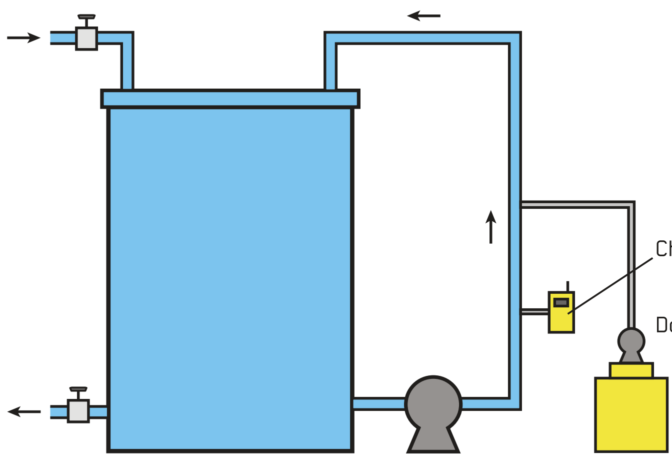
Chlorination

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



Chlorination is a final drinking water treatment step, as it inactivates pathogens such as bacteria and viruses. It is also used for other purposes such as disinfecting infrastructure (e.g. wells, pipes or boreholes) and equipment (e.g. in cholera treatment centres, X.14). It is used in all phases of an emergency.

Chlorination is applied at all treatment scales from a household level to centralised treatment. Chlorine provides ongoing protection from recontamination, which makes it unique over other disinfection processes such as Ultraviolet Light **(T.8)** or Ozonation **(T.14)**. It is strongly recommended for drinking water in emergencies, where hygienic conditions are often compromised and people are more prone to disease.

Design Considerations: For Chlorination to be effective, the water turbidity should be less than 5 NTU, although in emergencies, up to 20 NTU can be accepted for short periods while pre-treatment is established. Chlorinating turbid water (over 5 NTU) wastes chlorine, results in poorer disinfection (suspended solids can protect pathogens), increases the chlorine smell and taste (causing users to reject the water), and can generate potentially harmful by-products (e.g. trihalomethanes that are carcinogenic in the long term). For chlorine to disinfect properly, factors such as temperature and pH (should be < 8) have a major impact.
Chlorine exists in different forms with differing percentages of active chlorine. In emergencies, the most commonly used product for bulk treatment is calcium hypochlorite (also known as High Test Hypochlorite or HTH, 65–70 %). Other products are sodium hypochlorite (liquid bleach, 2–15 %), chlorinated lime powder (30 %) and chlorine gas (100 % elemental chlorine). Chlorine can be dosed at the source (e.g. borehole), as the final step of water

treatment in the treatment plant, at the Point of Supply **(H.7)** or at the Point of Use **(H.6)**. Types of dosing include batch dosing where chlorine is added to a fixed volume (e.g. a water truck), constant rate dosing where chlorine is added at a fixed rate (e.g. water flowing at a steady rate) and proportional dosing where chlorine is added at a variable rate (e.g. for solar pumping where water flow varies). In cholera outbreaks **(see X.14)**, batch dosing individual water containers at the point of supply/collection (known as 'bucket Chlorination', **H.7**) is useful as a temporary measure in areas identified as high risk (based on patient origins).
For drinking water, chlorine dosages range from 1–6 mg/L (0.5–2 mg/L for non-turbid water) for a standard 30-minute contact period. The amount that has then been used up is referred to as the 'chlorine demand', and the amount remaining is known as 'free residual chlorine' (FRC), which should be between 0.2–0.5 mg/L. The actual optimal dose for any water cannot be calculated in theory and is determined experimentally by a 'jar test' using a series of buckets containing an increasing dose of 1 % chlorine. Residual chlorine degrades over time, though will disappear faster when there is more contamination from pipes and containers, where temperature is higher and where there is more turbulence and mixing with air (e.g. pumping in long pipelines). Residual chlorine should still be present at 0.2 mg/L or more when the last cup is consumed at the household, so a higher FRC level might be required at tanks and tapstands depending on local conditions.

Materials: Materials include the chlorine product, a place for storing it safely, a mixing mechanism, a dosing mechanism (electric or mechanical) and equipment for monitoring residual chlorine.

Applicability: Chlorination should be carried out at all scales and in all phases of an emergency, especially in the acute response, because its residual presence can keep water safe for some time in storage tanks and distribution networks and during transport and storage in households. It is the method of disinfection that is often mandated for emergency response.

Operation and Maintenance: The main O & M tasks include the daily operation of chlorine mixing and dosing and monitoring the residual chlorine in the network. Monitoring in non-epidemic conditions should be carried out daily at tanks and treatment plants. A certain number of samples from the distribution network is recommended per month according to population, and chlorine should be continuously monitored at the household level via random checks. Chlorine should never be stored in or near metal containers and should not be stored in the sun, hot and humid warehouses or enclosed and unventilated buildings.

Health and Safety: Chlorine is a gas that is denser than air, is highly corrosive, can burn skin, cause blindness and damage internal organs, leading to death. Chlorine should always be kept in well-ventilated storage facilities and not near fuel, fertiliser or dry powder fire extinguishers. Different chlorine types should never be mixed (risk of explosion). Adequate training and safety equipment (protective glasses, gloves, mask) should be provided for all staff in contact with chlorine. Potentially carcinogenic trihalomethanes (THMs) can be produced when chlorinating turbid water or water with a high organic content. While chlorine can reduce bacteria and viruses by 3 to 6-log, it is not an efficient method of disinfection against Cryptosporidium, Giardia and some bacterial spores under normal dosing conditions.

Costs: Chlorination is generally not expensive, as not much is required to dose chlorine to water (e.g. typically under 35 kg of HTH will be sufficient to treat water for 20,000 people for a month). Most costs are related to the ongoing monitoring that requires employed staff.

Social and Environmental Considerations: Acceptance varies depending on the context and whether people have had previous exposure to it. There are mistaken perceptions linked to chlorine (e.g. chlorine confused with cholera), so community engagement is a key element for effective implementation. As chlorine changes the taste of water, this can also lead to rejection. Leakage of concentrated chlorine into the environment from poor storage, transport or treatment facilities is a severe environmental and health hazard. The release of chlorinated water into water bodies can harm the environment.

Strengths and Weaknesses:

(+) Provides residual disinfection
(+) Is cheap to operate
(+) Usually locally available
(+) Reliable method if water is not turbid

(−) Requires proper storage/transport
(−) May have limited availability in conflict areas
(−) Can limit acceptance due to high impact on taste
(−) Effectiveness depends on various factors like temperature, sanitary conditions, pH and turbulence
(−) Ineffective in turbid water or against certain organisms (e.g. Cryptosporidium)

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