addition the notice must describe, in terms that can be understood by a layman (such as a security guard), how to shut down the process safely if it is found in a malfunctional state.

8.4 Labelling

Ensure that all containers of chemicals are identified by legible labels. Do not use a private code which might be misconstrued or not understood by others. Check labels on chemical containers in your care regularly so that any in disrepair or becoming faded can be replaced before identity is lost. Disposal of unidentified chemicals is a costly process (see section 4.7.2).

8.5 Reporting accidents

The Health and Safety in Employment Act requires that any accident that harmed or might have harmed an employee must be recorded in a register kept by the employer (section 25 of the H & S E Act). Therefore all accidents, whether they result in injury or not, must be recorded on the **Massey University Accident or Incident Form** and copies submitted to the institute Manager and to your Workplace Safety Committee.

MU Accident or Incident Forms are available from the Institute Manager, the Institute Safety Officers and can be found in the First Aid cabinets in every laboratory.

Incidents are unusual events that did not result in damage or injury but might have caused damage or injury if they occurred at another time or in different circumstances. Your Workplace Safety Committee needs to be informed about incidents so that it can devise procedures to prevent a repeat occurrence which might result, at another time or in another place, in damage or injury.

Reports of accidents or incidents involving hazardous chemicals must include copies of the relevant **Material Safety Data Sheets** for perusal by the Workplace Safety Committee.

Accidents involving injuries that require medical treatment (excluding injuries requiring only minor first aid treatment) and/or time off from work must also be recorded on an **Accident Insurance Claim Form** and submitted as soon as possible to the Institute Manager, along with a copy of the claim form, so that they can be processed and sent to the payroll office and to the Insurer within 2 business days.

If the accident involves injury that causes serious harm, the Occupational Safety and Health service (OSH) and the insurer must be notified within 24 hours and a third form, the **OSH Accidents and Serious Harm Form**, must be completed as well as the other two.

8.6 Eating, drinking and smoking

No one is permitted to eat or drink in a laboratory or chemical store. Smoking is not allowed in any campus building, or outside within 10 m of a building, unless in a designated area. See <http://hrs.massey.ac.nz/hs-smoke.php3>

8.7 Smoke stop doors

Ensure that smoke stop doors close behind you when you pass through. In the event of a fire, it is essential that these doors are closed to prevent the circulation of smoke and possibly injurious fumes to other parts of the building where they could hinder the evacuation of persons there. Confining smoke to the floor of its origin will also enable firemen to approach the location of the fire quickly. It is good policy to close all doors as you exit the building, as this will ensure maximum containment of the fire as well as reducing smoke damage.

8.8 Building security

Persons working in buildings outside normal working hours and having the use of external door keys or key cards must ensure these doors are locked behind them on entering and leaving. No one shall leave buildings by way of the emergency exits except in an emergency.

If you see strangers in your building after normal working hours who are acting suspiciously, inform the Security Service immediately. To contact a Security guard on campus, telephone **5030** from telephones connected to the university exchange or **350 5030** from telephones outside the university system.

8.9 After hours register

Buildings are unlocked at 7.30 a.m. and locked at 6.20 p.m. on working days. From 6.20 p.m. to 7.30 a.m. between working days, on weekends and public holidays, the University is closed and these times are designated as after normal working hours.

A register is kept in each of the foyers to the three main entrances to the building. Everyone, including visitors, entering and leaving the building after normal working hours must enter in one of the registers his full name, times of entering and leaving the building, and location in the building.

Recording this information is an essential part of the after hours emergency plan for the building. In the event of a building evacuation after normal working hours, a roll call will be made of the names on the register and a search at the location given will be made for anyone who does not answer the roll call. If your name is not in the register and you were unable to leave the building because you suffered an injury or were trapped in the building, it may be a long time before you are found.

8.10 Visitors

Only scientific colleagues, technical and cleaning staff, and escorted visitors are allowed in working laboratories. Children are not allowed in these areas. Visits by school parties shall occur only after prior arrangement with the Head of Institute. See <http://hrs.massey.ac.nz/hs-child.php3> and <http://hrs.massey.ac.nz/hs-contractor.php3>.

