Government of Sudan

Federal Ministry of Health

Ministry of Water Resources, Irrigation and Electricity

Protocols for the chlorination of drinking water

(for small to medium sized supplies)

31 Dec 2017

Contents

Acronyms

Ct	Chlorine concentration x contact time
DWQ	Drinking water quality
DWS	Drinking water safety
FMoH	Federal Ministry of Health
FRC	Free residual chlorine
HTH	High test hypochlorite
HWTS	Household water treatment and safe storage
MoWRIE	Ministry of Water Resources, Irrigation and Electricity
NaDCC	Sodium dichloroisocyanurate
NTU	Nephelometric Turbidity Units
PPE	Personal protective equipment
RedR	Register of Engineers for Disaster Relief
SDW	Safe drinking water
THM	Trihalomethanes
UNICEF	United Nations Children's Fund
WHO	World Health Organisation
WSP	Water Safety Plan

Glossary of terms

Chlorine demand	The extent of reaction between chlorine and organic and / or inorganic material present in water that consumes chlorine and results in a decrease in the chlorine concentration.
Chlorine decay	The decrease in chlorine concentration as water passes through a water supply system due to the reaction between chlorine and organic and/ or inorganic materials.
Chlorine dose	The concentration of chlorine added to drinking water, usually expressed in milligrams per litre (mg/L).
Combined chlorine	The concentration of chlorine bound to nitrogen compounds (which have limited chlorination capacity).
Contact time	The time of contact between chlorine and water for disinfection to occur.
Detention time	The amount of time it takes for water to pass through a system at a given flow rate.
Pre-chlorination	A pre-treatment stage where chlorine is added before water treatment. For example, this may be employed to assist with the removal of minerals such as iron or manganese.
Residual chlorine	The concentration of chlorine remaining that is free for residual disinfection after the chlorine demand has been satisfied.
Total chlorine	The concentration of chlorine remaining after the chlorine demand has been satisfied and disinfection has occurred. It consists of residual and combined chlorine.
Turbidity	The opaque (or cloudy) appearance of water caused by the presence of organic and inorganic particles.
Water safety plan	A framework for assessing and managing water quality risk at all stages of a water supply system, from catchment to consumer.

Acknowledgements

Some of the content of this protocol has been taken directly from or adapted from material in the publications:

- *'Principles and practices of drinking water chlorination: a guide to strengthening chlorination practices in small to medium sized water supplies'* by the World Health Organization, Regional Office for South Asia; 2017. Licence: CC BY-NC-SA-SA 3.0 IGO.
- Training materials on 'Chlorination' prepared by Eric Fewster, BushProof.
- Reed, R.A. (Ed.) (2013) *Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies*, WHO and WEDC

Its development has been funded by the Qatar Fund for Development and the World Health Organisation (WHO). It has been supported by a Core team of representatives from: the Federal Ministry of Health (FMoH); the Ministry of Water Resources, Irrigation and Electricity (MoWRIE); the World Health Organisation (WHO); UNICEF; and Register of Engineers for Disaster Relief (RedR).

1. Key Facts: Chlorination

<u>Chlorine – the basics:</u>

1. Disinfection is one of the control measures that contributes to ensuring drinking water safety (DWS) and is often a key component of Water Safety Plans (WSPs).
2. Disinfection with chlorine is used to kill or inactivate the pathogens that can be found in drinking water that can lead to illness or death. People who may be the most vulnerable to poor drinking water quality include very young children, older people and people who are chronically ill.
3. Chlorine exists in different forms – as a solid (e.g. powder or tablet), liquid or gas. It can lose strength over time, a process which is accelerated by storage in hot and humid conditions.
4. Chlorine is very chemically reactive, reacting with, for example, organic material, microorganisms and metals (including metal pipe material and pipe fittings).
5. Chlorine has a distinctive, characteristic taste and odour, which can increase from reactions to organic matter and may be detected by individuals when smelling or drinking the water and may lead to consumer complaints and some people rejecting the drinking water and seeking out less safe water sources.

<u>Chlorine – hazards:</u>

6. Chlorine is a hazardous chemical and is corrosive. It can cause severe irritation and chemical burns to human tissues such as skin, can damage material such as metal pipes and can also cause fires and explosions.
7. Chlorine must be stored and handled very carefully. Storage must be in a well-ventilated unoccupied place and not next to other volatile substances, and people who handle it must wear the appropriate personal protective equipment.

<u>Chlorine – dosages and residuals:</u>

8. The disinfection efficiency of chlorine is affected by pH, turbidity and temperature and it requires a certain contact time to allow the disinfection process to take place. Water that is chlorinated should always be visually clear and have a low turbidity level (ideally < 1 NTU) – where this is the case, adequate disinfection can be assured after a contact time of 30 minutes in standard conditions (at 20 ^{o}C, where the pH is less than 8).
9. Once chlorine is dosed into water, it becomes more volatile. Exposure to air means the chlorine may be lost from the water phase and it is also affected by the heat and can more easily evaporate in hotter climates.
10. If the dosage is calculated properly, some free residual chlorine (FRC) will remain in the water after disinfection has occurred; this can protect drinking water from re-contamination by harmful microorganisms during bulk storage, distribution to the consumer and storage in the household.
11. The chlorine dose is usually between 1-5 mg/l for drinking water depending on the level of turbidity, pH, temperature and contact time.
12. It is important to monitor the FRC on a regular basis to ensure that the appropriate dosages have been made and adequate residual remains. For Sudan, which has a very hot climate, this means aiming for:
    a. 0.2 mg/L FRC in the household after 24 hours storage
    b. 0.5 to 1.0 mg/L FRC at the point of distribution – but the exact FRC for a particular context must be based on testing downstream at the household level to check if this results in the required household residual after 24 hours. Where this is not the case, FRC needs to be adjusted upstream.

2. Introduction

2.1 Why chlorinate?

The biggest risk from unsafe drinking water supplies is for people who are most vulnerable due to their age or poor health situation, such as young children (and in particular children who are malnourished), older people, and people with chronic illnesses. People affected by humanitarian emergencies, including those who have faced displacement, can also be particularly vulnerable due to crowded and unhygienic living conditions.

