



**PART IX**

References, annexes  
and index



# References

1. *Safety in health-care laboratories*. Geneva, World Health Organization, 1997, ([http://whqlibdoc.who.int/hq/1997/WHO\\_LAB\\_97.1.pdf](http://whqlibdoc.who.int/hq/1997/WHO_LAB_97.1.pdf)).
2. Garner JS, Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *American Journal of Infection Control*, 1996, 24:24–52, (<http://www.cdc.gov/ncidod/hip/isolat/isolat.htm>).
3. Hunt GJ, Tabachnick WJ. Handling small arbovirus vectors safely during biosafety level 3 containment: *Culicoides variipennis sonorensis* (Diptera: Ceratopogonidae) and exotic blue-tongue viruses. *Journal of Medical Entomology*, 1996, 33:271–277.
4. National Research Council. *Occupational health and safety in the care and use of research animals*. Washington, DC, National Academy Press, 1997.
5. Richmond JY, Quimby F. Considerations for working safely with infectious disease agents in research animals. In: Zak O, Sande MA, eds. *Handbook of animal models of infection*. London, Academic Press, 1999:69–74.
6. *Biosafety in microbiological and biomedical laboratories*, 4th ed. Washington, DC, United States Department of Health and Human Services/Centers for Disease Control and Prevention/National Institutes of Health, 1999.
7. *Class II (laminar flow) biohazard cabinetry*. Ann Arbor, MI, National Sanitation Foundation, 2002 (NSF/ANSI 49–2002).
8. Richmond JY, McKinney RW. *Primary containment for biohazards: selection, installation and use of biological safety cabinets*, 2nd ed. Washington, DC, United States Department of Health and Human Services/Centers for Disease Control and Prevention/National Institutes of Health, 2000.
9. *Microbiological safety cabinets. Recommendations for information to be exchanged between purchaser, vendor and installer and recommendations for installation*. London, British Standards Institution, 1992 (Standard BS 5726–2:1992).
10. *Microbiological safety cabinets. Recommendations for selection, use and maintenance*. London, British Standards Institution, 1992 (Standard BS 5726–4:1992).
11. *Biological containment cabinets (Class I and II): installation and field testing*. Toronto, Canadian Standards Association, 1995 (Standard Z316.3–95 (R2000)).
12. Collins CH, Kennedy DA. *Laboratory acquired infections: history, incidence, causes and prevention*, 4th ed. Oxford, Butterworth-Heinemann, 1999.
13. Health Canada. *Laboratory biosafety manual*, 2nd ed. Ottawa, Minister of Supply and Services Canada, 1996.
14. *Biological safety cabinets – biological safety cabinets (Class I) for personnel and environment protection*. Sydney, Standards Australia International, 1994 (Standard AS 2252.1–1994).
15. *Biological safety cabinets – laminar flow biological safety cabinets (Class II) for personnel, environment and product protection*. Sydney, Standards Australia International, 1994 (Standard AS 2252.2–1994).

16. Standards Australia/Standards New Zealand. *Biological safety cabinets – installation and use*. Sydney, Standards Australia International, 2000 (Standard AS/NZS 2647:2000).
17. Advisory Committee on Dangerous Pathogens. *Guidance on the use, testing and maintenance of laboratory and animal flexible film isolators*. London, Health and Safety Executive, 1990.
18. Standards Australia/Standards New Zealand. *Safety in laboratories – microbiological aspects and containment facilities*. Sydney, Standards Australia International, 2002 (Standard AS/NZS 2243.3:2002).
19. Centers for Disease Control and Prevention. Recommendations for prevention of HIV transmission in health-care settings. *Morbidity and Mortality Weekly Report*, 1987, 36 (Suppl. 2):1S–18S.
20. Bosque PJ et al. Prions in skeletal muscle. *Proceedings of the National Academy of Sciences of the United States of America*, 2002, 99:3812–3817.
21. Bartz JC, Kincaid AE, Bessen RA. Rapid prion neuroinvasion following tongue infection. *Journal of Virology*, 2003, 77:583–591.
22. Thomzig A et al. Widespread PrP<sup>Sc</sup> accumulation in muscles of hamsters orally infected with scrapie. *EMBO Reports*, 2003, 4:530–533.
23. Glatzel M et al. Extraneural pathologic prion protein in sporadic Creutzfeld-Jakob disease. *New England Journal of Medicine*, 2003, 349:1812–1820.
24. Brown P, Wolff A, Gajdusek DC. A simple and effective method for inactivating virus infectivity in formalin-fixed tissue samples from patients with Creutzfeld-Jakob disease. *Neurology*, 1990, 40:887–890.
25. Taylor DM et al. The effect of formic acid on BSE and scrapie infectivity in fixed and unfixed brain-tissue. *Veterinary Microbiology*, 1997, 58:167–174.
26. Safar J et al. Prions. In: Richmond JY, McKinney RW, eds. *Biosafety in microbiological and biomedical laboratories*, 4th ed. Washington, DC, United States Department of Health and Human Services, 1999:134–143.
27. Bellinger-Kawahara C et al. Purified scrapie prions resist inactivation by UV irradiation. *Journal of Virology*, 1987, 61:159–166.
28. Health Services Advisory Committee. *Safe working and the prevention of infection in clinical laboratories*. London, HSE Books, 1991.
29. Russell AD, Hugo WB, Ayliffe GAJ. *Disinfection, preservation and sterilization*, 3rd ed. Oxford, Blackwell Scientific, 1999.
30. Ascenzi JM. *Handbook of disinfectants and antiseptics*. New York, NY, Marcel Dekker, 1996.
31. Block SS. *Disinfection, sterilization & preservation*, 5th ed. Philadelphia, PA, Lippincott Williams & Wilkins, 2001.
32. Rutala WA. APIC guideline for selection and use of disinfectants. 1994, 1995, and 1996 APIC Guidelines Committee. Association for Professionals in Infection Control and Epidemiology, INC. *American Journal of Infection Control*, 1996, 24:313–342.
33. Sattar SA, Springthorpe VS, Rochon M. A product based on accelerated and stabilized hydrogen peroxide: evidence for broad-spectrum germicidal activity. *Canadian Journal of Infection Control*, 1998, 13:123–130.
34. Schneider PM. Emerging low temperature sterilization technologies. In: Rutala WA, eds. *Disinfection & sterilization in health care*. Champlain, NY, Polyscience, 1997:79–92.
35. Springthorpe VS. New chemical germicides. In: Rutala WA, eds. *Disinfection & sterilization in health care*. Champlain, NY, Polyscience, 1997:273–280.

## REFERENCES

36. Steelman VM. Activity of sterilization processes and disinfectants against prions. In: Rutala WA, eds. *Disinfection & sterilization in health care*. Champlain, NY, Polyscience, 1997:255–271.
37. Taylor DM. Transmissible degenerative encephalopathies: inactivation of the unconventional causal agents. In: Russell AD, Hugo WB, Ayliffe GAJ, eds. *Disinfection, preservation and sterilization*, 3rd ed. Oxford, Blackwell Scientific, 1999:222–236.
38. *Infection control guidelines for hand washing, cleaning, disinfection and sterilization in health care*, 2nd ed. Ottawa, Laboratory Centre for Disease Control, Health Canada, 1998.
39. Springthorpe VS, Sattar SA. Chemical disinfection of virus-contaminated surfaces. *CRC Critical Reviews in Environmental Control*, 1990, 20:169–229.
40. *Recommendations on the transport of dangerous goods*, 13th revised edition, New York and Geneva, United Nations, 2003, ([http://www.unece.org/trans/danger/publi/unrec/rev13/13files\\_e.html](http://www.unece.org/trans/danger/publi/unrec/rev13/13files_e.html)).
41. *Technical instructions for the safe transport of dangerous goods by air*, 2003–2004 Edition. Montreal, International Civil Aviation Organization, 2002.
42. Economic Commission for Europe Inland Transport Committee. *Restructured ADR applicable as from 1 January 2003*. New York and Geneva, United Nations, 2002, (<http://www.unece.org/trans/danger/publi/adr/adr2003/ContentsE.html>).
43. *Infectious substances shipping guidelines*. Montreal, International Air Transport Association, 2003, (<http://www.iata.org/ads/issg.htm>).
44. *Transport of Infectious Substances*. Geneva, World Health Organization, 2004, ([http://www.who.int/csr/resources/publications/WHO\\_CDS\\_CSR\\_LYO\\_2004\\_9/en/](http://www.who.int/csr/resources/publications/WHO_CDS_CSR_LYO_2004_9/en/)).
45. Berg P et al. Asilomar conference on recombinant DNA molecules. *Science*, 1975, 188:991–994.
46. European Council. Council Directive 98/81/EC of 26 October 1998 amending Directive 90/219/EEC on the contained use of genetically modified microorganisms. *Official Journal*, 1998, L330:13–31.
47. O'Malley BW Jr et al. Limitations of adenovirus-mediated interleukin-2 gene therapy for oral cancer. *Laryngoscope*, 1999, 109:389–395.
48. World Health Organization. Maintenance and distribution of transgenic mice susceptible to human viruses: memorandum from a WHO meeting. *Bulletin of the World Health Organization*, 1993, 71:497–502.
49. Furr AK. *CRC handbook of laboratory safety*, 5th ed. Boca Raton, FL, CRC Press, 2000.
50. Lenga RE. *The Sigma-Aldrich Library of Chemical Safety Data*, 2nd ed. Milwaukee, WI, Aldrich Chemical Company, 1988.
51. Lewis RJ. *Sax's dangerous properties of industrial materials*, 10th ed. Toronto, John Wiley and Sons, 1999.

## ANNEX 1

# First aid

First aid is the skilled application of accepted principles of medical treatment at the time and place of an accident. It is the approved method of treating a casualty until he or she is placed in the care of a doctor for definitive treatment of the injury.

The minimum first-aid equipment consists of a first-aid box, protective clothing and safety equipment for the person rendering the first aid, and eye irrigation equipment.

### ***The first-aid box***

The first-aid box should be constructed from materials that will keep the contents dust- and damp-free. It should be kept in a prominent position and be easily recognized. By international convention, the first-aid box is identified by a white cross on a green background.

The first-aid box should contain:

1. Instruction sheet giving general guidance
2. Individually-wrapped sterile adhesive dressings in a variety of sizes
3. Sterile eye-pads with attachment bandages
4. Triangular bandages
5. Sterile wound coverings
6. Safety pins
7. A selection of sterile but unmedicated wound dressings
8. An authoritative first-aid manual, e.g. one issued by the International Red Cross.

Protective equipment for the person rendering first aid includes:

1. Mouthpiece for mouth-to-mouth resuscitation
2. Gloves and other barrier protections against blood exposures,<sup>1</sup> and
3. Clean-up kit for blood spills (see Chapter 14 of the manual).

Eye irrigation equipment should also be readily available and staff trained in its correct use.

---

<sup>1</sup> Garner JS, Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *American Journal of Infection Control*, 1996, 24:24–52, (<http://www.cdc.gov/ncidod/hip/isolat/isolat.htm>).

## Immunization of staff

The risks of working with particular agents should be fully discussed with individual researchers. The local availability, licensing state and utility of possible vaccines and/or therapeutic drugs (e.g. antibiotic treatments) in case of exposure should be evaluated before work with such agents is started. Some workers may have acquired immunity from prior vaccination or infection.

