Managing safety, health and environmental risks in laboratories

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1 The Dutch term ‘arbo’ (arbeidsomstandigheden) refers to safety, health and welfare in the workplace, i.e. working conditions.

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Ensure that the drip trays are large enough and that dispensers cannot drip outside the drip tray.

explosion. These substances must also be stored separately. It suffices to place the bottles in different drip trays. Working stock is also placed in drip trays when there is a risk of leaking or breakage. In case of an incident, the contents will not spread throughout the room and flow underneath equipment, between cables or to other inconvenient places. The evaporating surface area in a drip tray is small and contained. The spill can be moved to the fume hood quickly for risk-free cleanup. Ensure that the drip trays are always large enough to contain the contents of the largest bottle.
Tips on the storage of hazardous substances have been included in appendix 3.

Working with closed systems and in drip trays, clearing leakages, and collecting and storing hazardous waste responsibly is important to prevent hazardous substances from spreading into the environment.

Do not pipette with your mouth

Pipetting with your mouth carries the risk that chemicals will end up in your mouth. Moreover, it is not very hygienic. Always use a rubber bulb or pipetting controller.

Figure 4.8

Pipetboy and rubber bulb

Ventilation

Laboratory areas have extra ventilation in order to avoid the accumulation of chemicals in the air. The air is renewed at least five times every hour. As a result, under normal circumstances people usually work far below the Threshold Limit Value (TLV).

Possible peak exposure, however, cannot be avoided with room ventilation. These peaks arise when, for example, a laboratory worker transfers liquids, weighs powders, or bends his/her head over a solution that contains solvents. With regard to work activities that increase exposure, it is advisable to make use of the chemical fume hood.

Appendix 5 include tips on safe use of the fume hood.
The fume hood has its limitations, too.

If you extract large quantities of hazardous substances, you may exceed the fume hood's capacity. This does not present a problem with normal use in the laboratory. However, it can play a role with highly toxic substances that are volatile as well. In that case, you can use the fume hood's containment factor to calculate whether an overly high concentration of the substance can be released outside[17,18]. If necessary, a fume hood with an extra high containment factor must be used. Dilution efficiency plays a role with flammable liquids, such as diethyl ether, because otherwise the lower explosion limit may be reached in the fume hood (see the calculation example in the box). If there is any risk of explosion, it is always better to use an explosion-proof fume hood. If you want to use equipment in an explosion-proof fume hood, make sure the equipment is also explosion-proof.

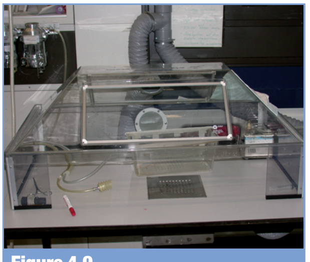


Figure 4.9

Local extraction of anaesthesia gases when working on laboratory animals

When you use localized extraction, it is good to know that the efficiency of extraction diminishes with the distance to the tube opening; at a distance equal to the tube's diameter, the extraction strength becomes negligible. Effective localized extraction is therefore located directly at the source, with the source being encased as much as possible (Figure 4.9). When encased, the casing directs the air flow to the extraction opening.
For powders, use dedicated exhaust systems. These have filters to capture the powder, thus keeping exhaust channels clean. Replace the filters in a timely manner.

Always check whetherthe fume hood or the local extractor is in good working order! The ventilator may have broken down or been switched off for maintenance, or may not work for other reasons. In chemical fume hoods, a tissue can be used to check whether the air is extracted in the right direction. The following are three examples of incidents related to ventilation:

- In a laboratory the chemical fume hood was switched off for maintenance for two days. This had not been properly communicated to the laboratory staff, who, during this period, continued working in the chemical fume hood as usual. Not until later was it discovered that the extraction did not work as it should.
- In an area where nitrogen was used for cryogenic storage the ventilation system stopped operating. The evaporating nitrogen was no longer extracted. A laboratory worker who walked into the room, suffocated. An oxygen meter combined with an emergency light on the outside of the laboratory area could have prevented this accident. If there is danger of asphyxiation, always check whether warning signals are present.
- A fume hood for weighing powders had no extraction: a control valve was closed. This was not discovered until for years, as no one checked the airflow during use and it had not been included in the maintenance schedule.