Some micro-organisms are naturally found in water sources, but others may be introduced through human activities, such as through contamination from human or animal open defecation. Micro-organisms that are harmful to health are called pathogens (which include bacteria, viruses and protozoa) and can cause a range of diseases, such as typhoid, polio, Giardia and Acute Watery Diarrhoea.

Disinfection is the process used to kill pathogenic micro-organisms in drinking water, rendering it safe to drink. Globally, chlorination is the most common method, and it is often the preferred method of disinfection because of the fact that chlorine residual remains in the water after the point of supply to respond to the challenge of post-supply contamination.

See **Fig. 1** for an overview of the Sudan Drinking Water Safety Strategic Framework (SDWSSF) and the locations in the water supply chain where disinfection usually occurs. The figure also highlights the process of WSPs and in particular the actions of operational monitoring, verification of the effectiveness of control measures, surveillance and remedial actions, all of which are critical for effective chlorination.

2.2 Purpose, scope, limitations and structure

2.2.1 Purpose of this document

This document aims to provide guidance for water sector professionals with responsibilities for the chlorination of drinking water supplies across Sudan. It aims to strengthen chlorination practices to ensure that adequate FRCs will remain in drinking water at the point of consumption, reducing risks to disease and loss of life.

2.2.2 Scope and limitations

This document covers chlorination in both longer-term and emergency contexts and considers both batch and on-line dosing.

It does not provide guidance on: a) the use of chlorine for treatment objectives other than disinfection; b) the use of chlorine gas; or c) chloramination. It also does not cover other types of disinfection such as the use of ozone, ultra-violet radiation, boiling, filtering using silver, or using chlorine dioxide or bromine.

2.2.3 Structure of the document

The document is structured:

3 – Chlorination theory – *describes the concepts and how chlorination works in practice*

4 – Health and safety – *describes how to keep safe when undertaking chlorination*

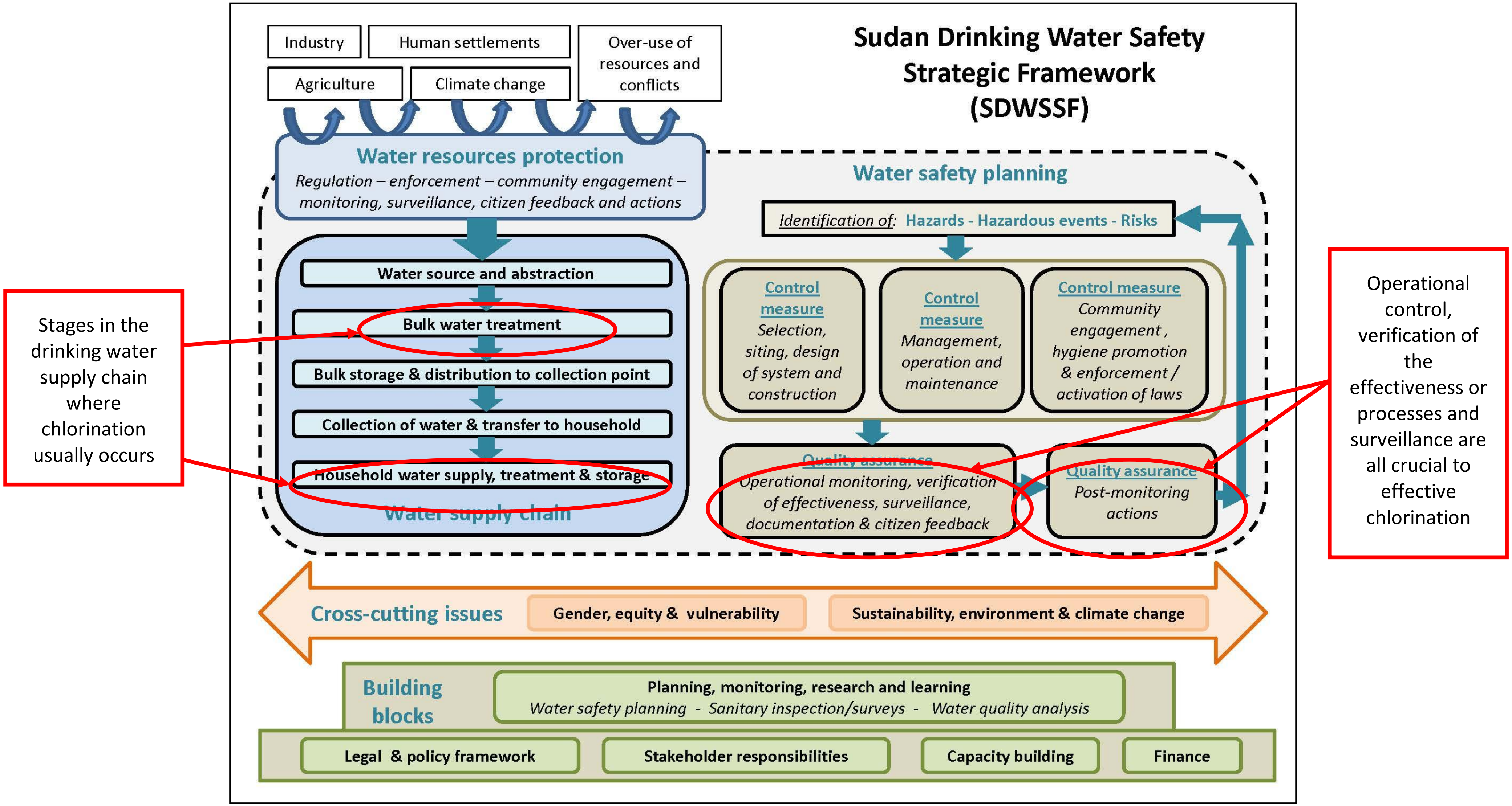
5 – Practical chlorination – the basics – *describes the basic steps in chlorination*

6 – Practical chlorination – by context – *covers chlorination in specific contexts*

Annex I – Protocols – *step by step guidance for specific tasks*

Annex II – References - *for more information*

Fig 1 - Sudan Drinking Water Safety Strategic Framework



3. Chlorination theory

3.1 Properties of chlorine

Chlorine is a powerful disinfectant which can kill or inactivate micro-organisms including harmful pathogens. But although it is an effective disinfectant it does not kill all harmful micro-organisms. See **Box 1** below.