If a particular vaccine or toxoid is locally licensed and available, it should be offered after a risk assessment of possible exposure and a clinical health assessment of the individual have been carried out.

Facilities for specific clinical case management following accidental infections should also be available.

## ANNEX 3

# WHO Biosafety Collaborating Centres

Information on the availability of training courses, aids and materials may be obtained by writing to any of the following:

- Biosafety programme, Department of Communicable Disease Surveillance and Response, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (<http://www.who.int/csr/>).
- WHO Collaborating Centre for Biological Safety, Swedish Institute for Infectious Disease Control, Nobels Väg 18, S-171 82 Solna, Sweden (<http://www.smittskyddsinstitutet.se/English/english.htm>).
- WHO Collaborating Centre on Biosafety Technology and Consultative Services, Office of Laboratory Security, Health Canada, 100 Colonnade Road, Loc.: 6201A, Ottawa, Ontario, Canada K1A 0K9 (<http://www.hc-sc.gc.ca/pphb-dgsp/ols-bsl>).
- WHO Collaborating Centre for Applied Biosafety Programmes and Training, Office of Health and Safety, Centers for Disease Control and Prevention, 1600 Clifton Road, Mailstop F05, Atlanta, GA 30333, USA (<http://www.cdc.gov/>).
- WHO Collaborating Centre for Applied Biosafety Programmes and Research, Division of Occupational Health and Safety, Office of Research Services, National Institutes of Health, Department of Health and Human Services, 13/3K04 13 South Drive MSC 5760, Bethesda, MD 20892-5760, USA (<http://www.nih.gov/>).
- WHO Collaborating Centre for Biosafety, Victorian Infectious Diseases Reference Laboratory, 10 Wreckyn St, Nth Melbourne, Victoria 3051, Australia. Postal address: Locked Bag 815, PO Carlton Sth, Victoria 3053, Australia (<http://www.vidrl.org.au/>).

## ANNEX 4

# Equipment safety

Certain items of equipment may create microbiological hazards when they are used. Other items are specifically designed to prevent or reduce biological hazards (see Chapter 11 of the manual).

### Equipment that may create a hazard

Table A4-1 lists equipment and operations that may create hazards and suggests how such hazards may be eliminated or reduced.

*Table A4-1. Equipment and operations that may create hazards*

EQUIPMENT	HAZARD	HOW TO ELIMINATE OR REDUCE THE HAZARD
Hypodermic needles	Accidental inoculation, aerosol or spillage	<ul style="list-style-type: none"><li>• Do not recap or clip needles.</li><li>• Use a needle-locking type of syringe to prevent separation of needle and syringe, or use a disposable type where the needle is an integral part of the syringe unit.</li><li>• Use good laboratory techniques, e.g.:<ul style="list-style-type: none"><li>— fill the syringe carefully to minimize air bubbles and frothing of inoculum</li><li>— avoid using syringes to mix infectious liquids; if used, ensure that the tip of the needle is held under the surface of the fluid in the vessel and avoid excessive force</li><li>— wrap the needle and stopper in a cotton pledget moistened with an appropriate disinfectant before withdrawing the needle from a rubber-stoppered bottle</li><li>— expel excess liquid and air bubbles from the syringe vertically into a cotton pledget moistened with an appropriate disinfectant or into a small bottle containing cotton.</li></ul></li><li>• Use a biological safety cabinet for all operations with infectious material.</li></ul>

EQUIPMENT	HAZARD	HOW TO ELIMINATE OR REDUCE THE HAZARD
		<ul style="list-style-type: none"> <li>• Restrain animals while they are being inoculated. Use blunt needles or cannulas for intranasal or oral inoculation. Use a biological safety cabinet.</li> <li>• Autoclave after use and ensure proper disposal. If a disposable needle and syringe unit is used, do not disassemble prior to autoclaving.</li> </ul>
Centrifuges	Aerosols, splashing and tube breakage	<ul style="list-style-type: none"> <li>• Use sealable buckets (safety cups) or sealed rotors. Open buckets or rotors after aerosols have settled (30 min) or in a biological safety cabinet.</li> </ul>
Ultra-centrifuges	Aerosols, splashing and tube breakage	<ul style="list-style-type: none"> <li>• Install a HEPA filter between centrifuge and vacuum pump.</li> <li>• Maintain a logbook of operating hours for each rotor and a preventive maintenance programme to reduce risk of mechanical failure.</li> <li>• Load and unload buckets or rotors in a biological safety cabinet.</li> </ul>
Anaerobic jars	Explosion, dispersing infectious materials	<ul style="list-style-type: none"> <li>• Ensure integrity of wire capsule around catalyst.</li> </ul>
Desiccators	Implosion, dispersing glass fragments and infectious materials	<ul style="list-style-type: none"> <li>• Place in a stout wire cage.</li> </ul>
Homogenizer, tissue grinders	Aerosols, leakage and container breakage	<ul style="list-style-type: none"> <li>• Operate and open equipment in a biological safety cabinet.</li> <li>• Use specially designed models that prevent leakage from rotor bearings and O-ring gaskets, or use a stomacher.</li> <li>• Before opening the blender bowl, wait 30 min to allow the aerosol cloud to settle. Refrigerate to condense aerosols.</li> <li>• If manual tissue grinders are used, hold tube in a wad of absorbent material.</li> </ul>
Sonicators, ultrasonic cleaners	Aerosols, impaired hearing, dermatitis	<ul style="list-style-type: none"> <li>• Operate and open equipment in a biological safety cabinet or sealed unit.</li> <li>• Ensure insulation to protect against subharmonics.</li> <li>• Wear gloves to protect skin against chemical effects of detergents.</li> </ul>

#### ANNEX 4. EQUIPMENT SAFETY

EQUIPMENT	HAZARD	HOW TO ELIMINATE OR REDUCE THE HAZARD
Culture stirrers, shakers, agitators	Aerosols, splashing and spillage	<ul style="list-style-type: none"> <li>• Operate in a biological safety cabinet or specially designed primary containment.</li> <li>• Use heavy-duty screw-capped culture flasks, fitted with filter-protected outlets, if necessary, and well secured.</li> </ul>
Freeze-dryers (lyophilizers)	Aerosols and direct contact contamination	<ul style="list-style-type: none"> <li>• Use O-ring connectors to seal the unit throughout.</li> <li>• Use air filters to protect vacuum lines.</li> <li>• Use a satisfactory method of decontamination, e.g. chemical.</li> <li>• Provide an all-metal moisture trap and a vapour condenser.</li> <li>• Carefully inspect all glass vacuum vessels for surface scratches. Use only glassware designed for vacuum work.</li> </ul>
Water baths	Growth of micro-organisms. Sodium azide forms explosive compounds with some metals.	<ul style="list-style-type: none"> <li>• Ensure regular cleaning and disinfection.</li> <li>• Do not use sodium azide for preventing growth of organisms.</li> </ul>

In addition to microbiological hazards, safety hazards associated with equipment should also be anticipated and prevented. Table A4-2 lists examples of some of the causes of accidents.

**Table A4-2. Common causes of equipment-related accidents**

ACCIDENT	ACCIDENT CAUSE	REDUCING OR ELIMINATING THE HAZARD
<b><i>Faulty design or construction</i></b>		
Electrical fires in incubators	No over-temperature cut-out	• Compliance with national standards.
Electrical shock	Failure to provide reliable earthing/grounding	
<b><i>Improper use</i></b>		
Centrifuge accident	Failure to balance buckets on swing-out rotors	• Train and supervise staff.
Anaerobic incubator explosion	Use of incorrect gas	• Train and supervise staff.
<b><i>Improper adaptation</i></b>		
Explosion in domestic vacuum flask	Improper transport of liquid nitrogen	• Use of specially designed equipment.
Explosion in domestic-type refrigerator	Dangerous chemical not stored in spark-/explosion-proof container, e.g. diethyl ether with leaking screw cap	• Store low-flashpoint solvents and extracts only in spark-/explosion-proof refrigerators or cabinets.
<b><i>Lack of proper maintenance</i></b>		
Fire in flame photometer	Incorrect reassembly of components during maintenance	• Train and supervise staff.

## ANNEX 5

# Chemicals: hazards and precautions

This annex lists the basic health and safety information, data and appropriate safety precautions for a selected number of chemicals found commonly in health-care and research laboratories. The list is not exhaustive and the absence of any particular chemical does not imply that it is non-hazardous. All laboratory chemicals should be treated with caution and in ways that will minimize exposure.

**Table A5-1. Chemicals: hazards and precautions**

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Acetaldehyde CH <sub>3</sub> CHO	Colourless liquid or gas with a pungent, fruity odour; m.p. -121 °C b.p. 21 °C.	Mild eye and respiratory tract irritation. Effects on the central nervous system, respiratory tract and kidneys. Possible carcinogen.	Extremely flammable; vapour/air mixtures are explosive; flash point -39 °C flammable range 4-57%.	No open flames, no sparks, no smoking, no contact with hot surfaces. Store in tightly sealed containers in areas separate from oxidizers; store only if stabilized. Use in exhaust cupboard or with good ventilation. Wear rubber gloves, safety goggles, and respiratory protection.	Can form explosive peroxides in contact with air. May polymerize under influence of acids, alkaline materials, in the presence of trace metals. A strong reducing agent, reacts violently with oxidants, with various organic substances, halogens, sulfuric acid and amines.	
Acetic acid CH <sub>3</sub> CO <sub>2</sub> H	Colourless liquid with pungent odour; m.p. 17 °C b.p. 118 °C; miscible with water.	Corrosive; causes severe burns; irritating vapour. Effects may be delayed.	Flammable; flashpoint 40 °C flammable range 5.4-16%.	Do not breathe fumes. In case of contact with eyes rinse immediately with water and seek medical advice. Wear nitrile gloves and eye protection.	Violent or explosive reaction with oxidizers.	
Acetic anhydride (CH <sub>3</sub> CO) <sub>2</sub> O	Colourless liquid with a strong pungent, vinegar-like odour; m.p. -73 °C b.p. 139 °C.	Severe irritation of eyes and upper respiratory tract irritation; corrosive action. Effects may be delayed.	Flammable; evolves irritation or toxic fumes or gases in a fire; flashpoint 49 °C explosive limits 2.7-10.3%.	No open flames, no sparks, no smoking. Prevent skin and eye contact.	Reacts violently with boiling water, steam, strong oxidants, alcohols, amines, strong bases and many other compounds. Attacks many metals in presence of water.	

## ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

Acetone $\text{CH}_3\text{COCH}_3$	Colourless volatile liquid with sweetish odour; m.p. $-95\text{ }^\circ\text{C}$ ; b.p. $56\text{ }^\circ\text{C}$ .; miscible with water.	Slight eye, nose and throat irritation. Inhalation may cause dizziness, narcosis and coma.	Highly flammable; flashpoint $-18\text{ }^\circ\text{C}$ explosive limits 2.2–12.8%.	Keep container in well-ventilated area; keep away from sources of ignition. Do not breathe vapour. Use respiratory protection; wear eye protection.	Reacts violently with oxidizers (e.g. chromic and nitric acids) and chloroform in the presence of base. Incompatible with concentrated sulfuric and nitric acid mixtures.	Earth/ground large containers and vessels to prevent static electricity.
Acetonitrile $\text{CH}_3\text{CN}$	Colourless liquid with an aromatic odour; m.p. $-46\text{ }^\circ\text{C}$ b.p. $82\text{ }^\circ\text{C}$ .	Respiratory, eye and skin irritation. Exposure may result in convulsions, unconsciousness, cyanide poisoning.	Highly flammable; flashpoint $12.8\text{ }^\circ\text{C}$ explosive limits 3.0–16%.	No open flames, no sparks, no smoking, no contact with oxidants. Use only in areas free of ignition sources. Store in tightly sealed containers in areas separate from oxidizers. Work with exhaust ventilation. Avoid skin, eye and mucous membrane contact. Use respiratory protection and rubber gloves.	Reacts with aqueous acids and bases, producing toxic fumes. Reacts with strong oxidants. Attacks some forms of plastic, rubber and coatings. Decomposes on burning producing hydrogen cyanide and nitrogen oxides.	
Acetylene $\text{HC}\equiv\text{CH}$	Colourless gas with a faint, ethereal or garlic-like odour; shipped under pressure, dissolved in acetone; m.p. $-81\text{ }^\circ\text{C}$ sublimes at $-84\text{ }^\circ\text{C}$ .	Simple asphyxiant; frostbite on skin contact.	Extremely flammable; flammable range 2.5–100%.	For skin protection use cold-insulating gloves and safety goggles or face shield. No open flames, no sparks, no smoking. Work with local exhaust ventilation, explosion-proof electrical equipment and lighting.	Strong reducing agent; reacts violently with oxidants and with fluorine or chlorine under influence of light. Reacts with copper, silver and mercury or their salts, forming shock-sensitive compounds.	

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Acrolein $\text{CH}_2=\text{CHCHO}$	Colourless or yellow liquid with a piercing, disagreeable odour; m.p. $-87^\circ\text{C}$ b.p. $53^\circ\text{C}$ .	Lacrimation. Severe respiratory irritation; lung oedema at high exposure levels. Effects may be delayed.	Highly flammable; flashpoint $-26^\circ\text{C}$ explosive limits 2.8–31%.	Prevent skin and eye contact. Work in fume cupboard or with good ventilation.	Oxidizers, acids, alkalis, ammonia, amines. Polymerizes readily unless inhibited, usually with hydroquinone. May form shock-sensitive peroxides over time.	
Ammonia solutions	Colourless liquid with pungent odour; for gas: m.p. $-78^\circ\text{C}$ b.p. $-33^\circ\text{C}$ ; for 25% solution: m.p. $-58^\circ\text{C}$ b.p. $38^\circ\text{C}$ ; miscible with water.	Corrosive to eyes, respiratory system and skin on ingestion; lung oedema at high levels of exposure to gas or vapour.	As ammonia gas; flammable range 15–28%.	Keep container tightly closed. In case of contact with eyes, rinse immediately and seek medical advice. Work in fume cupboard. Wear rubber or plastic gloves and chemical-grade goggles.	Reacts violently with heavy metals such as mercury and their salts to form explosive products.	
Aniline $\text{C}_6\text{H}_5\text{NH}_2$	Colourless to brown, oily liquid with an aromatic amine-like odour; m.p. $-6^\circ\text{C}$ b.p. $185^\circ\text{C}$ .	Cyanosis due to methaemoglobinemia. Eye and skin irritation. May be absorbed through the skin; repeated or prolonged exposure may cause sensitization.	Combustible; flashpoint $70^\circ\text{C}$ explosive range 1.2–11%.	Store in tightly sealed containers in areas separate from oxidizers. Prevent skin and eye contact. Work with local exhaust ventilation or respiratory protection, protective gloves, protective clothing, face shield.	Strong oxidizers, strong acids.	
Auramine 4,4'-Carbonyl- imidoyl-bis (N,N-dimethyl- benzenamine)	Yellow flakes or powder; m.p. $136^\circ\text{C}$ ; insoluble in water.	Harmful by ingestion, inhalation and skin contact. May cause eye or skin irritation. Possible carcinogen.		Avoid skin contact and inhalation of dust. Wear rubber or plastic gloves and chemical-grade goggles. Work in fume cupboard or wear dust respirator.	Strong oxidizing agents.	

Benzene C <sub>6</sub> H <sub>6</sub>	Colourless volatile liquid with characteristic aromatic odour; m.p. 6 °C; b.p. 80 °C.	Inhalation of vapour causes effects on central nervous system resulting in vertigo and headache; at high concentrations, unconsciousness and death. Risk of aplastic anaemia, leukaemia, liver damage on prolonged or chronic exposure. May be absorbed through skin.	Highly flammable; flashpoint -11 °C flammable range 1.3-8%.	Keep container in well-ventilated area and away from sources of ignition. Work in fume cupboard or hood with adequate ventilation. Wear eye protection and nitrile or PVC gloves. Prevent formation of electrical charges by earthing/grounding.	Can react violently with oxidizers including chromic acid, potassium permanganate and liquid oxygen.
Benzidine 1,1'-Biphenyl-4,4'-diamine	Light yellow powder; m.p. 128 °C; b.p. 400 °C; slightly soluble in water but very soluble in acids and organic solvents.	May be absorbed through skin. May cause bladder cancer. Avoid all exposure.	Combustible, gives off toxic fumes (gases) in a fire.	Avoid all exposure. Wear eye and skin protection. Work in fume cupboard with exhaust ventilation.	Use is prohibited or legally controlled in many countries.
Bromine Br <sub>2</sub>	Dark reddish-brown fuming liquid with pungent odour; m.p. -7.2 °C; b.p. 58.8 °C.	Corrosive. Vapour is corrosive to eyes and respiratory tract; inhalation may cause lung oedema and effects on central nervous system. Eye contact can cause blurred vision, redness, pain, severe tissue burns.	Not combustible but enhances combustion of other substances. Many reactions may cause fire or explosion. Heating will cause rise in pressure with risk of burning.	Use in closed system and with ventilation. Wear protective gloves and clothing, safety goggles, face shield or eye protection in combination with respiratory protection.	Strong oxidant, reacts violently with combustible and reducing materials. Reacts violently with aqueous ammonia, oxidants, metals, organic compounds and phosphorus. Attacks some forms of plastic, rubber and coatings.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Carbon dioxide (solid; "dry ice") CO <sub>2</sub>	Translucent white solid at -79 °C; sublimates to gas at ambient temperature.	Risk of asphyxiation in confined or poorly ventilated areas; contact with solid "dry ice" causes frostbite.		Wear protective insulated gloves. Store only in ventilated room or area in open container.	Alkali metals, strong bases.	
Carbon tetrachloride CCl <sub>4</sub>	Colourless liquid with characteristic ether-like odour; m.p. -23 °C b.p. 76.5 °C.	May be absorbed through skin; may cause dermatitis on prolonged exposure. Eye irritation. May cause liver and kidney damage and central nervous system disturbances resulting in headache, nausea, slight jaundice, loss of appetite and narcosis. An animal carcinogen.	Not combustible. Gives off irritating or toxic fumes or gases in a fire.	Avoid all contact. Work with ventilation, local exhaust or respiratory protection; use nitrile gloves and protective clothing, face shield or eye protection in combination with respiratory protection.	On contact with hot surfaces or flames, decomposes forming toxic and corrosive fumes and gases (hydrogen chloride, chlorine, phosgene). Reacts with some metals such as aluminium, magnesium, zinc.	
Chlorine Cl <sub>2</sub>	Greenish-yellow gas with pungent odour; m.p. -101 °C b.p. -34 °C.	Corrosive to eyes, skin and respiratory tract. Inhalation of gas may cause pneumonitis and lung oedema, resulting in reactive airways dysfunction syndrome (RAADS). Rapid evaporation of the liquid may cause frostbite. High exposures may result in death. Effects may be delayed; medical observation indicated.	Not combustible but enhances combustion of other substances.	Work with closed system and ventilation. Wear cold-insulating gloves, protective clothing, eye safety goggles or eye protection in combination with respiratory protection.	Solution in water is a strong acid, reacts violently with bases and many organic compounds, acetylene, butadiene, benzene and other petroleum fractions, ammonia, hydrogen, sodium carbide, turpentine and finely divided metals causing fire and explosion hazard.	Attacks many metals in presence of water. Attacks plastics, rubber and coatings.

ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

Chlorine dioxide ClO <sub>2</sub>	Yellow to red gas or a red-brown liquid; m.p. -59 °C b.p. 10 °C.	Severe irritation of eyes, skin and respiratory tract; inhalation of gas may cause lung oedema. Effects may be delayed; medical observation indicated.	Not combustible but enhances combustion of other substances; may explode on heating, on exposure to sunlight or if subjected to shock and sparks.	Work in closed system with ventilation. Wear protective gloves and clothing, safety goggles or eye protection in combination with respiratory protection.	A strong oxidant; reacts violently with combustible and reducing materials. Reacts violently with phosphorus, potassium hydroxide, sulfur, ammonia, methane, phosphine and hydrogen sulfide.
Chloroform CHCl <sub>3</sub>	Colourless volatile liquid with characteristic odour; m.p. -63 °C; b.p. 61 °C; slightly soluble in water.	Harmful by inhalation, ingestion and skin contact; skin irritation. May cause effects on liver, kidneys and central nervous system resulting in headache, nausea, slight jaundice, loss of appetite, narcosis. Prolonged or chronic exposure causes cancer in animals; suspected human carcinogen.		Wear protective clothing, nitrile gloves and eye protection. Work in a fume cupboard.	Strong bases; some metals such as aluminium or magnesium, zinc powder; strong oxidizers. When heated to decomposition, forms phosgene gas. Attacks plastics, rubber.
Chromic acid CrO <sub>3</sub> Chromium VI oxide	Dark red odourless flakes or powder often used in aqueous solutions; m.p. 197 °C.	Irritation of eyes, skin and respiratory system. Repeated or prolonged contact with skin may cause dermatitis, chrome ulcers and skin sensitization. Inhalation may cause asthma-like reactions. May cause perforation of nasal septum. Human carcinogen.	Decomposes above 250 °C to chromic oxide and oxygen with increased fire hazard. Many reactions may cause hazards.	Prevent skin and eye contact; avoid inhalation of fine dust and mist. Work with ventilation, local exhaust or respiratory protection.	In aqueous solution is a strong acid which reacts with bases and is corrosive. Strong oxidant, reacts with combustible, organic or other readily oxidizable materials (paper, wood, sulfur, aluminium, plastics etc.). Corrosive to metals.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Copper Cu	Reddish, lustrous, malleable, odourless solid; red powder, turns green on exposure to moist air; m.p. 1083 °C b.p. 2567 °C.	Inhalation of copper fume may cause metal fume fever.	Combustible.	Work with local exhaust or respiratory protection, protective gloves and goggles.	Shock-sensitive compounds are formed with acetylenic compounds, ethylene oxides azides and hydrogen peroxide. Reacts with strong oxidants like chlorates, bromates and iodates, causing explosion hazard.	
Cyanogen bromide BrCN	Colourless or white crystals, with pungent odour; m.p. 52 °C b.p. 61 °C.	Severe eye, skin and respiratory tract effects; inhalation of vapour may cause lung oedema which may result in convulsions, unconsciousness, respiratory failure and death.	Not combustible but forms flammable gas on heating. Gives off irritating or toxic fumes or gases in a fire.	Work in closed system with ventilation. Wear protective gloves and protective clothing, safety goggles face shield or eye protection in combination with respiratory protection.	Decomposes on heating and on contact with acids producing highly toxic and flammable hydrogen cyanide and corrosive hydrogen bromide. Reacts with strong oxidants. Reacts slowly with water and moisture to produce hydrogen bromide and hydrogen cyanide. Attacks many metals in the presence of water.	
Cytochalasin (A–J)	White powder; m.p. varies.	Toxic by ingestion, inhalation or absorption through skin. May cause congenital fetal malformation.		Avoid contact with eyes, skin, clothing; wear chemical-grade goggles and rubber or plastic gloves.	Strong oxidizing agents.	