Figure 5.7

A horizontal laminar flow cabinet blows air into your face; it is only suitable for work with harmless materials and microorganisms.

biological hazard

Biosafety labs and other rooms

Work activities with pathogens and genetically modified organisms must be carried out in specially-equipped laboratories. In these laboratories the risk of spreading microorganisms is much smaller. The higher the risk, the higher the containment level of the laboratory that should be used. Biosafety laboratories are classified accordingly (see table 5.3). Laboratories from containment level 2 and onwards and ML-II laboratories must attach biohazard signs to their doors. The biological safety officer will be able to help you to assess the conditions under which your work should be carried out.

Transgenic animals, plants and microorganisms are also handled in other rooms, for example laboratory animal rooms, greenhouses, and growth chambers. Depending on the risk, specific equipping criteria also apply in this respect[1]. In most laboratories slight underpressure is applied to prevent the spreading of agents into the environment. Underpressure can only be maintained if access doors are kept closed! Specific criteria are included in the license for operations that cannot be carried out in these special rooms, such as field tests with genetically modified organisms.

Table 5.3
Containment levels for work activities with biological agents and genetically modified organisms. EU directives differ; the principle is the same, but the requirements for GMOs are a bit stricter.

Containment level	*Biological agents (EU-directive 2000/54/EC)*	*GMOs (EU-directive 2009/41/EC)*
low	–	ML-I
moderate	containment level 2	ML-II
high	containment level 3	ML-III
extra high	containment level 4	ML-IV

UV-decontamination is less effective than usually thought

In some laboratories, UV lights are used to keep work areas free of living microorganisms. Research has shown that using UV light for this purpose has many disadvantages[17]:
- Not all microorganisms are UV sensitive
- Only direct radiation is effective, even dust particles may protect microorganisms sufficiently against UV
- Dirty and old lights radiate less effectively.
- Material ages rapidly under the influence of UV.
- Dead microorganisms are not removed and form a nutrient medium for growth of microorganisms.
- UV is harmful for skin and eyes (see section 7.4).

Using UV light to decontaminate large areas is not effective. UV lights can be used in biological safety cabinets in combination with other decontamination methods. Avoid exposure to the eyes. Leave UV lights on only if nobody is at work, not even in the close environment. Be aware of and ensure you make appropriate use of the warning signals available to draw laboratory workers' attention to UV light.

Equipment maintenance
All equipment that is used when working with biological agents or GMOs can be contaminated. These include centrifuges in which the centrifuge tubing has leaked, as well as a vortex that was contaminated because of a liquid overspill. This equipment must be decontaminated after a spill, during regular maintenance or major overhaul, or prior to removal. The Infection Prevention Working Party has developed a sample regulation for microbiological safety during maintenance of medical and laboratory equipment[18]. The HEPA filters in biological safety cabinets must be considered to be contaminated. The people who replace them must be properly informed about potential risks.

Collection and disposal of biological waste
Biological waste should be collected separately. Depending on its composition and the pre-treatment method, this waste should be either disposed of: as infectious waste; as chemical waste; as radioactive waste (RA-afval); as waste containing animal by-products (dierlijke bijproducten); or as domestic waste (restafval). A waste stream scheme is set out in Figure 5.8.

The disposal and transport requirements in part depend on the pathogenicity and the risk of spreading in the environment once escaped. Waste that may have been contaminated with unknown or not very harmful pathogens is disposed of as Specific Hospital Waste (*specifiek ziekenhuisafval* or *SZA-afval* for short) or clinical waste.

eye protection mandatory

- A researcher switches on a light box that he just repaired in order to check whether it works. Exposure lasts about 30 seconds[1].
- Cleaners are working in a laboratory unaware of the fact that the UV light is on. After a while they call on the company medical officer with skin and eye problems.

These examples show that even short-term exposure of the eyes to UV lights might cause damage. The eye reflex makes eyes adapt to the intensity of visible light, but not to that of UV light.

Another example from practice
Two workers in the same laboratory contracted cataracts at a young age. The specialists who treated them expressed their surprise about this phenomenon and UV exposure in the workplace was therefore further evaluated. While working with the UV transilluminator, the laboratory workers only used their face shields when looking directly into the UV source. The face shield was very dirty and therefore less clear, so that they took them off whenever they could. To offer adequate protection, face shields should be worn tight to the face, which will soon give a closed-in feeling. Laboratory workers were inclined to put their face shields further away from their faces which considerably reduced the protection provided.