Box 1 - The relative effectiveness of chlorine against micro-organisms

In general chlorine is more effective against bacteria and viruses[1] and least effective against certain protozoa. Protozoa may survive for long periods in the environment by forming a type of durable shell called a cyst or oocyst. This is an important consideration for the supply of safe drinking water, as chlorine has little practical effectiveness against these resistant protozoa (e.g. *Cryptosporidium*). Other drinking water treatment processes may be required to effectively remove or inactivate protozoa, such as filtration or disinfection by ultraviolet (UV) light.

See **Section 1** - for a summary of the key properties of chlorine.

3.2 Product types and strengths

Common chlorine types and strengths are summarised in **Table 1** - which also includes information on the stability of the product.

<u>Considerations for storing and selecting the chlorine type for disinfection:</u>

- Chlorine gas typically contains pure chlorine. Chlorine powder and liquid do not contain pure chlorine and are mixed with other substances such as calcium, sodium or water. The concentration of chlorine in a product is typically expressed as a percentage (%) of active chlorine present.
- The storage of chlorine affects its stability. Chlorine will lose some strength annually, and storage in hot and humid conditions (e.g. in a Rubbhall next to the sea) or in direct sunlight will speed up the reduction in its disinfection capacity.
- Sodium dichloroisocyanurate (NaDCC) tablets are often the first choice for chlorination during emergency situations, for household chlorination and for small water distribution points, due to its stability, ease of transportation including by air freight and lower health and safety risks.
- Calcium hypochlorite powder (also known as High Test Hypochlorite or HTH) is often used in small-scale water treatment plants and in emergency contexts, due to its stability, strength and lower transportation costs than chlorine liquid or gas.
- Although chlorine powder can be added directly to drinking water, typically it is firstly dissolved in water to form a liquid solution that is then added to the drinking water.
- Chlorine gas although considered an effective method of chlorination, is typically only used in large water treatment plants. This is because of:
  i. The high cost of the chlorine gas dosing equipment
  ii. The availability of expertise and specialist parts for O&M of the dosing system
  iii. The availability of chlorine gas supply

[1] References vary in their assessment of whether bacteria or viruses are more or less susceptible to chlorine. WHO Guidelines on DWQ notes that bacteria are the most susceptible to chlorine compared to viruses, but CDC data indicates viruses are more susceptible than bacteria (https://www.cdc.gov/safewater/effectiveness-on-pathogens.html). These statements may vary by the type of virus or bacteria, each having different levels of susceptibility. Bacteria typically exist as actively growing or 'vegetative' cells which are very susceptible to chlorine disinfection; however, under certain circumstances, particular bacteria may also form cyst-like 'spores' for environmental survival; chlorine may be ineffective against certain bacterial spores.

iv. Safety considerations as it is a very dangerous chemical (chlorine gas has been used as a weapon in conflicts)

- In some countries liquid sodium hypochlorite is increasingly being used, and chlorine can also be produced on site from sodium salts through a process of electrolysis.

Table 1 - Chlorine types and properties

Chlorine powder	
Appearance	• White powder or granules
Strength	• Typically 30 to 70% active chlorine • Generally mixed with water to make a liquid solution before use
Stability	• Loses strength over time; but more stable than chlorine liquid • HTH and bleaching powder after 40 days may lose: a) 5% if the container is opened for 10 minutes every day; b) 18% if left open for 40 days[2]. If it is kept in a sealed container the chlorine remains more stable - one estimate is that it would lose about 2% per annum and another is it will retain about 90% of its strength in 12 months.
Application	• Typically used for small water treatment plants and in emergency situations
Examples	• Bleaching powder, otherwise known as chlorinated lime (approx. 30-35% active chlorine) • Calcium hypochlorite / High Test Hypochlorite (HTH) (approx. 65-70% active chlorine) - $Ca(OCl)_2$
Chlorine liquid	
Appearance	• Pale yellow to clear liquid
Strength	• Typically 1 to 15% active chlorine.
Stability	• May lose strength over time; less stable than chlorine powder • Sodium hypochlorite (bleach) may expire in 6 months (15% strength solution may lose 50% potency in 3 months; 10% strength solution may lose 50% potency in 6 months; 5% strength solution may lose 50% potency after 2 years)[3].
Application	• Typically used in household chlorination • In some parts of the world is also used in small to medium-sized water treatment plants[4] • In some high-income countries (such as the UK), it is also increasingly being preferred instead of chlorine gas for use in the drinking water industry because of the high risks of health and safety when using chlorine gas
Examples	• Sodium hypochlorite (10 to 15% active chlorine; commercially prepared) • Domestic bleach (5 to 10% active chlorine; commercially prepared) • Antiseptic solutions (such as Milton or Javel - 1% or 2% active chlorine) • Chlorine liquid solution prepared from chlorine powder (typically 1 to 5% active chlorine)
Chlorine tablets	
Appearance	• White tablets with common sizes found in Sudan being: 33mg and 1.67g (although other sizes exist – see examples in **Protocol 8**)
Strength	• NaDCC - Typically 4-6 mg/L of FAC after 30 minutes as per instructions for emergency usage if dosed in recommended volumes of water. Approx 60% of the tablet weight being free available chlorine[5]
Stability	• More stable than powdered chlorine • NaDCC does not face International Aviation Transport Authority (IATA) restrictions unlike

[2] WHO (1996) Fact Sheets on Environmental Sanitation, Robens Institute, University of Surrey, UK, *Calcium hypochlorite,* Fact Sheet 2.19
[3] WHO SEARO, 2017
[4] WHO SEARO, 2017
[5] Medentech (no date) *Aquatabs,* Medentech Ltd.

	other forms of chlorine
Application	• Typically used for chlorination at household level, for batch chlorination in water storage tanks and in floating pot chlorinators in wells
Examples	• Sodium dichloroisocyanurate (NaDCC) – various sizes • Calcium hypochlorite tablets and 'Swimming pool tablets' (the latter containing trichloroisocyanuric acid) – but as both are not so commonly used as NaDCC they have not been discussed in detail in this guidance
Chlorine gas	
Appearance	• Green-yellow gas • Liquefied chlorine gas tends to be supplied in cylinders containing approximately 45kg or 70kg at about 5 atmospheres pressure. 1 ton containers are also available and small cylinders containing 5kg or 9kg also exist[6].
Strength	• Approximately 100% active chlorine. Cylinders of 45kg or 70kg are sufficient for small water treatment plants (WTPs) of up to 1,800 m^3/day.
Stability	• Most stable over time. Must be stored in a cool place.
Application	• Typically used for medium- to large-sized water treatment plants
Examples	• Chlorine gas (liquefied)

3.3 The chlorination process

3.3.1 Chlorine dose

The chlorine dose refers to how much chlorine is added to the drinking water. It is usually expressed as milligrams per litre (or mg/L). For example if a drinking water has a chlorine concentration of 1mg/L, this means that there is 1 mg of chlorine present in 1 litre of water.