Diethyl ether $C_2H_5OC_2H_5$	Colourless highly volatile liquid with sweet characteristic odour; m.p. $-116\text{ }^\circ\text{C}$ b.p. $34\text{ }^\circ\text{C}$ ; slightly soluble in water.	Irritation of eyes and respiratory tract. May affect central nervous system causing drowsiness and unconsciousness. Repeated inhalation may cause addiction.	Extremely flammable; flashpoint $-45\text{ }^\circ\text{C}$ flammable range 1.7–48%.	Keep container in well-ventilated area; keep away from sources of ignition; earth/ground containers to prevent static electrical discharges. Work in fume cupboard. Wear nitrile gloves to prevent defatting of skin.	Exposure to air and light may result in formation of explosive peroxides. Can react violently with oxidizers and halogens.
Dimethylamine $(CH_3)_2NH$	Colourless volatile liquefied gas with pungent odour; m.p. $-93\text{ }^\circ\text{C}$ b.p. $7\text{ }^\circ\text{C}$ ; miscible with water.	Severe irritation of eyes and respiratory system; inhalation may cause lung oedema. Rapid evaporation may cause frostbite. Solution is corrosive to eyes and skin.	Extremely flammable; flashpoint $-26\text{ }^\circ\text{C}$ flammable limits 2.8–14%. Solution highly flammable; flashpoint $-18\text{ }^\circ\text{C}$ .	Keep away from sources of ignition; in case of contact with eyes rinse immediately and seek medical advice. Work in fume cupboard. Wear nitrile gloves and chemical-grade goggles.	Can react with oxidizers, mercury.
2,4-Dinitro-phenyl-hydrazine $C_6H_3(NO_2)_2NHNH_2$ 1-Hydrazino-2,4-dinitrobenzene	Orange-red crystalline powder; m.p. $200\text{ }^\circ\text{C}$ ; slightly soluble in water.	Irritation of skin and eyes. Harmful by ingestion, inhalation and skin contact.		Keep moist to reduce explosion risk. Wear dust respirator, rubber or plastic gloves and chemical-grade goggles.	Can react vigorously with oxidizers and reducers.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Dioxane $C_4H_8O_2$ Diethylene dioxide	Colourless liquid, with characteristic odour, m.p. 12 °C b.p. 101 °C.	Irritation of eyes and respiratory tract. May affect central nervous system resulting in headache, nausea, cough, sore throat, abdominal pain, dizziness, drowsiness, vomiting, unconscious- ness. May be absorbed through skin. Kidney and liver damage. Probably a human carcinogen.	Highly flammable; distant ignition possible; as a result of flow, agitation, etc., electrostatic charges can be generated.	Work with ventilation, local exhaust. No open flames, no sparks, no smoking, no contact with strong oxidants or hot surfaces. Do not use compressed air for filling, discharging or handling. Use non-sparking tools. Wear protective gloves, clothing, face shield or eye protection, in combination with respiratory protection.	Can form explosive peroxides. Reacts vigorously with strong oxidants and concentrated strong acids. Reacts explosively with some catalysts. Attacks many plastics.	
Ethanol $CH_3CH_2OH$	Colourless volatile liquid with slight, characteristic odour; m.p. -117 °C b.p. 79 °C; miscible with water.	Harmful if ingested. Irritation of eyes. May affect central nervous system.	Highly flammable; flashpoint 12 °C flammable limits 3–19%.	Keep container tightly closed; keep away from ignition sources.	Reacts violently with strong oxidizers.	
Ethanolamine $H_2NCH_2CH_2OH$ 2-Amino- ethanol	Colourless non-volatile viscous liquid with ammoniacal odour; m.p. 10 °C b.p. 171 °C; miscible with water.	Corrosive to eyes, respiratory system and skin. May cause skin sensitization.	Flashpoint 85 °C.	Wear rubber or plastic gloves and eye protection.	Reacts with strong oxidizers.	

## ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

<p>Formaldehyde solution (37–41% formaldehyde with 11–14% methanol) HCHO</p>	<p>Colourless liquid with a pungent odour; b.p. 96 °C; miscible with water.</p>	<p>Severely irritation of eyes and skin, irritation of respiratory tract; prolonged exposure to the vapour may cause asthma-like symptoms, conjunctivitis, laryngitis, bronchitis or bronchopneumonia. May cause sensitization by skin contact. Possible risk of irreversible health effects. Possible carcinogen.</p>	<p>Flashpoint 50 °C.</p>	<p>Wear protective clothing such as plastic apron, rubber or plastic gloves and chemical-grade goggles. Work in fume cupboard or well-ventilated area.</p>	<p>Can react vigorously with oxidizers, with nitromethane to produce explosive products, with hydrochloric acid to produce the potent carcinogen <i>bis</i> (chloromethyl) ether.</p>	<p>Concentrated formaldehyde solutions become cloudy if stored below 21 °C and should be kept at 21–25 °C. Dilute solutions (1–5%) and medium-strength solutions (5–25%) retain many of the hazards of the concentrated form.</p>
<p>Glutaraldehyde <math>\text{OHC}(\text{CH}_2)_3\text{CHO}</math></p>	<p>Colourless or pale yellow solution with pungent odour; m.p. –14 °C; b.p. 189 °C; miscible with water.</p>	<p>Severe irritation of eyes and upper respiratory tract; prolonged inhalation exposure or skin contact may cause sensitization.</p>		<p>Work in fume cupboard or well-ventilated area. Wear rubber or plastic gloves and eye protection.</p>	<p>Can react vigorously with oxidizers.</p>	<p>Often supplied in aqueous solution at various concentrations with added stabilizer to enhance stability.</p>
<p>Hydrochloric acid (10–37%) HCl Hydrogen chloride</p>	<p>Colourless fuming liquid with a pungent odour; b.p. –121 °C; miscible with water.</p>	<p>Corrosive to eyes, respiratory system and skin; repeated inhalation of vapour can cause chronic bronchitis.</p>		<p>Do not breathe fumes; use respiratory protection. In case of contact with eyes, rinse immediately with water and seek medical advice; in case of contact with skin, wash immediately with plenty of water. Work in fume cupboard. Wear rubber or plastic gloves and eye protection (spectacles or goggles).</p>	<p>Reacts violently with bases (solids and concentrated solutions), explosively with solid potassium permanganate. Gives off toxic or explosive gases on contact with many metals.</p>	<p>Releases highly toxic fumes in fires.</p>

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Hydrogen peroxide $H_2O_2$	Colourless liquid; m.p. $-39\text{ }^\circ\text{C}$ ( $70\%$ ) b.p. $125\text{ }^\circ\text{C}$ ( $70\%$ ); miscible with water; supplied in aqueous solution at various concentrations.	Corrosive at high concentration ( $60\%$ ), and at low concentration ( $6\%$ ) if contact with skin is prolonged. Dilute solutions are irritating to eyes, respiratory system and skin.	Oxidizing agent; contact with combustible material can cause fire.	In case of contact with skin, wash immediately with plenty of water. Wear nitrile gloves and eye protection if concentration exceeds $20\%$ .	Reacts vigorously with a variety of chemical reagents including oxidizers and bases. Attacks most metals or their salts, flammable liquids and other combustible materials (paper, textiles), aniline and nitromethane.	Can decompose evolving oxygen, causing pressure rise in container. Store in dark, cool place. Do not use metallic containers or equipment, e.g. brass, copper, iron.
Hydrogen sulfide $H_2S$	Colourless gas with a strong odour of rotten eggs; b.p. $-60\text{ }^\circ\text{C}$ m.p. $-85\text{ }^\circ\text{C}$ .	May cause effects on central nervous system resulting in headache, dizziness, cough, sore throat, nausea, laboured breathing, unconsciousness and death. Inhalation may cause lung oedema. Redness, pain, severe deep burns of eyes.	Extremely flammable; explosive limits $4.3\text{--}46\%$ .	Work with ventilation, local exhaust. Wear safety goggles or eye protection in combination with respiratory protection.	Strong oxidizers and strong nitric acid. Attacks many metals and plastics.	Sense of smell becomes rapidly fatigued and cannot be relied on to warn of the continuous presence of the gas.
Iodine $I_2$	Bluish-black crystalline scales with a characteristic odour; m.p. $114\text{ }^\circ\text{C}$ b.p. $184\text{ }^\circ\text{C}$ ; practically insoluble in water.	Irritation of eyes, respiratory system and skin. Repeated exposure may cause skin sensitization. May have effect on thyroid.	Not combustible but enhances combustion of other substances. Many reactions may cause fire or explosion. Gives off irritating or toxic fumes (or gases) in a fire.	Do not breathe vapour; avoid contact with eyes. Wear nitrile gloves.	Reacts violently with metals including aluminium, potassium and sodium, and with ethanol/phosphorus mixtures, acetylene and ammonia.	

## ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

<p>Mercury Hg (Quicksilver)</p>	<p>Heavy silvery liquid; m.p. <math>-39\text{ }^{\circ}\text{C}</math> b.p. <math>357\text{ }^{\circ}\text{C}</math>; insoluble in water.</p>	<p>May be absorbed through skin. Repeated exposure may affect kidneys and central nervous system, and may cause vomiting, diarrhoea, headache, nausea, swollen gums, loose teeth.</p>	<p>Not combustible. Gives off irritating or toxic fumes in a fire.</p>	<p>Keep container tightly closed. Work in fume cupboard or well-ventilated area. Prevent spills. Observe strict hygiene. Wear nitrile gloves.</p>	<p>Acetylene, fulminic acid. Reacts with ammonia, azides and ethylene oxide to form explosive products. Reacts violently with bromine. Forms amalgams with many metals.</p>	<p>Store containers and use over catchment trays to contain spillage; suck up spilt droplets into a small respiratory bottle fitted with a capillary connecting tube and connected to a pump; treat spilt areas with zinc dust to form an amalgam.</p>
<p>Methanol <math>\text{CH}_3\text{OH}</math></p>	<p>Colourless volatile liquid with characteristic odour; m.p. <math>-98\text{ }^{\circ}\text{C}</math> b.p. <math>65\text{ }^{\circ}\text{C}</math>; miscible with water.</p>	<p>Effects on central nervous system resulting in unconsciousness; mucous membrane irritation. Chronic exposure can cause damage to retina and optic nerve. Prolonged skin contact may cause dermatitis. May be absorbed through skin.</p>	<p>Highly flammable; flashpoint <math>-16\text{ }^{\circ}\text{C}</math> flammable range <math>7\text{--}37\%</math>.</p>	<p>Keep container tightly closed; keep away from ignition sources. Avoid breathing vapour and contact with skin. Work in fume cupboard or well-ventilated area. Wear rubber or plastic gloves and eye protection.</p>	<p>Can react vigorously with oxidizers. Reactions with magnesium or bromine can be violent and those with strong oxidants or chloroform with sodium can be explosive.</p>	
<p>Naphthylamine (alpha and beta) <math>\text{C}_{10}\text{H}_9\text{N}</math> <i>M</i>-phenyl-<math>\alpha</math>-naphthylamine and <i>M</i>-phenyl-<math>\beta</math>-naphthylamine</p>	<p>White to pink crystals with characteristic odour; alpha: m.p. <math>50\text{ }^{\circ}\text{C}</math> b.p. <math>301\text{ }^{\circ}\text{C}</math>; beta: m.p. <math>113\text{ }^{\circ}\text{C}</math> b.p. <math>306\text{ }^{\circ}\text{C}</math>; poorly soluble in water but hydrochloride is water-soluble.</p>	<p>Both forms very toxic by inhalation, ingestion and skin contact. Human carcinogen causing bladder cancer. Experimental mutagen and teratogen. Absorbed through skin.</p>	<p>Combustible.</p>	<p>Avoid all exposure; wear suitable protective clothing. Work in fume cupboard or hood, or with exhaust ventilation.</p>	<p>Use is prohibited or legally controlled in many countries.</p>	