9. Personal protection

9.1 Eyes



The eyes are the laboratory worker's most valuable sensory organs. They are the most delicate and most easily damaged of all the external tissues. **Safety spectacles** should be worn at all times in the laboratory. Prescription spectacle wearers should be aware that the glass normally used in these aids has low impact resistance, relative to polycarbonate used to make safety spectacles. Face shields should be used in work situations requiring head protection. (1, p 746-748)



For protection from occupational overuse syndrome (OOS) see <http://hrs.massey.ac.nz/hs.php3>

9.2 Lungs

Work involving the use of chemicals with noxious or corrosive vapours should be performed whenever possible in fume cupboards (see Section 5.2). If the type of work precludes the use of a fume cupboard, a suitable respirator should be used; (11, p. 22 has a good discussion of the choice and limitations of respirators). Since fume cupboards do not provide complete containment of fumes generated within them, work with chemicals having highly toxic vapours should be avoided unless special containment facilities for using these chemicals safely are available. (1, p 739-745)



Work involving the possible production of infectious aerosols should be performed in a biohazard cabinet. Only biohazard cabinets with a current performance certificate should be used. Massey University only has biohazard cabinets suitable for work with microorganisms belonging to risk groups 1 and 2.

9.3 Skin

Laboratory coats and rubber surgical gloves should be worn at all times when working with hazardous chemicals or infectious microorganisms.

Rubber household or surgical gloves or plastic gloves may be worn for hand protection against corrosive or toxic chemicals. Glove users should be aware that the protection afforded against a particular chemical may depend upon the type of material from which the gloves are made (internet reference 3 and library reference 4, p 157-160). No one type of glove will give protection against all harmful substances.



People handling large quantities of corrosive liquids need extra protection. For protection against a large scale splash wear plastic or rubber aprons over the laboratory

coat, a face mask, long plastic or rubber gauntlets and rubber boots with tops that are higher than the bottom of the coat or apron.

Anyone wearing gloves for protection against chemicals or infectious microorganisms should take care not to wear their gloves when handling facilities in communal use, such as door handles, telephones, light and power switches, taps, transilluminator, etc.

Users of gloves made from natural latex rubber should be aware of the possibility of becoming sensitised to proteins in latex. Persons who suffer from allergies to foods such as avocado, potato, tomato, kiwi fruit, corn, soybean and hazelnuts are recorded as being particularly prone to contracting latex allergy.

Footwear with closed uppers should be worn to protect the feet from splashes of hazardous chemicals and liquids containing infectious microorganisms.

9.3.1 Hand protection

Protective gloves shall be worn where there is reasonable probability of skin contact with irritant or corrosive chemicals or with chemicals that can be absorbed through the skin.

Protective gloves that provide protection against cuts and abrasions shall be worn when handling sharp, rough or abrasive objects.

Gloves that provide thermal insulation shall be worn when hot or very cold objects must be handled.

Gloves should be selected on the basis of the materials being handled, the physical conditions that exist, and the requirements of the tasks performed.

Before each use, chemical resistant gloves shall be inspected for punctures, tears or other signs of degradation and new gloves used if these conditions are found.

All glove materials are permeable to some extent. A suitable glove is one that has an acceptably low permeation for the chemical, concentration, and for the degree and duration of contact. Permeation is generally inversely related to glove thickness.

Thin cotton gloves worn under rubber gloves improve comfort by absorbing perspiration during prolonged use. They also reduce chances for skin absorption by separating the glove surface and the skin. However, if the cotton lining contacts a hazardous material, it can act as a wick and soak up the hazardous material.

Gloves, other than single use types, should be decontaminated before removal by rinsing or washing.



9.3.2 Guide for Glove Selection:

Some chemical resistant glove materials commonly available are described below. This is not intended to be a complete list.

For chemical protective gloves, factors other than chemical resistance are also important. These include: Resistance to abrasion, Tear and puncture resistance, Dexterity limitations, Length (arm protection), Grip characteristics wet/dry.