3.3.2 Chlorine reactions in water and chlorine demand

Once chlorine has been added to drinking water, a number of chemical reactions take place. Chlorine reacts with any organic material (e.g. microorganisms) and inorganic material (e.g. metals, pipe fittings) that are present in the water. Chlorine is used up (or consumed) during these reactions, so the concentration of chlorine decreases. The amount of chlorine that is consumed through the reaction between chlorine and the chlorine reactive substances present in the water is called the **chlorine demand**.

Once the chlorine demand has been satisfied, and the disinfection reactions are complete, the remaining chlorine is referred to as the **total chlorine residual**, which consists of **combined residual chlorine** and **free residual chlorine (FRC)**.

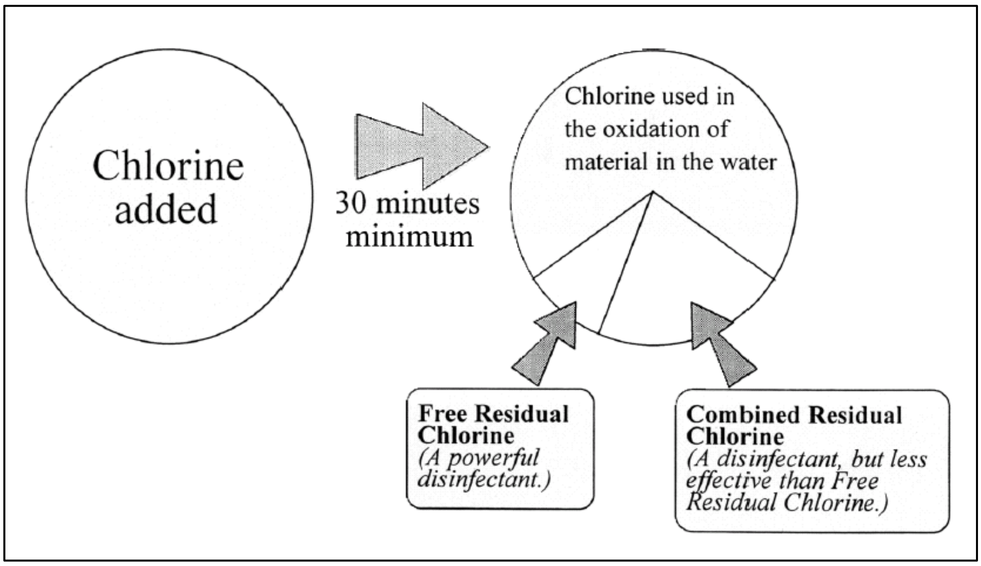
Fig. 2 shows this process diagrammatically, while Table 2 below gives more details about components of residual chlorine types.

Table 2 - Residual chlorine types

Total residual chlorine	**Combined residual chlorine**	This is the chlorine that has reacted with organic material and nitrogen compounds (such as ammonia) to form weak disinfectants.	Present as chloramines and organic chlorine compounds.
	Free residual chlorine (FRC)	The free chlorine that is remaining and available for disinfection which has good disinfecting properties and protects the water from recontamination from microorganisms.	Present as pure chlorine, hypochlorous acid and hypochlorite ions.

[6] WHO (1996) Fact Sheets on Environmental Sanitation, Robens Institute, University of Surry, UK, *Chlorine gas or liquid in cylinders,* Fact Sheet 2.18

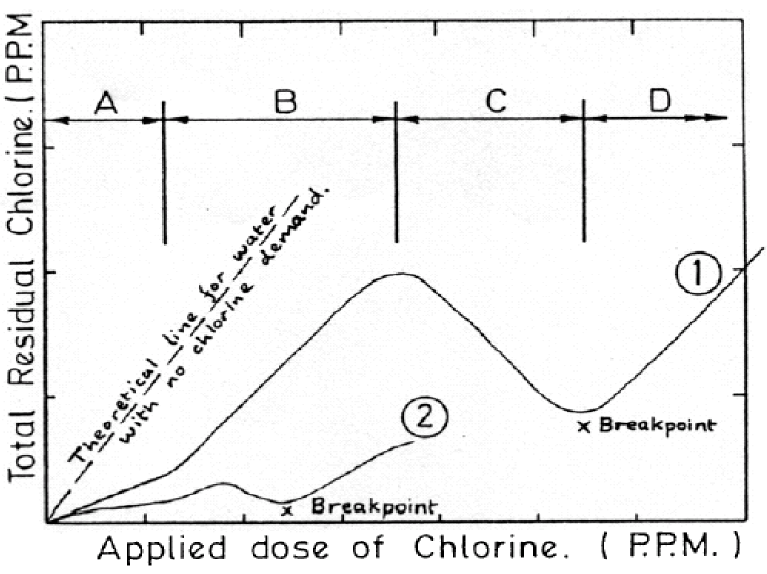
Fig 2 - Chlorine reactions in water[7]



3.3.3 Breakpoint chlorination

The “breakpoint” in a chlorination process is the point at which all organic matter has been oxidised including chloramines and there is a free residual of chlorine.

Fig 3 - Breakpoint chlorination graph[8]



A. Chlorine absorbed by organic matter
B. Formation of chloramines – chlorine available as combined available chlorine
C. Oxidation of chloramines by chlorine
D. Chlorine present as free residual chlorine in proportion to dose

1. Water with significant free ammonia
2. Water without or with little free ammonia

3.3.4 Chlorine decay

Chlorine decay describes the decrease in the concentration of chlorine in drinking water as it passes through a water treatment plant through to the end of the distribution system. Once disinfection is complete at the water treatment plant, chlorine will continue to react with any organic or inorganic material that may be

[7] Original source unknown, possibly Institution of Water Engineers, UK
[8] Original source unknown, possibly Institution of Water Engineers, UK

present in intermediate storage tanks or distribution pipes (for example, organic sediments, dissolved metals and corroded pipes, pipe fittings, pipe materials and microbial slimes or biofilms).