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Nimhydrin $C_9H_6O_4$	Pale yellow solid, decomposes before melting at 241 °C. Supplied in aerosol spray cans as 0.5% solution in butanol; soluble in water.	Harmful by ingestion and inhalation. Irritation of eyes, respiratory system and skin. Repeated exposure may cause skin sensitization.	Flammable, combustible solid; flashpoint 39 °C.	Avoid inhalation of the spray or vapour and contact with eyes. Wear rubber or plastic gloves and chemical-grade goggles.		Contact with skin produces a persistent violet stain.
Nitric acid (50–70%) $HNO_3$	Colourless or pale yellow fuming liquid; m.p. –42 °C; b.p. 83–121 °C; miscible in water.	Corrosive; causes severe burns to eyes and skin. Inhalation of vapour may cause lung oedema.	Oxidizer; contact with combustible material may cause fire. Evolves toxic fumes in a fire.	Do not breathe vapour; use respiratory protection. In case of contact with eyes, rinse immediately and seek medical attention; in case of contact with skin, wash off immediately; remove contaminated clothing. Wear PVC gloves, plastic apron and chemical-grade goggles. Work in fume cupboard.	Acetic acid, chromic acid, hydrocyanic acid, aniline, carbon, hydrogen sulfide, bases, metals and many other substances.	Concentrated nitric acid is involved in more dangerous reactions than any other chemical reagent.
Nitrobenzene $C_6H_5NO_2$	Pale yellow oily liquid, with characteristic odour; m.p. 6 °C; b.p. 211 °C.	Methaemoglobinaemia with cyanosis, liver damage; symptoms include blue lips or fingernails, blue skin, dizziness, nausea, weakness, unconsciousness. Absorbed through skin.	Combustible; risk of fire and explosion; flashpoint 88 °C.	Work with ventilation, local exhaust or respiratory protection. Wear protective gloves, protective clothing, safety goggles.	On combustion forms corrosive fumes including nitrogen oxides. Reacts violently with strong oxidants and reducing agents, causing fire and explosion hazard. Attacks many plastics. Forms explosive (thermally unstable) substances or mixtures with many organic and inorganic compounds.	

Osmium tetroxide $\text{OsO}_4$	Pale yellow crystals with pungent odour; m.p. $40\text{ }^\circ\text{C}$ b.p. $130\text{ }^\circ\text{C}$ ; sublimes below boiling point; soluble in water.	Very toxic by inhalation, ingestion and skin contact, causing severe burns and irritation. Vapour, solid and solutions are corrosive to skin and respiratory tract. Inhalation may cause lung oedema.	Powerful oxidizing agent. Not combustible but enhances combustion of other substances.	Keep container tightly closed and in a well-ventilated area. Work with solid and solutions in fume cupboard or hood. Wear chemical-grade goggles and protective gloves. To make up solutions, add unopened ampoule to required volume of water, stopper and shake to break ampoule.
Oxalic acid $\text{HO}_2\text{CCO}_2\text{H}$	Colourless crystals; soluble in water; m.p. $190\text{ }^\circ\text{C}$ ; decomposes.	Harmful if in contact with skin or if ingested. Dust irritates respiratory tract and eyes. Solutions irritate eyes and may cause skin burns.	Combustible. Gives off irritating or toxic fumes (or gases) in a fire.	Avoid contact with skin and eyes; wear eye protection and gloves. Oxidizing agents; also silver and mercury and their compounds.
Oxygen $\text{O}_2$	Colourless compressed gas; m.p. $-218.4\text{ }^\circ\text{C}$ b.p. $-183\text{ }^\circ\text{C}$ .	At very high concentrations, irritation of respiratory tract.	Not combustible but enhances combustion of other substances. Heating will cause rise in pressure of container with risk of bursting.	A strong oxidant, reacts with combustible and reducing materials, causing fire and explosion hazard. Reacts with oils, greases, hydrogen, and flammable liquids, solids and gases.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Perchloric acid $\text{HClO}_4$	Colourless liquid; miscible with water.	Corrosive; causes severe burns to eyes and skin and if ingested. Vapour is corrosive to eyes, skin, and respiratory tract. Inhalation of vapours may cause lung oedema.	Powerful oxidizing agent. Not combustible but enhances combustion of other substances.	Avoid breathing vapour and other exposure; wear protective clothing including nitrile gloves, eye and face protection. With hot solutions work in fume cupboard or hood.	Combustible materials and reducing agents: acetic anhydride, bismuth and its alloys, alcohol, metal, paper, wood and other organic materials.	Powerful oxidizing agent; may form explosive products if in contact with many inorganic and organic materials; contaminated wooden floors, benches, etc. May explode on percussion.
Phenol $\text{C}_6\text{H}_5\text{OH}$	Colourless or pale pink crystals with characteristic odour; m.p. $41^\circ\text{C}$ ; b.p. $182^\circ\text{C}$ ; soluble in water.	Substance and vapours are corrosive to eyes, skin and respiratory tract causing severe burns; absorbed through skin. Central nervous system disturbance, coma. Kidney and liver damage. Symptoms include abdominal pain, vomiting, diarrhoea, skin irritation, eye pain. Prolonged contact with dilute solutions may cause dermatitis.	Flashpoint $80^\circ\text{C}$ flammable range 1.7–6%.	Do not breathe vapour; use respiratory protection. Avoid eye and skin contact. Work in fume cupboard. Wear nitrile gloves and eye protection. In case of contact with eyes, rinse immediately with water and seek medical advice; in case of contact with skin, remove any contaminated clothing and swab the contaminated area with glycerol, polyethylene glycol 300 or a mixture of liquid polyethylene glycol (70%) and methylated spirit (30%) and then flush with water.	Reacts with oxidants causing fire and explosion hazard.	

ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

Phosphoric acid $H_3PO_4$	Colourless viscous liquid or hygroscopic white crystals; m.p. 42 °C decomposes below boiling point at 213 °C; soluble in water.	Corrosive; causes burns to the skin and eyes.	Attacks many metals producing hydrogen. Gives off toxic fumes in a fire.	In case of contact with eyes, rinse with water and obtain medical advice. Wear nitrile gloves and eye protection.
Phosphorus pentoxide $P_2O_5$	Hygroscopic white crystals or powder; m.p. 340 °C, sublimation point 360 °C.	Corrosive to the eyes, skin, respiratory tract, leading to sore throat, cough, burning sensation, shortness of breath; skin burns, pain, blisters, eye burns. Inhalation may cause lung oedema. Ingestion may cause abdominal cramps, burning sensation, diarrhoea, sore throat, vomiting.	Not combustible but enhances combustion of other substances. Many reactions may cause fire or explosion. Gives off irritating or toxic fumes (or gases) in a fire.	Work with local exhaust protection. Wear protective gloves and clothing, face shield, or eye protection in combination with respiratory protection.
Picric acid $C_6H_2(NO_2)_3OH$ 2,4,6-Trinitrophenol	Yellow crystals moistened with water or dissolved in alcohol; m.p. 122 °C; slightly soluble in water.	Toxic by ingestion, inhalation or skin contact. Ingestion may result in headache, nausea. Irritation of eyes.	Explosive when dry.	Keep moistened with water at all times or use only in alcoholic solution.
			Forms salts with many metals which are more explosive than the acid itself. In contact with concrete may form calcium picrate, which is a friction-sensitive explosive. May react vigorously with reducing agents.	Yellow skin stains.
			Solution in water is a strong acid; reacts violently with bases and is corrosive. Reacts violently with perchloric acid causing fire and explosion hazard. Reacts violently with water forming phosphoric acid. Attacks many metals in presence of water.	

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Potassium hydroxide KOH	White flakes, powder, pellets or sticks; m.p. 360 °C b.p. 1320 °C; very soluble in water.	Corrosive to respiratory system, eyes and skin; inhalation of dust causes lung oedema.		In case of contact with eyes, rinse immediately with water and seek medical advice; in case of contact with skin, wash immediately; remove contaminated clothing. Wear rubber or plastic gloves and eye protection even for dilute solutions.	Reacts violently with acids and with nitrobenzene and many other detergents. Evolves large quantity of heat when mixed with water; store in a well-sealed container.	Attacks some metals (aluminium, zinc, tin) in the presence of moisture.
Potassium permanganate KMnO <sub>4</sub>	Purple crystals; m.p. 240 °C (decomposes); readily soluble in water.	Corrosive if swallowed or if dust is inhaled. Extreme irritation of eyes and respiratory tract, inhalation of dust may cause lung oedema.	Powerful oxidizing agent; may ignite combustible materials.	Wear protective clothing, eye protection and particulate respirator if dust is produced.	Reacts violently or explosively if mixed with a wide variety of inorganic and organic compounds or powdered metals.	
Potassium tellurite K <sub>2</sub> TeO <sub>3</sub>	White deliquescent crystals; very soluble in water.	Toxic by ingestion and inhalation of dust. Irritation of skin and eyes.		Wear protective clothing.		
Propan-2-ol (CH <sub>3</sub> ) <sub>2</sub> CHOH Isopropanol	Colourless liquid with alcoholic odour; m.p. -89 °C b.p 82 °C; miscible with water.	Irritation of eyes and respiratory tract. May affect central nervous system causing headache, dizziness, nausea, vomiting and coma.	Highly flammable; flashpoint 112 °C flammable range 2.3–12.7%.	Keep container tightly closed; keep away from ignition sources. Work in fume cupboard. Wear nitrile gloves and eye protection.	Can react vigorously with oxidizers to form unstable peroxides on prolonged exposure to air and light.	70–85% propan-2-ol in water used as a disinfectant spray remains a flammable hazard and should not be used near ignition sources.