Chemical resistant gloves		
Material	Description	Specific use
Vinyl Nitrile	Thin disposable	Nuisance materials Preventing product contamination
Butadiene Rubber	Flock lined, 15 mm thick	Perchloroethylene Ammonium Fluoride Sodium Hydroxide Freon TF Hydrofluoric Acid Hydrochloric Acid Perchloric Acid Phosphoric Acid Potassium Hydroxide Alcohols Hexane
Neoprene	Flock lined, 18 mm thick	Degreasing Solvents Alkalis/Caustics Oils Cellosolve Mineral Acids Alcohols Plating Solutions
Natural Rubber	Surgeons type, 9 mm thick Flock lined, 18 mm thick	Acetone Alcohols Alkalis/Caustics Ammonium Fluoride Dimethyl Sulfoxide Phenol

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- (38) United Nations, Recommendation on the Transport of Dangerous Goods, 7th ed. (1991) (343.093 Uni)
- (39) Standards Australia, Australian Standard 2243.3 Safety in Laboratories, Part 3: Microbiology (1991) (R363.1162 Sta)
- (40) Collins, C.H., Laboratory-acquired Infections, 3rd ed. (1993) (616.9045 Col)
- (41) Block, S.S. (ed.), Disinfection, Sterilisation and Preservation, 4th ed. (1991) (614.48 Dis)

10.2 Safety information on the internet

- [1] ChemWatch Material Safety Data Sheet data base (Massey University licenced to use): <http://chemwww.massey.ac.nz/>
- [2] Where to find MSDS on the internet - links to a large number of MSDS data bases: <http://www.ilpi.com/msds/index.html>
- [3] Chemical application and recommendation guide for gloves: <http://www.ansellpro.com/specware/>
- [4] Massey University Health and Safety: <http://hrs.massey.ac.nz/hs.php3>

11. Appendix

11.1 Classification of chemicals

The classification of chemicals is according to NZS5433 : 1988.

11.1.1 Class 1 Explosives

Explosives are any substance or mixture of substances which, in their normal state, are capable of either decomposition at such a rapid rate as to result in an explosion or of producing a pyrotechnic effect.

Division 1.1 Substances and articles which have a mass explosion hazard.

Division 1.2 Substances and articles which have a projection hazard but not a mass explosion hazard.

Division 1.3 Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard, or both, but not a mass explosion hazard.

Division 1.4 Substances and articles which present no significant hazard.

Division 1.5 Very insensitive substances which have a mass explosion hazard.

11.1.2 Class 2 Gases

These are substances which are normally stored and transported under pressure. Includes substances, such as compressed gases, which are stored under high pressure and others, such as cryogenic gases, which are stored under low pressure.

Division 2.1 Flammable gases.

Division 2.2 Non-flammable gases.

Division 2.3 Poisonous gases.

11.1.3 Class 3 Flammable Liquids

Those liquids or mixtures which give off a flammable vapour at or below 61°C.

Packaging group I Flammable liquids with a boiling point less than 35°C.

Packaging group II Flammable liquids with a boiling point greater than 35°C and a flashpoint less than 23°C.

Packaging group III Flammable liquids with a boiling point greater than 35°C and a flashpoint greater than 23°C but less than 61°C.

Flammable Liquid: Class I liquids: flash point below 37.8°C

Class IA: flashpoints below 22.8°C and a boiling point below 37.8°C (eg., pentane)

Class IB: flashpoints below 22.8°C, boiling point at or above 37.8°C (eg., acetone)

Class IC: flashpoints at or above 22.8°C and below 37.8°C (eg., 2-butanol).

Combustible Liquid: A liquid having a flash point at or above 37.8°C.

Class II: flashpoints at or above 37.8°C and below 60.0°C (eg., acetic acid).

Class IIIA: flashpoints at or above 60.0°C and below 93.3°C (eg., butyric acid).

Class IIIB: flashpoints at or above 93.3°C (eg., stearic acid).

Flashpoint: The minimum temperature at which a liquid gives off a vapour in sufficient concentration to ignite.

11.1.4 Class 4 Flammable solids

Class 4.1 Flammable Solids

These are solids which are easily ignited by external heat sources, such as flames and sparks, and are readily combustible. They also include substances which might contribute to a fire or cause one through friction, or may, due to an increase in temperature during transport, self ignite.

Class 4.2 Spontaneously Combustible

Solid or liquid substances which are liable, spontaneously, to heat and ignite in air.

Class 4.3 Dangerous When Wet

Solids or liquids which, when in contact with water, evolve flammable gases. This includes gases which may ignite spontaneously in air and gases which require an ignition source to ignite.

11.1.5 Class 5 Oxidising agents

Class 5.1 Oxidisers

Substances which may not be combustible themselves, but will cause or contribute to combustion by evolving oxygen.