Due to chlorine decay, the concentration of chlorine at the water treatment plant has to be higher than at the very end of the distribution system. The rate and extent of chlorine decay will depend on a number of factors, including:

- The level of chlorine reactive substances that are present in the treated water as well as the distribution network – these will be increased in piped networks which have leaks and where flows are intermittent;
- How long the water remains in the distribution system (as the chlorine concentration decreases over time, older water will typically have a lower concentration of chlorine);
- How much the water has contact with air (e.g. large surfaces of water allow chlorine to be lost);
- The temperature of the environment in which the distribution network is based.

Chlorine decay is an important concept with regards to the supply of safe drinking water. Due to chlorine decay in a water supply system, drinking water may have a sufficient amount of chlorine at the water treatment plant, but not enough chlorine remaining in the drinking water during distribution system to protect the water from potential recontamination by harmful microorganisms.

The following strategies may be considered to minimize chlorine decay in a water supply system:

1. Optimize water treatment processes to minimize the level of chlorine reactive substances entering the distribution system (e.g. particulates);
2. Routinely clean and maintain intermediate storage tanks and distribution pipes (for removal of accumulated sediment and microbial biofilms) and by mending leaks;
3. Optimize the hydraulic regime (i.e. the flow of water) in the distribution system to minimize water age and low-flow sections (or dead-legs);
4. Use chlorine compatible materials (such as pipework, fittings and tank liners) in the distribution system; and
5. Where feasible, provide continuous (i.e. 24-hour) water supply.

3.3.5 Ct value, pH, turbidity and temperature

During the disinfection process, chlorine requires time to kill or inactivate microorganisms present in drinking water – this is referred to as 'contact time'. The contact time must be considered in conjunction with the chlorine concentration and other factors, to ensure that effective disinfection of drinking water occurs – this is referred to as the Ct concept for disinfection.

Box 2 - Ct value
The Ct value is = the chlorine concentration (C) x the contact time (t) with the drinking water
(WHO recommends a minimum Ct of 15 - using minutes and mg/L)

The Ct value required for effective disinfection is dependent on the combination of several factors, including:

1. **The concentration of chlorine in the water** - *more contact time needed for lower dosages*
2. **The temperature of the water** - *more contact time needed for <20^{o}C; higher dosage for hotter temperatures*
3. **The pH of the water - i.e. a measure of the water's acidity or alkalinity** - *pH 5-8 is optimum, more contact time needed for pH >8*
4. **The turbidity of the water** - *more contact time needed for higher turbidity; but aim to always keep below 5 NTU*

Turbidity:

Turbidity occurs in water as a result of the presence of organic and inorganic material. It gives water a cloudy (or opaque) appearance and indirectly influences the effectiveness of chlorination, since these substances can consume chlorine as well as protect (or shield) microorganisms from the chlorine. For effective disinfection, the WHO recommends that the turbidity of water should be <1 Nephelometric Turbidity Unit (NTU). In certain settings, achieving <1 NTU in the water prior to disinfection may not be possible (for example, for small supplies or lower resource settings). In such situations, the aim should be to maintain turbidity <5 NTU prior to disinfection. Above 5 NTU, chlorination should still be practised, but higher chlorine doses or contact times will be required to inactivate harmful microorganisms.

Two additional reasons why turbidity should be as low as possible are:

- It can result in a bad smell or taste when reacting with chlorine
- By-products can occur when chlorine reacts with organic matter (e.g. Trihalomethanes – see **Section 3.3.7**)

Contact time and types of micro-organisms:

The type of microorganism may also influence the effectiveness of disinfection, with vegetative bacteria requiring less contact time or lower concentrations of chlorine and certain viruses and protozoa (such as *Giardia*) requiring more contact time or higher concentrations of chlorine, and certain protozoan oocysts (e.g. *Cryptosporidium*) and bacterial spores requiring such long contact times or high chlorine doses that chlorine disinfection is considered impractical or ineffective. Ct values are typically based on the inactivation of the protozoa *Giardia*, as most bacteria and viruses that are susceptible to chlorine are considered to be inactivated within this time.

Box 3 - Recommended contact time for effective disinfection

For effective disinfection of drinking water, WHO recommends a minimum contact time of 30 minutes where the free residual chlorine concentration is ≥0.5mg/L and the pH of the water is <pH 8.

*(Note that for Sudan the chlorine residual will need to be higher at the point of disinfection to ensure that 0.2 mg/L residual remains at the household for 24 hours – see **Section 5.1** for more details)*

3.3.6 Aesthetic considerations

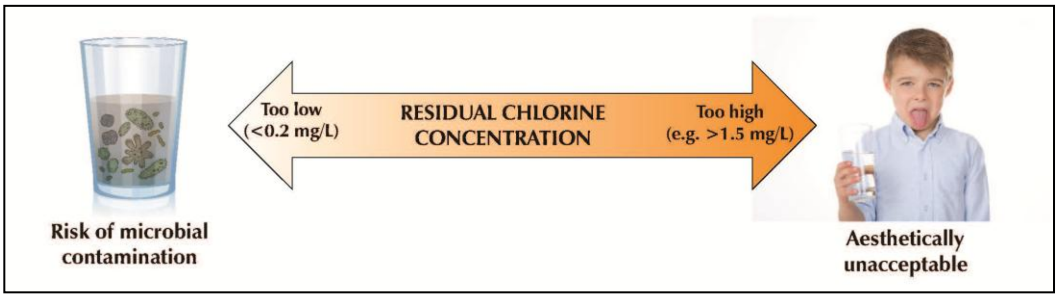
In the context of drinking water quality, the term 'aesthetic' means how acceptable the drinking water is to a consumer. The acceptability of drinking water may be based on the consumer's perception of:

1. The appearance of the water (does the water appear clear, coloured, cloudy, milky);
2. The taste of the water (does the water taste acceptable, or does the water have an unpleasant taste such as a chemical, stale, earthy or metallic taste); and
3. The odour of the water (is the water odourless, or does it have an odour such as an earthy, musty or chemical odour).