Immersion lights, photochemical reactors, grow lights, and UV transilluminators all transmit high-intensity UV radiation. With some of these lights, the level of harmful exposure is already reached after a relatively short period. UV light in laboratories is mostly used for decontamination purposes. Lights that are most effective for decontamination purposes are also the most harmful ones for the eyes. Some laboratories use UV lights for detection, in chromatography, for example. This could also result in exposure.

Mercury-vapor lamps, xenon lamps and neon lights transmit UV of a lower intensity. When the work is carried out at a normal distance from these lights, exposure will not be higher than in the outside air.

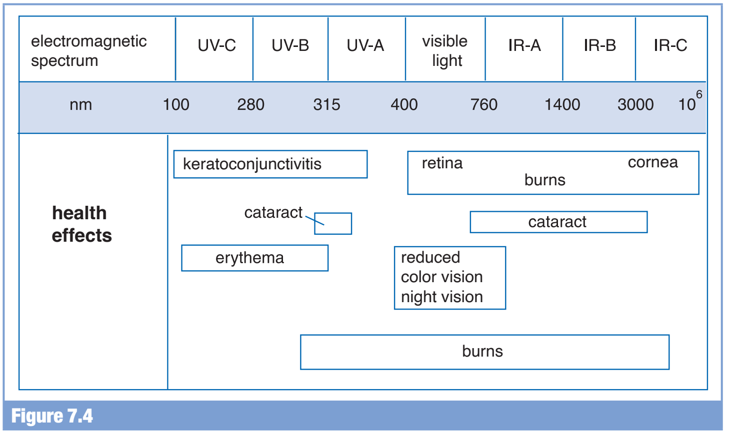
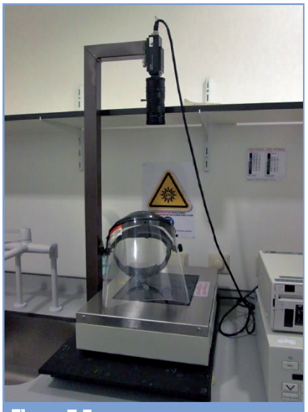


Figure 7.4

Biological effects of extensive exposure to UV light, visible light and infrared light (source: International Commission on Illumination)



Transilluminator with face shield.

Preventive measures

Determine whether using UV actually has added value in your case. The following key points apply if you still need to work with UV:

- Opt for UV lights whereby radiation is shielded as far as possible.
- Shield the UV radiation in experimental set-ups in order to limit the amount of scattered radiation.
- Inform your colleagues if you need to work with UV. This can be done by switching on the warning signs present in the laboratory.

In the event of potential UV exposure, UV goggles should definitely be worn. These goggles should also be worn when not looking directly into the radiation source. From a viewpoint of availability and hygiene, the use of personal UV goggles is preferred. It is also advisable to wear protective clothing and a UV-resistant face shield. Of course, UV goggles do not prevent exposure of the skin. Properly maintain goggles and face shields so that they remain pleasant to use.

Blue Light Hazard[6]

Sources of light and radiation with other wavelengths may also be harmful (figure 7.4). Intensely radiating blue LEDs, for instance, may cause photochemical aging of the retina (Blue Light Hazard). Blue LEDs are also close to UV and sometimes inadvertently radiate UV. When using intense radiation sources, check whether screening of the light source or the use of laser goggles is necessary.

7.5 Lasers

The light transmitted by lasers carries particular risks[7]. A laser is characterized by an electromagnetic beam with a small diameter but with a high power density. As a result of the high power density, lasers may damage the skin and eyes. The eye usually projects incoming light at a single point (see figure 7.6).

Because of this projection, the laser beam as such is concentrated even more on a small surface. All the heat is released at this point and, with high-power lasers, it cannot be discharged quickly enough to avoid retinal damage. With normal light, the eye reflex protects the eye if exposure is too high. However, the laser beam may have such a high intensity that the eye reflex no longer responds in time. Furthermore, lasers are generally used in darkened rooms so that the pupil's diameter is particularly large, which, in turn, increases the risk of eye damage. The eye reflex does not respond at all with UV and infrared lasers and therefore offers no protection whatsoever. Far infrared lasers (FIR) and far ultraviolet lasers (FUV) do not penetrate deep into the eye but could still damage the cornea and/or lens.