Class 5.2 Organic Peroxides

Organic substances which contain peroxy-groups and may be unstable and decompose violently or explosively if subjected to heat, contact with impurities, friction or impact.

11.1.6 Class 6 Toxic agents

Class 6.1 Poisons

Substances with the potential to cause death, or serious injury, or harm to human health if swallowed, inhaled, or taken up by skin contact.

Packaging group I Substances and preparations presenting a very serious toxicity risk.

Packaging group II Substances and preparations presenting a serious toxicity risk.

Packaging group III Substances and preparations presenting a relatively low toxicity risk.

Class 6.2 Infectious Substances

Substances or articles containing viable micro-organisms, including bacteria, viruses, parasites, fungi, or recombinant mutants of these, or their toxins, which are known to cause disease in animals or humans.

Risk group I Low individual and community risk.

Risk group II Moderate individual risk, limited community risk.

Risk group III High individual risk, low community risk.

Risk group IV High individual risk, high community risk.

11.1.7 Class 7 Radioactives

Substances emitting invisible radiations that may damage body tissue.

11.1.8 Class 8 Corrosives

Substances that cause burning or chemical destruction of body tissues.

11.1.9 Class 9 Miscellaneous

Substances that do not meet the criteria for another class but represent a relatively low health hazard or an environmental hazard.

11.2 Introduction to radioactivity

Radiation is emitted in the form of *particles* or *photons*. Two of the more commonly-encountered radioactive particles are *alpha* and *beta* particles. Radiation in the form of photons can be either *gamma rays* or *X-rays*.

Alpha particles are made up of two protons and two neutrons (equivalent to a helium nucleus) and carry a +2 charge. Since alphas are relatively heavy particles and carry charge, they cannot travel very far; they typically travel up to a few centimetres in air, depending on their energy.

Alpha particles are not generally considered to be an external radiation hazard, as they cannot penetrate the outer protective layer of your skin.

Beta particles can be either negatively or positively charged and carry a charge of 1. Negatively charged beta particles are often referred to as *electrons* and positively charged beta particles are often referred to as *positrons*.

A rule of thumb for the distance that beta particles can travel in air is that they can travel about twelve feet per MeV of energy. Therefore, ^{32}P , which has a maximum beta energy of 1.71 MeV, can emit beta particles which travel up to **more than twenty feet**.

A mistake often made when shielding beta emitting materials is to use a high Z (atomic number) shielding material such as lead. *High Z materials should not be used to shield beta emitters*. Using a high Z material can actually generate more radiation than it shields. A better choice in shielding materials would be substances with a low Z, such as plexiglass/perspex or wood.

Gamma rays are photons originating from an atomic nucleus. Although gamma rays are not charged, they can create charge by causing ionization in the materials with which they interact.

Photons such as gamma rays do not have definite ranges of travel as particles do. Instead, the intensity of a photon beam falls off exponentially as it travels through a medium such as air.

The best materials to use for shielding gamma rays are high Z materials, such as lead. However, lead is considered to be a hazardous material. Therefore, care should be taken not to contaminate lead shielding with radioactive material, as it can create a mixed-waste problem.

The unit commonly-used for measuring the activity of a radioisotope is called the **curie**, abbreviated Ci and named after Marie Curie.

A curie is defined as being the number of radioactive decays undergone by a gram of radium. Specifically,

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ dpm}$$

where dpm means disintegrations per minute.

Radioisotope activities typically used are in the **microcurie** (10^{-6} curies, abbreviated μCi) to **millicurie** (10^{-3} curies, abbreviated mCi) range.

Internationally, the unit typically used to measure activity is the **becquerel**, abbreviated Bq and named after Henri Becquerel. A bequerel is equal to one disintegration per second.

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq or } 37 \text{ GBq (gigabecquerel)}$$

It might help to remember the following:

1 μCi = 37 kBq (kilobecquerel)
 1 mCi = 37 MBq (megabecquerel)

Since radiation detectors cannot be 100% efficient, they cannot directly report results in terms of disintegrations per minute. Another measure, known as **cpm**, or **counts per minute**, is what the radiation detector actually “sees,” which will be lower than the actual rate of disintegrations occurring.

The **disintegrations per minute (dpm)** is calculated by dividing the cpm reading from the detector by the efficiency of the detector. Note that the efficiency of a detector will be different for each radioisotope being monitored, and different detectors will each have different efficiencies.