Providing drinking water that is acceptable to every individual consumer is a challenge, as different individuals have different sensitivities to the appearance, taste and odour of water. For example, water may have no smell to one individual, whereas the same water may be unacceptable to another individual who has a more sensitive sense of smell.

Chlorine also has a characteristic taste and odour. This may be noticeable to sensitive individuals at chlorine concentrations > 0.3 mg/L. If chlorine is present in drinking water at concentrations that are too high, the stronger taste and odour of chlorine may result in an individual using alternative, less safe, water sources. For this reason the aesthetic impact of chlorine on drinking water should be considered when optimizing the chlorine dose. However the **World Health Organisation (WHO) states that when setting the chlorine dose, aesthetic considerations should never compromise disinfection**.

Fig 4 - Optimising the chlorine residual concentration[9]



See **Section 5.1** for the recommended minimum FRCs for Sudan at various points in the water supply chain.

3.3.7 Health impacts of chlorine and disinfection by-products

Health impacts of chlorine

In relation to chlorine, the WHO DWQ 2017 guideline (page 334-335) says the following about the guideline level for the maximum amount of chlorine for drinking water (5 mg/l) - *'The guideline value is conservative, as no adverse effect level was identified in the critical study'*. It also says *'In humans and experimental animals exposed to chlorine in drinking water, no specific adverse treatment-related effects have been observed. IARC has classified hypochlorite in Group 3 (not classifiable as to its carcinogenicity to humans)'.*

In reality people will drink water with much lower levels of chlorine than 5 mg/l (as this tends to be the maximum dosage rate), so the risk of any adverse health effects are negligible.

Disinfection by-products

Disinfection by-products (or DBPs) result from the reaction of chlorine with organic and inorganic material present in the drinking water. Some of these compounds have been linked to public health concerns.

Examples of disinfection by-products include: Trihalomethanes (THMs); haloacetic acids; chlorate; and chlorite.

Strategies to control disinfection by-product formation include:

- Optimizing water treatment processes to remove organic and inorganic material that, if present, might cause by-products forming;
- Optimizing the chlorine dose point to ensure that only treated water is dosed (without compromising contact times), i.e. pre-chlorination is not practiced;
- Reducing the water age in the distribution network (as time is an important factor for disinfection by-product formation).

Box 4 - Risks from by-products are very small - do not compromise disinfection for this issue

As the risks to health from disinfection by-products are extremely small in comparison with the risks associated with inadequate disinfection, the WHO DWQ guidelines (2017, p6) notes: ***"The risks from these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection efficacy not be compromised in attempting to control such by-products"*** [10]**.**

[9] WHO SEARO (2017)
[10] WHO (2017) *Guidelines for drinking water quality*, Fourth edition with Addendum

3.3.8 Points of chlorine application

Chlorine may be added to drinking water in the water supply chain to achieve different water quality objectives:

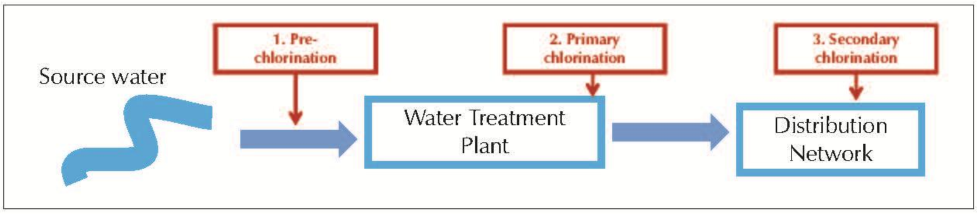
1. **Pre-chlorination (immediately before other steps in water treatment)** – to aid the removal of iron or manganese or reduce the effects of algae or other compounds that cause taste or odour problems. Higher dosages are usually required at this stage because of the higher level of turbidity. It is often associated with the potential for formation of disinfection by-products (see **Section 3.3.7**).

2. **Primary chlorination (immediately after the other steps in water treatment)** – to disinfect the water and leave a residual in the water to cope with the contamination in the supply chain to the point of use.

3. **Secondary (or booster) chlorination (in the distribution system, such as in a water storage tank or by on-line dosing)** – to boost the chlorine where it has not been possible for optimal primary chlorination or where the chlorine has decayed passing through the earlier stages of the supply system (for example because of very long pipelines in a hot climate).

4. **Bucket chlorination at the distribution point or disinfection at household level as part of household water treatment and safe storage (HWTS) relevant in both emergency and non-emergency situations** – to ensure that the drinking water is safe where the water supplied cannot be guaranteed to have been adequately treated.

Fig 5 - Examples of points in a water supply system where chlorine may be added to the water[11]



3.3.8 Optimising chlorine concentration in the water supply system

Optimizing the chlorine dosage in a water supply system may be a challenge due to the need to balance:

1. Adequate initial disinfection;
2. Having enough chlorine residual for ongoing disinfection during distribution, in order to provide protection from recontamination to the point of use by the consumer, alongside;
3. Consumer acceptability.

3.3.9 Summary of conditions required for effective chlorination

The following table provides a summary of the conditions required for effective chlorination.

[11] WHO SEARO (2017)

Table 3 - Summary of conditions required for effective chlorination

For effective primary chlorination of drinking water, the following ideal conditions are recommended *(Refer to the **Section 5.1** and **Protocol 4** for more details when conditions are outside of optimum)*	
Turbidity	**<1 NTU (preferably lower where achievable)** Where not achievable, <5 NTU should be the aim; above 5 NTU, chlorination should still be practised, but higher chlorine doses or contact times will be required to inactivate harmful microorganisms. 20 NTU can be permitted for short periods in the immediate stages of an emergency, but efforts should be made to reduce the turbidity to < 5NTU as soon as possible.
pH	**<pH 8.0** Above pH 8.0, chlorination should still be practised, but higher chlorine residual and/or contact times will be required to inactivate harmful microorganisms.
Temp.	**$20\ ^{o}C$** Where water temperature is lower than this, higher chlorine residual and/or contact time will be required to inactivate harmful micro-organisms. Where temperature is higher, chlorine decay will accelerate, and higher chlorine residual will be required upstream to assure adequate residual after 24 hours downstream.
Minimum contact time	**At least 30 minutes contact time** For where the residual chlorine concentration is ≥ 0.5 mg/L, pH of the water is < 8 and temperature is $20\ ^{o}C$.

