### 6.9.2 Ultraviolet irradiation

Ultraviolet (UV) irradiation is the preferred method for disinfection of small supplies except for larger schemes in which it is necessary to maintain a residual disinfectant during storage and distribution. UV disinfection efficiency is particularly affected by water quality and flow rate. The water to be disinfected must be of good quality and particularly low in colour and turbidity. It is generally necessary for the turbidity of water to be less than 5 NTU, preferably much lower, for successful UV disinfection. Therefore pre-filtration is advisable, especially if *Cryptosporidium* is likely to be present, as discussed below.

Special lamps are used to generate UV radiation, and are enclosed in a reaction chamber made of stainless steel or, less commonly, plastics. Low pressure mercury lamps, which generate 85% of their energy at a wavelength of 254 nm, are most commonly used; their wavelength is in the optimum germicidal range of 250 to 265 nm. These lamps are similar in design, construction and operation to fluorescent tubes except that they are constructed of UV-transparent quartz instead of phosphor-coated glass. The optimum operating temperature of the lamp is around 40 °C so the lamp is normally separated from the water by a 'sleeve' to prevent cooling by the water. The intensity of UV radiation emitted decreases with lamp age; typical lamp life is about 10 to 12 months after which the output is about 70% of that of a new lamp, and lamp replacement is required.

The usual UV reactor configuration is a quartz-sleeved low pressure mercury lamp in direct contact with the water; water enters the unit and flows along the annular space between the quartz sleeve and the wall of the chamber. Other configurations include lamps separated from the water, for example lamps surrounded by 'bundles' of PTFE tubes through which the water flows.

Disinfection will only be effective provided that a sufficient dose of UV is applied. The 'dose' of UV radiation is expressed as an energy flux, in units of $mW.s/cm^2$ (milliwatt seconds per square centimetre), which is the product of the intensity given out by the lamp and the residence time of water in the reactor. The minimum dose required for disinfection depends on several factors, including the susceptibility of micro-organisms but is generally taken to be in the range 16 to 40 $mW.s/cm^2$.

It is important, to ensure effective disinfection, that both residence time and UV intensity are adequate. UV intensity will be diminished by ageing of the lamp, fouling of the lamp by deposits, and absorption of UV radiation by water contaminants such as natural colour. For these reasons, lamps need to be changed at the recommended intervals and the quartz sleeve may require periodic cleaning. Some units incorporate a manual 'wiper' for cleaning whilst others incorporate automatic mechanical cleaning.

Colour and turbidity will both affect radiation intensity in the reactor and turbidity may protect micro-organisms from the radiation. The water to be treated should be tested for transmissivity by the manufacturer or supplier in order to estimate worst-case transmission values and to adjust contact time accordingly. More advanced units incorporating UV monitors have the facility to automatically adjust the energy input to the UV lamp to achieve the required UV intensity.

### 6.9.2 Ultraviolet irradiation (continued)

The water flow rate affects the retention time in the reactor, which is designed for a maximum flow rate. The maximum water flow rate should not be exceeded.

There is evidence that UV is effective in inactivating *Cryptosporidium* provided that a sufficient UV dose is applied although there is a dearth of data on effectiveness under high-risk conditions of water quality. However, where *Cryptosporidium* is likely to be present and cyst removal is required then pre-filtration capable of removing particles of 1 mm diameter is recommended prior to UV disinfection. Pre-filtration provides an additional barrier to passage of oocysts into the treated water, removes particles that shield micro-organisms from the UV light and helps to reduce fouling of the UV lamp.

Several new treatment technologies have been developed for inactivation of *Cryptosporidium*. These include pulsed UV or white light systems and combined filtration-irradiation or adsorption-irradiation techniques that increase exposure to UV, for example by trapping the micro-organisms on a filter then subjecting them to UV irradiation. Pulsed UV and pulsed white light devices that generate high intensity, short duration, pulses of radiation are reported to give more effective inactivation of oocysts than conventional UV systems. At present, such systems are not applied to any extent for treatment of small water supplies.

UV irradiation equipment is compact and simple to operate. Maintenance requirements are modest, although specific systematic maintenance is essential. Other advantages include short contact time and the absence of any known by-products of significance to health. An ‘overdose’ of UV presents no danger and actually adds a safety factor. The principal disadvantage is the absence of any residual effect, necessitating careful attention to hygiene in the storage and distribution system.

The build-up of scale on the sleeves of the lamps will eventually reduce their transmittance and they must be cleaned or replaced regularly. Some units have UV intensity monitors and alarms which provide a continuous check on performance and these are strongly recommended. These devices may prevent the flow of water if the required intensity of UV radiation is not achieved, for example when the lamps are warming-up or because of scale formation. UV intensity monitors may not be available on smaller units and it is therefore essential that the manufacturer’s instructions regarding lamp warm-up, cleaning and replacement are followed to ensure optimal performance.

Lamp replacement is usually a simple operation but may involve a significant downtime for reactors with many lamps. This difficulty may be overcome by use of multiple units or by having a treated water storage tank capable of maintaining supply whilst maintenance is carried out. The materials of construction and design of storage systems should not allow deterioration in water quality to occur.