Typical efficiencies for a Geiger counter (ratemeter + Geiger-Mueller probe) are:

40-75% for beta particles above 300 keV
 2-5% for alpha particles
 0.5-5% for gamma rays and x-rays

Roentgen (R): A unit for measuring the amount of gamma or x-rays in air. Most of the instruments used to measure radiation exposure read out in “R”.

Rem: The most commonly used unit for measuring radiation dose to people is called the **rem**, which stands for roentgen equivalent man (or mammal), and is a measure of the deposition of energy per unit mass of tissue.

Most of the radiation exposure during an incident will be from gamma or x-rays. Radiation exposure other than gamma and x-ray (such as beta) will be factored in to the final radiation exposure.

As the rem is a relatively large unit, it is more common to use the **mrem**, or one-thousandth of a rem, when measuring doses which might be encountered in a university research setting.

Internationally, the Systeme Internationale unit for radiation dose is called the **sievert (Sv)**, and is equal to 100 rem.

System International (SI) Units for Ionizing Radiation

Quantity	Unit Name (Symbol)	Definition	Former Unit	Conversion Factor
Activity	Becquerel (Bq)	Disintegrations /sec	Curie (Ci)	1 Ci = 3.7×10^{10} Bq
Absorbed Dose	Gray (Gy)	Joule/kilogram	rad	1 Gy = 100 rads
Dose Equivalent	Sievert (Sv)	Joule/kilogram	rem	1 Sv = 100 rems

There are several ways in which measures of radiation are presented. Some of these rely on direct measurements of disintegrations over time, and others are used to determine radiation hazard to living tissue.

Energy emitted during radioactive processes can be measured in joules (J). The absorbed dose of radiation is considered in terms of grays (Gy), where 1 Gy is equivalent to absorption of 1 joule (J) of radiation by 1 kg of material (for example, a human body). (While Gy is the SI unit for absorbed radiation, a commonly used unit is the rad where 1 Gy = 100 rads). However, the situation is complicated for living matter because certain types of radiation energy do more damage to living tissue than others.

The radiation dose equivalent, which takes such differences into account, is the sievert (Sv), also with dimensions of joules per kilogram. For the most penetrating radiation (like X-rays, gamma rays or beta rays) 1 Sv = 1 Gy. For neutrons and alpha particles, however, a multiplication factor is required. For neutrons, 1 Gy is considered equivalent to 10 Sv; for alpha particles, 1 Gy is considered equivalent to 20 Sv.

For a substance with a known activity, the dose is calculated by taking into account the energy released during each decay. For example, consider that a mass M_t of radioactive waste contains some weight percent (w) of a radioisotope, the mass of the radioisotope can be found:

$$M_i = M_t * w/100 \text{ (kg)}$$

The number of moles of the isotope (m_i) can be determined by:

$$m_i = M_i / w_i$$

where w_i is the atomic weight of the radioisotope. The number of atoms of the isotope can be determined by

$$n_i = N * m_i$$

where N is Avagadro's Number, 6.02×10^{23} . Activity (in Becquerels, or disintegrations per second) is measured as

$$A = nc$$

where c is the decay rate. Assuming that all energy emitted is in heat, radioactive heat production, H (in cal/s), can be evaluated using

$$H = A * E * f$$

where E is the energy per disintegration in MeV, and f is a conversion factor:

$$f = 3.83 \times 10^{-14} \text{ cal/MeV}$$

so that by dimensional analysis:

$$H \text{ (cal/s)} = A \text{ (disintegrations/s)} * E \text{ (MeV/disintegration)} * f \text{ (cal/MeV)}$$

Radiation is emitted in all directions from a source. The total radiation emitted from a source at some distance, r , can be modelled for the area of a sphere (S_a) with radius r :

$$S_a = 4 \pi r^2$$

The approximate dose, D (in cal), that would be received by a 100 kg person with an area of 0.5 m^2 standing at distance r from the radioactive source for one minute can be modelled as:

$$D = H / (4 \pi r^2) * 0.5 \text{ m}^2 * 60 \text{ seconds}$$

The absorbed dose in Gy (J/kg) could then be estimated as:

$$[D \text{ (cal)} * 4.18 \text{ J/cal}] / 100 \text{ kg}$$