4. Health and safety

4.1 Trained personnel

Chlorine is a hazardous substance and mishandling can have severe consequences. The health and safety of staff is critical at all times. All staff in contact with chlorine should receive training on the dangers of chlorine, how to handle and store it safely and basic first aid measures in the event of accidental contact.

What do to do if accidental exposure occurs should be included in the training of all staff working in the vicinity of a water treatment plant or other site where chlorine is being handled, not just the staff who are handling the chlorine. This is because if the person handling the chlorine is injured they may need assistance from other colleagues to respond.

Only trained personnel may be permitted to handle chlorine. No other personnel should have access to the chlorine stocks, be present when they are being used, or have access to the area where chlorine gas cylinders are in use.

4.2 Personal protective equipment (PPE) for handling chlorine

Contact with, or inhalation of, concentrated forms of chlorine may result in irritation, severe chemical burns, breathing complications, blindness and even death. Hence personal protective equipment (PPE) is critical to be worn to protect the person handling the chlorine from becoming injured.

Box 5 - State Water Corporation member – blinded by chlorine gas

It can be common for personnel working on drinking water treatment to not wear protective equipment. However this can have serious implications. A State Water Corporation staff member was not wearing goggles to protect his eyes. The gas got in his eyes and it led to him becoming blind.

Protocol 1 in Annex I - identifies the requirements for PPE when handling chlorine. It is the responsibility of the employer to provide appropriate PPE and to train the staff in how to wear it appropriately. It is the responsibility of the staff member to demand appropriate PPE when the employer has not provided it automatically, and they have the right to refuse to handle chlorine if it is not provided.

4.3 Storing and handling chlorine

The storing and handling of chlorine is very important. Mishandling can lead to serious and potentially fatal accidents, and the poor storage of chlorine can lead to it losing strength or can result in a fire.

Protocol 2 in Annex I - identifies the requirements for the storage and handling of chlorine contribute to preventing health and safety accidents (explosions, splashing, burns etc) and also aim to preserve the strength of the chlorine for a longer period of time.

4.4 What to do if a fire or accidental exposure occurs

Protocol 3 in Annex I - identifies the actions which should be taken if a fire or accidental exposure occurs. Acting quickly and correctly can reduce the impact on the affected person and even save their sight or their life.

5. Practical chlorination – the basics

5.1 Minimum FRCs for drinking water supply in Sudan

It has generally been understood from several editions of the WHO guidelines for drinking water quality (including the 2017 version) that the FRC at the point of delivery should be at 0.2 – 0.5 mg/L. This assumes that this will enable a residual of 0.2 mg/L at the household and point of consumption. However, recent research[12] has indicated that a residual of 0.2 – 0.5 mg/L at the point of delivery is not enough to ensure a 0.2 mg/L in households in hot climates where there are also high levels of contamination. The research has indicated that a residual of at least 0.6 – 1.0 mg/L is more likely to result in a residual of 0.2 mg/L remaining at the household after 24 hours in hot and contaminated conditions.

The WHO Geneva Environmental Health team (2017)[13] also confirmed that: *"WHO recommends maintenance of a FRC of 0.2 mg/L in stored household water... the general recommendation is 0.2 – 0.5 mg/L at the point of delivery, but if the risks of faecal contamination are evident, there should be at least FRC of 0.5 mg/L throughout the system. Moreover, the Guidelines state that chlorine dosing to achieve stable 0.2 mg/L in household stored water may require 2 mg/L dosing for clear watp.er or even 4 mg/L when water is turbid. The point is that the Guidelines' fixed recommendation is to maintain that residual, while the dosing is flexible (within the limits of our Guideline Value, maximum concentration of 5 mg/L, and [considering the risk of] consumer rejection based on unacceptable taste)".*

Pg 151 of the WHO 2017 guidelines also notes: *"During outbreaks of potentially waterborne disease or when faecal contamination of a drinking water supply is detected, the concentration of free chlorine should be increased to greater than 0.5 mg/L throughout the system as a minimum immediate response".*

As Sudan has a very hot climate and there tends to be a high level of contamination (as many of the piped networks are old and leaking, have intermittent flow and run in areas where there are still high levels of open defecation), the recommendation is to increase the residual to 0.5 – 1.0 mg/L at the point of distribution. Checks should then be made: a) on the chlorine residual in the household storage at the end of the supply chain to establish if there is a 0.2 mg/L residual after 24 hour storage; and b) that people will accept the taste of the water with these levels of chlorine. The levels of chlorine dosing should be adjusted in response.

Maximum level of chlorine permitted in drinking water (SSMO, 2016 standards and WHO, 2017) is 5 mg/L.

Table 4 - Minimum FRCs for drinking water supply in Sudan

Minimum free residual chlorine for drinking water supply in Sudan	
In household storage	• Minimum FRC of 0.2 mg/L after 24 hours storage
At the point of distribution (from a tapstand, tanker or donkey cart)	• The minimum FRC is expected to need to be 0.5 – 1.0 mg/L at the point of distribution (i.e. from a public tapstand, from a tanker or donkey cart) in any area with a hot climate, irrespective of outbreak or normal conditions. • There will be a need to monitor the effects along the water chain to check: a) Chlorine residual levels in households b) The community acceptance of the chlorine taste/rejection levels including after hygiene promotion; and then to adjust accordingly

[12] Ali, S. I., Ali, S.S., Fesselet, J.F (2017) *Study report: Evidence Based FRC Targets for Centralized Chlorination in Emergencies,* MSF OCA
[13] WHO Geneva Environmental Health team (2017) *Personal communication*

5.2 Use of pH, turbidity and chlorine testing equipment

The common equipment that can be used for testing pH, turbidity and chlorine residual are included in Table 5 with an indication of their strengths and weaknesses.

