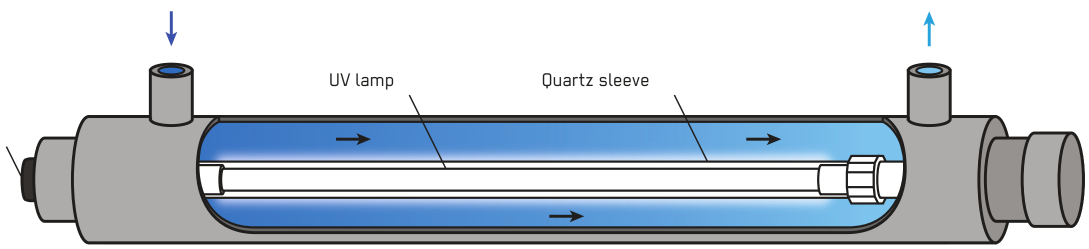
Ultraviolet (UV) Light

Response Phase	Application Level	Management Level	Objectives / Key Features
* Acute Response ** Stabilisation ** Recovery	** Household ** Neighbourhood ** City	** Household ** Shared ** Public	Disinfection
Local Availability	**Technical Complexity**	**Maturity Level**	
** Medium	** Medium	*** High	



Under correct design and operational conditions, Ultraviolet (UV) Light can have anti-bacterial and anti-viral properties and can destroy pathogenic organisms in non-turbid water.

UV Light can cause irreparable cell damage to pathogenic microorganisms, and its effectiveness depends on the exposure time, the intensity of the UV light, the wavelength of the UV light and the raw water quality. UV provides a 3-Log inactivation of vegetative bacteria and protozoan parasites, including Cryptosporidium and Giardia at low exposures (1–10 mJ/cm^2). For the inactivation of enteric viruses and bacterial spores, higher exposures (30–150 mJ/cm^2) are needed. The exposure time depends on the design and the flow rate. UV is more effective on some pathogens (e.g. Cryptosporidium) that are resistant to the most widely applied chemical disinfectant (chlorine) and, unlike chlorine, UV does not form harmful disinfection by-products (DBPs). However, UV disinfection does not provide any residual protection from microbial recontamination and regrowth.

Design Considerations: A typical UV disinfection system includes a series of UV tubes. UV lamps are installed inside a tube in a covered channel, ensuring proximity of the water to the UV source. If the lamp is not placed directly in the flow, it will need a fused quartz sleeve to allow UV emission. The tube is usually made of plastic or stainless steel with a light-reflecting inner surface. To avoid unwanted turbulence, the inlet piping should have no upstream expansions for at least 10 pipe diameters, and all valves in the piping should be fully open during UV operation. The required UV dose for water disinfection is usually $\geq$ 40 mJ/cm^2, and only certified UV systems providing at least this dose under typical flow regimes should be used.
Turbidity and suspended solids reduce the disinfection efficiency. To be effective, turbidity should be < 1 NTU, suspended solids < 10 mg/L, no colour, iron < 0.3 mg/L, and manganese < 0.05 mg/L; otherwise, pre-treatment is required. Conventional clarification processes, such as Rapid Sand Filtration **(T.2)**, Microfiltration **(T.3)** or Ozonation

(T.14), can be used depending on the composition of the raw water and the context. Decentralised drinking water treatments most commonly use low pressure, low intensity mercury lamps that emit a single peak of UV radiation at 254 nm. For large-scale systems, medium pressure lamps are typically used that emit UV radiation over a very broad range (185–400nm). UV-emitting LEDs are also becoming more popular.

Materials: UV disinfection reactors can be skid-mounted and shipped to site. Validation can be conducted off-site, pre-shipment. UV requires reliable electrical power, so many installations include backup power, and specialised consumables, such as cleaning materials, chemicals and wipers, and periodic lamp replacements. UV lamps may not be readily available in some contexts and may have to be imported or flown in.

Applicability: UV systems can potentially be applied in all phases of an emergency and implemented quickly when materials, spare parts and skilled operators are available. These systems require a reliable power source **(see S.9–S.12)** and water pre-treated to a minimal turbidity (< 1 NTU). UV does not provide residual protection, so additional Chlorination **(T.6)** is needed.

Operation and Maintenance: UV systems require careful operation, knowledgeable and well-trained operators and monitoring to ensure effectiveness. Accurate measurements of flow rate, UV intensity, UV transmittance, and lamp status are required. Large-scale UV systems are designed for continuous operation and should be shut down only if there is no need for treatment for several days. Lamps need to be warmed-up for a few minutes before operation. For community and small-scale systems, daily operation includes switching the lamp on and off depending on the water flow, which is usually a fully automated process.
When the set lamp exposure deviates too far from the measured UV dose (~70 % or less from set/initial value), a number of reasons should be considered: (1) UV-absorbing matter (dissolved or suspended) may interrupt the path of light, and the reactor should be flushed. Upstream water should be checked for turbidity, and if necessary, pre-treatment must be improved. (2) The UV sensor or lamp may be dirty. Here, the reactor has to be opened, and the sensor, lamp and inner reactor surface should be cleaned with a soft cloth to avoid scratching. In many systems, an integrated sensor monitors the UV light intensity at each treatment tube. Some systems have an automated cleaning mechanism that wipes the quartz sleeves around the lamps once the sensor indicates a reduction of intensity below a certain set threshold. When fouling of the lamp chambers occurs too fast, any upstream treatment should be checked for proper operation. (3) If neither (1) or (2) applies, the UV lamp must be replaced. The nominal lifetime ranges from 8,000–12,000 operating hours (about 1 year of continuous operation) for mercury lamps. For LEDs, the life span varies depending on the specifications and manufacturer. During lamp replacement, the inner surface of the reactor should be inspected and cleaned.

Health and Safety: UV provides no residual protection from downstream microbial recontamination during transport or storage at home. UV-treated water should therefore be distributed and stored safely (constant overpressure in the distribution networks and/or adding residual chlorine). If the lamp breaks, toxic mercury may be released into the environment, potentially causing a health risk to the operator and harming the environment. Low pressure lamps represent less of a threat to operators in the case of breakage, and LEDs are generally safe. The operational monitoring of UV disinfection is less difficult than chlorine dosing systems, as it can be done by monitoring technical operational parameters of the UV lamp or through microbial water testing.

Costs: Capital costs vary depending on the system type. Low pressure systems will cost in the range of 50 USD/m^3/day capacity. Operational costs are context-dependent and vary in the range of 2.7–4 USD/m^3/day capacity and include electricity consumption and the periodic replacement of lamps and other specialised components.

Social and Environmental Considerations: UV treatment is usually well accepted by consumers, as it does not affect the taste of water. UV lamps should be disposed of safely and in accordance with national regulations to prevent harm to the environment.

Strengths and Weaknesses:

- (+) Requires no chemicals and forms no disinfection by-products
- (+) Does not modify taste and odour
- (+) Efficiently disinfects microorganisms, including those with high chlorine resistance

- (−) Requires reliable power supply
- (−) Has no residual disinfectant (safe distribution and storage must be assured)
- (−) Requires pre-treatment for turbid waters to reduce turbidity and total organic matter content
- (−) Spare parts might be not available locally

→ **References and further reading material for this technology can be found on page 218**