Pyridine C <sub>5</sub> H <sub>5</sub> N	Colourless liquid with characteristic odour; m.p. 42 °C b.p. 115 °C.	Affects central nervous system causing dizziness, headache, nausea, shortness of breath, unconsciousness. May be absorbed through skin causing redness and burning sensation. Ingestion causes abdominal pain, diarrhoea, vomiting, weakness. Repeated exposure causes liver and kidney effects.	Highly flammable; flashpoint 20 °C explosive limits, 1.8–12.4%. Gives off irritating or toxic fumes (or gases) in a fire. Vapour/ mixtures are explosive.	Work with ventilation, local exhaust or respiratory protection; wear gloves and protective clothing.	Reacts violently with strong oxidants and strong acids.
Selenium Se	Odourless solid in various forms, dark red-brown to bluish-black amorphous solid or red transparent crystals or metallic grey to black crystals; m.p. 170–217 °C b.p. 685 °C.	Irritation of skin and eye. Inhalation of dust may cause lung oedema. Repeated exposure may cause loss of nails, gastrointestinal effects.	Combustible. Gives off irritating or toxic fumes (or gases) in a fire.	Prevent dispersion of dust. Observe strict hygiene. Work with local exhaust. Wear protective gloves, clothing, and safety spectacles.	Reacts violently with oxidants and strong acids. Reacts with water at 50 °C forming flammable hydrogen and selenious acids. Reacts with incandescence on gentle heating with phosphorus and metals such as nickel, potassium, platinum, sodium and zinc.
Silver Ag	White metal, turns dark on exposure to ozone, hydrogen sulfide or sulfur; m.p. 962 °C b.p. 2212 °C.	Inhalation of high amounts of metallic silver vapours may cause lung damage with pulmonary oedema. May cause a grey-blue discoloration of the eyes, nose, throat and skin on long-term or repeated exposure (argyria).	Not combustible except as powder.	Work with local exhaust. Wear protective gloves and safety spectacles or eye protection in combination with respiratory protection for powder or fume.	Incompatible with acetylene, ammonium compounds, oxalic acid and tartaric acid.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Silver nitrate AgNO <sub>3</sub>	White crystals; m.p. 212 °C b.p. 444 °C; soluble in water.	May cause severe irritation and burns to eyes and skin. Corrosive by ingestion. May cause a red-blue discoloration of the skin on long-term or repeated exposure (argyria).	Not combustible but enhances combustion of other substances.	Prevent dispersion of dust. Observe strict hygiene. Wear protective rubber or plastic gloves, and face shield or eye protection in combination with respiratory protection. In case of contact with eyes, rinse with water and seek medical advice.	Ammoniacal solutions can precipitate explosive silver nitrite in the presence of base or glucose. Can form explosive products with ethanol and may cause explosive polymerization with acrylonitrile. May cause ignition of explosion if mixed with charcoal, magnesium, phosphorus or sulfur.	
Sodium azide N <sub>3</sub> Na	Colourless crystalline solid; m.p. 300 °C; soluble in water.	Very toxic by ingestion, inhalation and skin contact; may cause burns. Dust and solution irritate eyes and skin; may be absorbed through skin.	Decomposes explosively when heated above its melting point. Gives off toxic fumes when heated; do not use water to extinguish fires.	In case of contact with skin, wash immediately. Do not inhale dust. Wear rubber or plastic gloves and eye protection.	Explosive reactions with bromine, carbon disulfide or chromyl chloride. Solid reacts with heavy metals including copper, lead and mercury to form explosive metal azide salts. On contact with acid, develops highly toxic and explosive gas.	
Sodium biselenite NaHSeO <sub>3</sub>	Colourless, white crystalline powder; soluble in water.	Toxic by ingestion and inhalation of dust; possible danger of cumulative effects. Experimental teratogen. Prolonged skin contact may cause dermatitis.		Wear protective clothing.	Oxidizing agents.	

ANNEX 5. CHEMICALS: HAZARDS AND PRECAUTIONS

Sodium cyanide NaCN	Extremely toxic by ingestion, inhalation and skin contact; severely irritating to eyes. May be absorbed through skin. Repeated exposure may affect thyroid.	May give off toxic fumes in a fire.	Do not inhale dust; use respiratory protection. Avoid eye and skin contact; in case of contact with skin, wash immediately with water and remove contaminated clothing. Wear chemical-grade goggles and rubber or plastic gloves. Keep in a securely locked, ventilated store.	Liberates extremely toxic hydrogen cyanide (HCN) gas on contact with acids or with water containing dissolved carbon dioxide. Can form explosive mixtures with nitrites.	Treat spillage of solutions with bleaching powder (sodium hypochlorite) and leave for 24 h. Sweep up solid spills carefully and add to water containing bleaching powder; leave for 24 h before discarding. Keep cyanide antidote kit available in the laboratory.
Sodium hydroxide NaOH	Solid and concentrated solute. Inhalation of dust causes damage to respiratory tract, lung oedema. Corrosive by ingestion. Dilute solutions irritating to eyes or may cause severe damage if eye contact is prolonged.	Not combustible. Contact with moisture or water may generate sufficient heat to ignite combustible substances.	In case of contact with eyes rinse immediately and seek medical advice; in case of contact with skin wash immediately with water, remove contaminated clothing. Wear rubber or plastic gloves and eye protection even with dilute solutions.	Evolves large quantity of heat when mixed with water. Reacts vigorously with chloroform-methanol mixtures and with strong acids.	Store in well-sealed container in dry place.

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Sodium hypochlorite solution (10–14% available chlorine) NaOCl	Colourless or pale yellow solution with chlorine odour; miscible with water.	Corrosive to eyes and skin; corrosive by ingestion and to respiratory tract; inhalation may cause lung oedema. Repeated exposure may cause skin sensitization.	Strong oxidant. May give off toxic fumes in a fire.	In case of contact with eyes, rinse immediately with water and seek medical advice; in case of contact with skin, wash immediately. Do not inhale vapour; use respiratory protection. Work in well-ventilated area. Wear rubber or plastic gloves and chemical-grade eye protection.	Liberates highly toxic gas in contact with acids. Can react vigorously with combustible and reducing compounds. May react with nitrogen compounds to form explosive N-chloro-compounds; may react violently with methanol.	Gradually loses chlorine during storage; dilute solutions used as disinfectant rapidly deteriorate. Store away from acids in a dark, cool, well-ventilated area.
Sulfuric acid H <sub>2</sub> SO <sub>4</sub>	Colourless, odourless viscous liquid; m.p. 10 °C b.p. (decomposes) 340 °C.	Concentrated solution (15%) corrosive, causes severe burns; mist and vapour highly corrosive by inhalation; dilute solutions irritating to eyes and skin; cause burns and dermatitis.	May give off toxic fumes in a fire. Not combustible. Many reactions may cause fire or explosion. Dilution with water generates heat and spattering or boiling may occur. Always add acid to water, <b>never add water to acid.</b>	In case of contact with eyes rinse immediately and seek medical advice; in case of contact with skin wash immediately remove contaminated clothing. Wear nitrile gloves, eye and face protection. <b>No contact with flammable substances.</b>	Is a powerful oxidizing desiccant and reacts violently with many reagents including organic nitro compounds, potassium permanganate, alkali metals and perchlorates, combustible materials, oxidizers, amines, bases, water, excess heat and most metals.	Localized boiling may occur if concentrated acid is added to water.

<p>Tetrahydrofuran <math>C_4H_8O</math></p> <p>Diethylene oxide m.p. <math>-108.5\text{ }^{\circ}\text{C}</math></p> <p>Tetramethylene oxide b.p. <math>66\text{ }^{\circ}\text{C}</math>.</p>	<p>Colourless liquid, with characteristic odour;</p> <p>Central nervous system depressant causing narcosis. Eye, skin and respiratory irritation.</p>	<p>Highly flammable; may form explosive peroxides; flashpoint <math>-14\text{ }^{\circ}\text{C}</math>. Water may be ineffective to fight fires involving tetrahydrofuran, but it can be used to cool fire-exposed containers.</p>	<p>Work with ventilation, local exhaust or respiratory protection, protective gloves, safety spectacles.</p>	<p>Reacts violently with strong oxidants, strong bases and some metal halide, causing fire and explosion hazard. Attacks some forms of plastics, rubber and coatings. Tetrahydrofuran may polymerize in the presence of cationic initiators. Refluxing with calcium hydroxide can cause explosions.</p>
<p>Thallium acetate <math>Tl_2C_2H_3O_2</math></p> <p>White deliquescent crystals; m.p. <math>110\text{ }^{\circ}\text{C}</math>; very soluble in water.</p>	<p>Extremely toxic by ingestion with possible cumulative effects. Affects nervous and cardiovascular systems. Harmful through eye and skin contact.</p>			
<p><i>o</i>-Tolidine <math>(C_6H_5-(3CH_3)-(4NH_2))_2</math></p> <p>3,3'-Dimethyl-(1,1'-biphenyl)-4,4'-diamine</p> <p>Colourless crystals; m.p. <math>131\text{ }^{\circ}\text{C}</math> b.p. <math>200\text{ }^{\circ}\text{C}</math>; poorly soluble in water.</p>	<p>Harmful by contact with skin or ingestion. Dust irritates respiratory tract and eyes. Probably a human carcinogen.</p>	<p>Combustible. Gives off irritating or toxic fumes (or gases) in a fire.</p>	<p>Avoid contact; wear eye protection and gloves.</p>	<p>Oxidizing agents.</p>

CHEMICAL	PHYSICAL PROPERTIES	HEALTH HAZARDS	FIRE HAZARDS	SAFETY PRECAUTIONS	INCOMPATIBLE CHEMICALS	OTHER HAZARDS
Toluene C <sub>7</sub> H <sub>8</sub> Methylbenzene	Colourless liquid with characteristic odour; m.p. -95 °C; b.p. 111 °C; not miscible with water.	Central nervous system depressant. Irritation of eyes, mucous membranes, skin. Repeated exposure may cause toxicity in human reproduction or development.	Highly flammable; vapour may cause flash fire; flashpoint 4 °C flammable range 1.4–7%. Extinguishing media for a small fire: dry chemicals, carbon dioxide, foam, water fog or inert gas (nitrogen).	Keep container tightly closed; keep away from ignition sources; earth/ (ground) containers to prevent static electrical discharge. Do not inhale vapour; use respiratory protection. Work in fume cupboard or well-ventilated area. Wear nitrile gloves.	Can react with strong acids, alkalis and oxidizers.	
Trichloroacetic acid CCl <sub>3</sub> COOH	White hygroscopic crystals with pungent odour; m.p. 58 °C b.p. 197.5 °C; soluble in water, ethanol, diethyl/ether.	Corrosive; causes severe burns to eyes, skin, respiratory tract.	Not combustible. May give off toxic fumes in fire.	Avoid contact with eyes and skin; wear rubber or plastic gloves and chemical-grade goggles or face shield in combination with respiratory protection. In case of contact with eyes, rinse immediately and seek medical advice.	Violent reaction with copper/dimethyl sulfoxide mixtures and on contact with bases, strong oxidizing agents and metals such as iron, zinc, aluminium.	Store in a dry place. Concentrated aqueous solutions may decompose violently.

Trichloroethylene CHClCCl <sub>2</sub>	Colourless liquid, characteristic odour; m.p. -73 °C b.p. 87 °C.	Irritation of eyes, skin; prolonged exposure may cause dermatitis and affect the central nervous system resulting in loss of memory. May affect liver and kidneys. Probably a human carcinogen.	Combustible under specific conditions.	Work with ventilation, local exhaust. Wear gloves, safety spectacles or other eye protection in combination with respiratory protection.	On contact with hot surfaces or flames, decomposes forming toxic and corrosive gases (phosgene, hydrogen chloride). Decomposes on contact with strong alkali producing dichloroacetylene; reacts violently with metal powders such as aluminium, barium, magnesium and titanium; slowly decomposed by light in the presence of moisture, with formation of hydrochloric acid.
Xylene (mixed isomers) C <sub>8</sub> H <sub>10</sub> (CH <sub>3</sub> ) <sub>2</sub> Dimethylbenzene	Colourless liquid with aromatic odour; m.p. -95 to -13 °C b.p. 136-145 °C; insoluble in water.	May affect central nervous system resulting in headache, dizziness, fatigue and nausea. Liquid and vapour irritate eyes, skin, mucous membranes, respiratory tract. Harmful if ingested. Prolonged skin contact may defat the skin. Non-specific neurological impairment. Exposure may enhance hearing damage caused by exposure to noise. Animal tests suggest toxicity to human reproduction or development.	Flammable liquid; flashpoint 27-32 °C.	Avoid contact with eyes. Wear nitrile gloves and eye protection. Keep container tightly closed; keep away from ignition sources.	May contain ethylbenzene as an impurity. Ethylbenzene is a possible human carcinogen.