Figure 11.1

Lifting a crate from a lower cabinet with all materials needed for a single analysis is unnecessarily heavy and the cables hamper this action. Use manageable crates and remove obstacles.

- Frequent lifting of material weighing up to 10 kg (jars, bottles, small laboratory animals), or occasional lifting of heavier material: use the appropriate lifting technique – do not lean down but bend the knees, keep the object straight in front of, and close to, the body.
- Exposure to vibrations (vortex, vibrating equipment): do not continue operations for too long.
- Visual information that is not in the field of vision: this will force prolonged looking up or down, turning the neck frequently, or sitting in a huddled position. Put important data carriers in the field of vision.
- Not enough leg room when sitting: this will force you into constantly leaning forward and reaching. Do not use the space under the lab tables for storage. Use a cabinet without bottom cupboards, if possible. When working for a long time in a chemical fume hood without leg room, use a saddle stool.

Figure 11.2

It is also possible to sit up straight when working at a biological safety cabinet. Sufficient leg room and a saddle stool that is properly adjustable, or a chair with a foot rest, are essential in this respect. It is very useful if the biological safety cabinet itself has a narrow sash edge and a sloping sash framework, so that the laboratory worker's view is not obstructed and the stool can be pulled up close.

Computer work

By now, computer work has become a well-known cause of pain in the shoulders, neck, arms and wrists.
Postures that usually give rise to complaints include:

- Holding the arms too far in front of you when typing or using the mouse: shoulder pain.
- Positioning the computer screen to one side instead of in front of you: neck ache.
- Leaning the arms on the tabletop and looking up: neck ache, pain in the elbow and forearm.
- Leaning the wrists on the tabletop while typing or using the mouse: pain in the wrist.

Figure 11.3 outlines the basic principles of an ergonomically correct computer workstation. Make sure the angles at the elbow and knee are larger than 90° to support good blood flow. Make sure that a fist fits in the space between the knee cavity and the seat, so you have enough

support from the chair and pinching is prevented. Make sure you look at the screen at a relaxed angle.
Pay attention to the workstations where PCs are connected to laboratory equipment. A chair on wheels is absolutely essential because, one moment people will be working with analysis equipment and the next they will be at the computer. Because people of different sizes will be working with these machines, it is particularly important that chairs are adjustable in height.

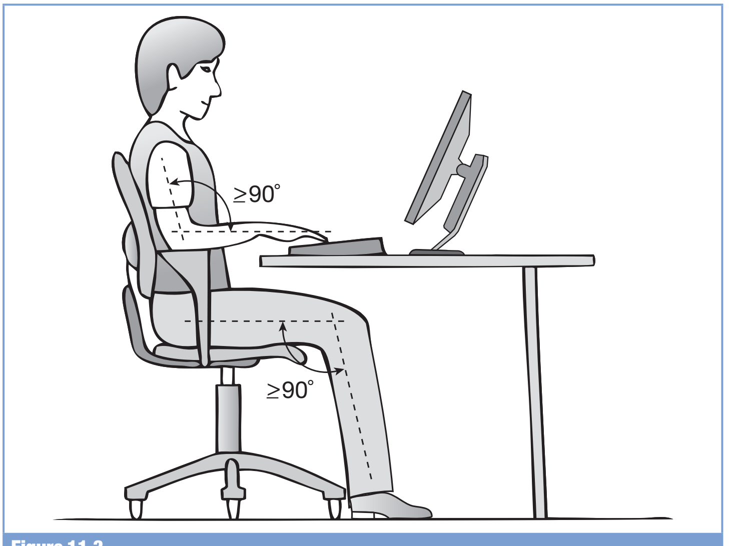


Figure 11.3

Basic principles of an ergonomically correct workstation

Figure 11.4

When using computers linked to analysis equipment, also pay attention to your posture. Do not lean on your wrist when using the mouse. Use a height-adjustable chair when you must work behind the computer for longer periods of time.