# Index

- abrasions 79
- access
  - animal facilities 29, 30, 31
  - laboratory 9–10, 21, 26
- accidents 11
  - equipment-related 144
  - see also* first aid; injuries; spills
- acetaldehyde 146
- acetic acid 146
- acetic anhydride 146
- acetone 147
- acetonitrile 147
- acetylene 147
- acrolein 148
- aerosols
  - activities generating 51
  - biological safety cabinets and 15, 51
  - pipetting hazards 63
  - release of potentially infectious 79
  - safety equipment and 61
- air, exhaust *see* exhaust air
- air filters *see* high-efficiency particulate air (HEPA) filters
- airflow, directional
  - alarms 21, 60
  - animal facilities 29, 30, 31
  - biological safety cabinets 53, 56
  - Biosafety Level 3: 21
  - Biosafety Level 4: 26–27
- air systems
  - biological safety cabinets 51–52, 53–54, 56–57
  - protective suit 26
  - see also* ventilation systems
- airlocks 26, 27, 31
- alarms 21, 60
- alcohol-based hand rubs 87–88, 90
- alcohols **87–88**
- allergy, latex 66
- 2-amino-ethanol 154
- ammonia solutions 148
- ammonium bicarbonate 89
- ampoules of infectious materials
  - opening **74**
  - storage **74**
- anaerobic jars/incubators 142, 144
- aniline 148
- animal facilities 10, **28–32**
  - Biosafety Level 1: 29
  - Biosafety Level 2: 29–30
  - Biosafety Level 3: 30–31
  - Biosafety Level 4: 31–32
  - containment levels 28
  - invertebrates 32
- animal facility Biosafety Levels (ABSL) 28
- animals
  - disposal of carcasses 30
  - non-experimental 10, 29
  - transgenic and knock-out **102–103**
- anterooms 21, 30, 31
- antimicrobial 82
- antiseptics 82, 87, 88
- aprons 64, 65
- arthropods
  - control of verminous 12, 29
  - housing facilities 32
- audit 36–37
- auramine 148
- autoclaves 63, **90–92**
  - animal facilities 30, 31
  - availability 13, 16, 22, 27
  - double-door pass-through 26, 27

- fuel-heated pressure cooker 91
- gravity displacement 90, 91
- loading 91
- pre-vacuum 91
- precautions for use 92
- validation 16
- autoclaving 18, **90–92**
- azides 108, 164
  
- backflow prevention 14, 22
- basic laboratory (Biosafety Levels 1 and 2) **1, 9–19**
  - chemical, fire, electrical, radiation and equipment safety 19
  - code of practice 9–12
  - design and facilities 12–14, 15
  - equipment 13–16
  - health and medical surveillance 16
  - safety survey forms 38–42
  - training 16–17
  - waste handling 17–19
- bedding, animal 30, 31
- bench tops 12
- benzene 149
- benzidine 149
- biocide 82
- biohazard warning sign 9, 10, 20, 29
- biological expression systems 102
- biological safety cabinets (BSCs) **51–60, 62**
  - air connections 56–57
  - animal facilities 30
  - certification 59
  - class I 51–53, 55
  - class II 52–54, 55
    - type A1 53–54
    - types A2, B1 and B2 54, 55
  - class III 55, 56
    - laboratory 25–27
  - decontamination 59, **89**
  - exhaust air *see* under exhaust air
  - location 22, 57
  - operation and maintenance 58
  - prion contamination 77
  - required use 15, 21, 22
  - safe use **57–60, 70–71**
  - selection 52, 57
- biosafety
  - management 12
  - versus* laboratory biosecurity 47
- Biosafety Collaborating Centres, WHO **140**
- biosafety committee **118**
- Biosafety Level 1: 1, 3, **9–19**
  - animal facilities 29
  - laboratory design 12–14
  - laboratory safety survey form 38–40
  - health and medical surveillance 16
  - see also* basic laboratory
- Biosafety Level 2: 1, 3, **9–19**
  - animal facilities 29–30
  - laboratory design 12–14, 15
  - laboratory safety survey form 41–42
  - health and medical surveillance 16
  - see also* basic laboratory
- Biosafety Level 3: 1, 3, **20–23**
  - animal facilities 30–31
  - laboratory design 21–22
  - laboratory safety survey form 43
  - see also* containment laboratory
- Biosafety Level 4: 1, 3, **25–27**
  - animal facilities 31–32
  - laboratory design 25–27
  - see also* maximum containment laboratory
- biosafety levels 1
  - animal facility (ABSL) 28
  - facility requirements 3
  - microbiological risk groups and 1–3
- biosafety officer 17, **117–118**
- biosecurity **47–48**
  - 1,1'-biphenyl-4,4'-diamine" 149
- bleach (sodium hypochlorite) **84–85, 89, 166**
- blenders 63–64, **73**
- blood, standard precautions **74–76**
- body fluids, standard precautions **74–76**
- boiling 90
- bottles, screw-capped 16, 63
- bromine 149
- BSCs *see* biological safety cabinets
- building maintenance services **119**
- Bunsen burners 70, 71

- cages
  - animal 30, 31
  - flying insects 32
- calcium hypochlorite 84
- carbon dioxide, solid (dry ice) 150
- carbon tetrachloride 150
- 4,4'-carbonyimidoylbis
  - (N,N-dimethylbenzamine) 148
- ceilings 12, 21
- centrifuges 72–73, 142
  - breakage of tubes in 79–80
  - containment accessories 22
  - improper use 144
- certification
  - biological safety cabinets 59
  - laboratory/facility 36–37
- checklist, safety 125–131
- chemical germicides 82, 83–88
- chemicals (hazardous) 19, 107–109
  - biological safety cabinets 57
  - explosive 108, 144
  - incompatible, general rules 107, 108
  - routes of exposure 107
  - safety checklist 130–131
  - specific 145–169
  - spills 108–109
  - storage 107
  - toxic effects 107–108
- children 10
- chilling facilities, arthropods 32
- chloramines 84, 85
- chlorine 84–85, 150
- chlorine dioxide 85–86, 151
- chlorine-releasing compounds 84–85
- chloroform 151
- chromic acid 151
- chromium VI oxide 151
- circuit-breakers 111
- class III cabinet laboratory 25–26
  - controlled air system 26–27
- clean-air work stations 51
- clean-up procedure, spills 95–97
- cleaning
  - biological safety cabinets 59
  - domestic 119
  - laboratory materials 83
  - refrigerators and freezers 73
- clothing, protective *see* personal protective equipment/clothing
- coats, laboratory 64, 65
- codes of practice
  - Biosafety Level 1 and 2: 9–12
  - Biosafety Level 3: 20–21
  - Biosafety Level 4: 25
- commissioning, laboratory/facility 33–35
- commissioning agent 33–34
- communication facilities 25
- contact lenses 11
- containers
  - broken 79
  - contaminated waste 18–19
  - leakproof 62
  - sharps disposal 18, 62
  - specimen 69, 75, 95
- containment, primary
  - at Biosafety Level 4 25–26
- containment laboratory (Biosafety Level 3)
  - 1, 3, 20–23
  - code of practice 20–21
  - design and facilities 21–22, 23
  - equipment 22
  - health and medical surveillance 22–23, 24
  - safety survey form 43
- containment levels, animal facility 28
  - see also* biosafety levels
- contaminated liquids/effluents 11, 27
- contaminated materials *see* infectious materials
- contingency plans 78
- copper 152
- cosmetics 11
- coveralls 64, 65
- Creutzfeldt-Jakob disease (CJD) 76
- culture stirrers, shakers, agitators 143
- cuts 79
- cyanogen bromide 152
- cytochalasin 152
- decontamination
  - biological safety cabinets 59, 89
  - blood/body fluids 76

- definition 82
- effluents 11, 27
- hand **90**
- local environmental **88–89**
- prion-contaminated materials 77
- waste materials 18, 22
  - see also* cleaning; disinfection
- desiccators 142
- design, laboratory
  - Biosafety Level 1 and 2: 12–14, 15
  - Biosafety Level 3: 21–22, 23
  - Biosafety Level 4: 25–27
  - commissioning requirements and 33
- diethyl ether 153
- diethylene dioxide 154
- diethylene oxide 167
- 3,3'-dimethyl-(1,1'-biphenyl)-4,4'-diamine 167
- dimethylamine 153
- dimethylbenzene 169
- 2,4-dinitrophenyl-hydrazine 153
- dioxane 154
- disasters, natural 78, 80
- disinfectants 82, **83–88**
- disinfection **82–93**
  - biological safety cabinets 59
  - chemical 83–88
  - cleaning prior to 82, 83
  - definition 82
  - heat 90–92
  - spills 95–97
  - waste materials 19
  - see also* decontamination; sterilization
- dispersal of infectious materials, avoiding 70
- doors
  - animal facilities 29
  - laboratory 13, 21, 26
- drains, containment 27
- drinking 11, 13, 30
- earth-fault-interrupters 111
- eating 11, 13, 30, 71
- effluents, contaminated 11, 27
- electrical hazards 19, **111**, 144
  - safety checklist **128**
- electricity supply 14, 27
- emergencies **78–81**
  - Biosafety level 4: 25, 27
  - contingency plans 78
  - laboratory procedures 79–81
- emergency equipment 81
- emergency services 80–81
- engineering services **119**
- equipment
  - basic laboratory **14–16**
  - containment laboratory **22**
  - emergency 81
  - hazards **141–144**
  - personal protective *see* personal protective equipment/clothing
  - safety 19, **61–66**
    - checklist **130**
- Escherichia coli* K12 102
- ethanol (ethyl alcohol) 87–88, 154
- ethanolamine 154
- ethers 108
- excreta, standard precautions **74–76**
- exhaust air
  - animal facilities 30
  - biological safety cabinets 22, 26, 51, 52–54, 56, 57
  - containment laboratory 21, 22
  - maximum containment laboratory 26–27
- explosive chemicals 108, 144
- expression systems, biological 102
- expression vectors 102
- eye protection 11, 64–65, 71
- face protection 11, 64–65
- face shields (visors) 11, 65
- facilities, laboratory
  - Biosafety Level 1 and 2: 12–14
  - Biosafety Level 3: 21–22, 23
  - Biosafety Level 4: 25–27
  - biosafety level designations 1
- films, for microscopy 75
- fire extinguishers 110–111
- fires 19, **110–111**
  - causes 110, 144
  - emergency procedures 80

- prevention and protection checklist 127
- first aid 13, **138**
- first-aid box 138
- flame photometer 144
- flames, open 59, 70
- flammable liquid storage **128**
- floors 12, 21
- food 11
- footwear 11, 20, 25, 65
- formaldehyde **86**, 89, 155
- formalin 86, 89
- freeze-dryers 143
- freezers **73–74**
- fumigation 89
- furniture, laboratory 12
- gas(es)
  - compressed and liquefied 109, **128**
  - supply to laboratory 14
- gene transfer 101, 102
- genetic engineering 101
- genetically modified organisms (GMOs) **101–104**
  - further considerations 104
  - risk assessments 103–104
  - types 102–103
- germicides, chemical 82, **83–88**
- glass 75
  - handling broken 79, 80, 95
  - precautions in use 71, 75
- gloves 10, 60, 65, **66**
- glutaraldehyde 86, 155
- GMOs *see* genetically modified organisms
- goggles 64–65
- good microbiological technique (GMT) 9–12, **69–77**
- gowns 64, 65
- hand decontamination **90**
- hand rubs, alcohol-based 87–88, 90
- hand washing 10, 66, **90**
  - animal facility staff 30
  - facilities 13, 21, 30
- health and medical surveillance
  - basic laboratory **16**
  - checklist **129**
  - containment laboratory **22–23**, 24
- hearing protection 111
- heat
  - disinfection and sterilization **90–92**
  - dry 90
  - moist 90
- heating, ventilation and air-conditioning (HVAC) system 21
  - safety checklist **126**
- HEPA filters *see* high-efficiency particulate air filters
- high-efficiency particulate air (HEPA) filters
  - animal facilities 30
  - biological safety cabinets 51, 53, 56
  - Biosafety Level 3: 21, 22
  - Biosafety Level 4: 26, 27
  - prion-contaminated 77
- homogenizers 63–64, **73**, 142
- horizontal and vertical outflow cabinets 51
- 1-hydrazino-2,4-dinitrobenzene 153
- hydrochloric acid 155
- hydrogen chloride 155
- peroxide **88**, 89, 156
- hydrogen sulfide 156
- illumination *see* lighting
- immunization, staff **139**
- incidents *see* accidents; spills
- incineration 19, **92–93**
- incinerators 31, 92
- infectious materials
  - autoclaving and reuse 18
  - avoiding dispersal **70**
  - contact with skin and eyes 71
  - decontamination *see* decontamination
  - disposal 18–19, 22
  - ingestion 71, 79
  - safety checklist **130**
  - spills 11, 79, **95–97**
- infective microorganisms, risk groups *see* risk groups, microbiological
- ingestion of infectious material 71, 79
- injuries
  - animal facility staff 30

- emergency procedures 79
- prevention 71–72
- inoculation, accidental 71–72
- insects, flying 32
- inspection, laboratory 36–37
- International Air Transport Association (IATA) 94
- International Civil Aviation Organization (ICAO) 94
- international transport regulations **94–95**
- invertebrates 32
- iodine **88**, 156
- iodophores **88**
- isolator cages 30, 31
- isolators, negative-pressure flexible-film **61**, 62
- isopropanol (isopropyl alcohol) 87, 162
  
- knock-out animals **102–103**
  
- labelling, specimen 74–75
- laboratory
  - biosafety levels *see* biosafety levels
  - biosecurity **47–48**
  - certification **36–37**
  - commissioning **33–35**
  - facilities *see* facilities, laboratory
  - premises, safety checklist **125**
  - safety survey forms 38–43
  - services, safety checklist **126–127**
  - techniques **69–77**
  - working areas 11
  - see also* basic laboratory; containment laboratory; maximum containment laboratory
- laboratory director 12, 117
- laboratory supervisors 12, 117
  - training role 17, 120
- latex allergy 66
- lighting 12, 14, **126**
- loops *see* transfer loops
- lyophilized infectious materials, opening ampoules **74**
- lyophilizers 143
  
- maintenance personnel 119
- maximum containment laboratory (Biosafety Level 4) 1, 3, **25–27**
  - code of practice 25
  - design and facilities 25–27
- medical contact card 22–23, 24
- medical surveillance *see* health and medical surveillance
- mercury 157
- methanol 157
- methylbenzene 168
- microbicide 82–83
- microbiological risk assessment *see* risk assessment, microbiological
- microincinerators 62, **64**
- microscopy, films and smears for 75
- mites 32
  
- naphthylamine 157
- natural disasters 78, 80
- needle-stick injuries, avoiding 71–72
- needles, hypodermic 11, 75, 141–142
  - disposal 18
- negative-pressure flexible-film isolators **61**, 62
- ninhydrin 158
- nitric acid 158
- nitrobenzene 158
- noise **111**
  
- osmium tetroxide 159
- outbreaks, diseases of unknown etiology 8
- oxalic acid 159
- oxygen 159
  
- packaging systems **95**, 96
- paraformaldehyde 86, 89
- peracids **88**
- perchloric acid 108, 160
- personal protective equipment/clothing **64–66**
  - animal facility 30, 31
  - basic laboratory 10–11
  - biological safety cabinet 60
  - checklist **129**
  - containment laboratory 20–21

- maximum containment laboratory 25, 26
- prions 77
- personnel
  - biosafety management 12
  - biosecurity issues 47
  - facilities, safety checklist **126**
  - health and medical surveillance *see* health and medical surveillance
  - immunization **139**
  - personal items/clothing 13
  - responsibility for own safety 117
  - support **119**
  - training *see* training
- phenol 160
- phenolic compounds **86–87**
- N*-phenyl- $\alpha$ -naphthylamine 157
- N*-phenyl- $\beta$ -naphthylamine 157
- phosphoric acid 161
- phosphorus pentoxide 161
- picric acid/picrates 108, 161
- pipettes 16, 70
- pipetting **70**
  - aids 15, 62, 63, 70
  - mouth 11, 63
- plants, transgenic 101, **103**
- plasmid pUC18 102
- poliovirus-susceptible mice 102–103
- potassium hydroxide 162
- potassium permanganate 162
- potassium tellurite 162
- precleaning 82, 83
- primary containment 25–26
- primates, non-human 29
- prions 76–77
- product protection 51, 53
- propan-2-ol (2-propanol) 87, 162
- protective suit 26
  - see also* suit laboratory
- pyridine 163
- quaternary ammonium compounds **87**
- radiation, ionizing 19, **111–114**
  - harmful effects 111
  - principles of protection 112–113
  - safety checklist **130–131**
    - work-bench area 113–114
- radiation area 113
- radiation hazard symbol 113, 114
- radioactive waste 114
- radionuclides
  - biological safety cabinets 57
  - safe working practices **112–113**
  - substitution 113
- recombinant DNA technology **101–104**
- refrigerators **73–74**, 144
- respirators (respiratory protective equipment) 21, **65–66**
- rest facilities 13
- risk assessment, microbiological 2, **7–8**
  - animal facilities 28–29
  - genetically modified organisms **103–104**
- risk groups, microbiological
  - basic laboratories 9
  - biosafety levels and 2–3
  - classification 1–2
- rodent control 12, 29
- safety checklist **125–131**
- safety equipment *see* equipment, safety
- sanitation facilities 126
- screens, arthropod-proof 32
- screw-capped bottles 16, 63
- security precautions 14, 127
- selenium 163
- serum, separation 72
- shakers 63–64, **73**
- sharps **18**
  - animal facilities 30
  - avoiding injuries 66, 71–72, 75
  - disposal containers 18, 62
- shoes *see* footwear
- showers 26, 30
- silver 163
- silver nitrate 164
- skin
  - contact 71
  - puncture wounds, cuts and abrasions 79
  - see also* injuries

- smears, for microscopy 75
- smoking 11, 30
- soda ash (sodium carbonate) 109
- sodium azide 164
- sodium bicarbonate 109
- sodium biselenite 164
- sodium cyanide 165
- sodium dichloroisocyanurate (NaDCC)
  - 84, **85**
- sodium hydroxide 165
- sodium hypochlorite (bleach) **84–85**, 89, 166
- sonicators 63–64, **73**, 75, 142
- spatter shield 62
- specimens **69**
  - collection 74–75
  - containers 69, 75, 95
  - labelling 74–75
  - with limited information 8
  - opening packages 69
  - opening tubes and sampling contents 75
  - receipt 69
  - standard precautions 74–75
  - transport 69, 74–75
  - triple packaging system **95**, 96
- spectacles, safety 64–65
- spills
  - in biological safety cabinets 59
  - blood 76
  - chemical **108–109**
  - infectious materials 11, 79, **95–97**
- sporocide 83
- staff *see* personnel
- standard precautions **74–76**
- sterilization 27, **82–93**
  - cleaning prior to 82, 83
  - definition 83
  - heat **90–92**
  - prion-contaminated materials 77
  - see also* decontamination; disinfection
- storage
  - ampoules of infectious materials **74**
  - chemicals 108
  - compressed and liquefied gases 109, **128**
  - facilities, checklist **125**
  - flammable liquids **128**
  - space, laboratory 12
- suit, protective 26
- suit laboratory 26
  - controlled air system 26–27
- sulfuric acid 166
- support staff **119**
- survey, laboratory safety 36–37
  - forms 38–43
- syringes 11, 18
- tetrahydrofuran 167
- tetramethylene oxide 167
- thallium acetate 167
- ticks 32
- tissue grinders **73**, 142
- tissues
  - prion-containing 77
  - standard precautions 75
- o*-tolidine 167
- toluene 168
- total exhaust cabinet 57
- training **120–121**
  - animal facility workers 30, 31
  - biological safety cabinet use 60
  - biosecurity 47
  - laboratory workers **16–17**
- transfer loops
  - disposable 15, 62, **64**
  - microincinerators 62, **64**
  - safe use 70
- transgenic animals **102–103**
- transgenic plants 101, **103**
- transmissible spongiform encephalopathies (TSEs) 76
- transport 11, **94–97**
  - infectious waste 18–19, 22
  - international regulations 94–95
  - specimens 69, 74–75
  - triple packaging system 95, 96
- trichloroacetic acid 168
- trichloroethylene 169
- triclosan 87
- 2,4,6-trinitrophenol (picric acid) 108, 161
- triple packaging systems **95**, 96

- tubes
  - breakage in centrifuges 79–80
  - screw-capped 16
- two-person rule 25, 31
- ultra-centrifuges 142
- ultrasonic cleaners 142
- ultraviolet lights 58
- United Nations Committee of Experts on the Transport of Dangerous Goods (UNCETDG) 94
- universal precautions 74–76
- vacuum flasks 144
- vacuum lines 22, 63
- validation, equipment 16
- vectors 102
- ventilation systems
  - animal facilities 29, 30, 31
  - basic laboratory 14
  - checklist **126**
  - containment laboratory 21
  - maximum containment laboratory 26–27
- viral vectors 102
- walls 12, 21
- warranty periods, laboratory/facility 33
- waste **17–19**
  - animal facilities 30, 31
  - Biosafety Level 4: 27
  - decontamination 18, 22
  - disposal 18–19, 22, 93
  - invertebrate facilities 32
  - prion-contaminated 77
  - radioactive 114
- water baths 143
- water supply 14, 22
- windows
  - animal facilities 29, 31
  - invertebrate facilities 32
  - laboratory 11, 14, 21
- women of childbearing age 16, 129
- work surfaces
  - animal facilities 29
  - laboratory 11, 12
- working areas, laboratory 11
- World Health Organization (WHO)
  - Biosafety Collaborating Centres **140**
  - Biosafety programme 25
- xylene 169