When selecting the appropriate testing equipment it is important to consider:

- The capital cost of the instrument
- The operational costs of the on-going replacement of the reagents and parts, as well as servicing
- The level of operator training needed to use the equipment
- The availability of specialist knowledge for the technical support and equipment maintenance
- The durability of the equipment under field conditions (i.e. ability to withstand shock, dust & water)
- The level of accuracy and sensitivity required for the equipment balanced against the available resources

Table 5 - Comparison of testing equipment for measuring pH, turbidity and chlorine residuals

Test equipment	Parameters	Accuracy	Resolution	Cost	Advantages	Disadvantages
Test strips	pH or chlorine residual	L	L	M	• Easy to use • No calibration / servicing required	• Poor degree of resolution (e.g. may only measure in 0.5 mg/L increments) • Visual measurement (colour change) open to user interpretation • Requires supply chain for replacement strips
Comparator (pooltester)	pH and chlorine residual	M	M	M	• Easy to use • Durable for field use • No calibration / servicing required	• Visual measurement (colour change) open to user interpretation • Requires supply chain for DPD1 tablets
Comparator (wheel)	pH or chlorine residual	M	M	M	• Easy to use • Durable for field use • No calibration / servicing required • Visual measurement (colour change) easier to interpret than pooltester comparator	• Requires supply chain for DPD1 tablets • Still open to some interpretation (but less so than a pooltester)
Photometer	pH, turbidity and chlorine residual	H	H	H	• High degree of resolution over a wide range (such as 0.05 to 10 mg/L for chlorine in 0.01 mg/L increments) • Easy to use	• Less durable for field use • Calibration / servicing required • Requires reagents, replacement parts (bulb) and supply chain
Turbidity meter	Turbidity	H	H	H	• High degree of resolution • Easy to use	• Less durable for field use • Calibration / servicing required • Requires reagents, replacement parts (bulb) and supply chain
Turbidity tube	Turbidity	M	L	M	• Durable for field use • Easy to use	• Visual measurement open to user interpretation • Only goes down to 5 NTU
L = Low; M = Medium; H = High						

Note that DPD1 tablets are used to indicate FRC; and DPD3 tablets to indicate combined chlorine residual. For most purposes it is not necessary to know the combined chlorine residual (as this is has a weak disinfection property) and **hence only DPD1 tablets are required**. Care must be taken to ensure the DPD1 tablets are in-date and effective to ensure accurate test results. Testing water with known chlorine concentrations can be a useful way to test the tablets.

Fig 6 - Examples of testing equipment

Turbidity tube
(Credit: E. Fewster / Medair)

Pooltester (pH/chlorine residual)
(Credit: E. Fewster / Medair)

Turbidity meter, photometer and 1.67g chlorine tablets
(Khartoum State Locality)
(Credit: S. House / RedR)

5.3 Making a 1% solution and establishing dosage and chlorine quantities

The following flow chart provides an overview of the steps that should be taken to make a 1% solution and establishing the dosage and the chlorine quantities required.

Fig 7 - Making a 1% solution and establishing dosage and chlorine quantities

Step 1 - Test pH, turbidity and temperature and adjust the process

Step 2 - Make a 1% solution

Step 3 - Undertake a jar test to find the correct dosage

Step 4 - Calculate the chlorine dose for your application

Protocols 4 to 6 in Annex I provide step by step instructions for undertaking these tasks and also provide some worked examples.

5.4 Establishing the strength of chlorine solution (before dosing)

The WATA test is a simple test now available for testing the strength of strong chlorine solutions and also if necessary the strength of the chlorine solution or powder. This is normally only necessary in certain situations, for example to verify the strength of chlorine solution used in cholera treatment centres or Ebola management centres. If you are undertaking Jar Tests to establish the dosage for the water in drinking water, it is not necessary to know the exact concentration of the chlorine. An alternative but more complicated method is also available when the WATA test is not available. See **Protocol 12** for more details.

5.5 Dosing systems

5.5.1 Dosing systems overview

Chlorine may be dosed by the following methods:

1. **Batch** – where the chlorine is put into a standing container or tank of water for the required contact time and then discharged.
2. **Continuous constant rate** – where the chlorine is injected at a constant rate into a pipeline (with water flowing at a constant rate) or into a tank.
3. **Continuous proportional dosing** – where a differential pressure is created across an orifice (or a venturi) which displaces solution from the flexible bag and injects it into the flow (which can be at a variable flow rate). Another model using a piston system also exists.[14]

Continuous or proportional dosing requires more complicated equipment and trained operators to operate and maintain the system, and so they tend to only be used in medium or larger sized water treatment plants or in high yielding boreholes (with no treatment plant).

A number of non-pump based chlorine dosing systems are available and in use worldwide. Such systems are basic, simple to use, inexpensive and require relatively less specialised maintenance compared to pump-based systems. As such, these systems may be appropriate in lower resource settings. However, non-pump based dosing systems are less accurate and offer less operational control. For these reasons, they are more likely to result in chlorine under- or over-dosing.

A typical chlorine liquid dosing system may include a bulk storage tank, which stores a large volume of chlorine liquid. Where chlorine powder is used to prepare chlorine liquid on site, this bulk storage tank may also contain a fixed mechanic agitator, where chlorine powder may be mixed with water directly within the bulk storage tank itself. See **Fig 11** at the end of this section. Bulk storage tanks are typically designed to hold sufficient chlorine liquid to supply disinfection needs at the water treatment plant for a period of days to weeks. A day tank may also be used, which may hold a smaller volume of chlorine liquid (typically, the day tank will hold enough chlorine for one day's usage). Chlorine liquid is transferred from the bulk storage tank to the day tank by a transfer pump. In some cases, bulk storage and day tanks may have high and low level alarms – these are intended to alert water treatment plant staff if the tank is about to overflow or run-out, respectively. As chlorine liquid may release gas over time, chlorine storage tanks should have a vent pipe to safely release gas (mostly harmless oxygen) to the atmosphere outside of the building.

There is a need to calibrate continuous or proportional dosers so that they dose at the correct rate required. The exact rate they dose at depends on the back pressure in the pipe. Calibration can occur by putting the suction end into a 1L beaker, filling to 1L mark, starting the clock and seeing how much goes out in 1 or 5 minutes and then adjusting if it's too fast or slow. A misconception can be that people think the "%" on the dial is somehow related to mg/L or ml/L, whereas it is only showing % of doser ability up to the rated maximum.

[14] Dosatron, Water powered dosing technology, http://www.dosatron.com

The doser should be chosen based on its rated flow which should be higher than required e.g. if dosing into a pipeline and the dose is 3L/hr of chlorine, then the doser should be selected with max 3L/hr, since with some back pressure in the pipe it would dose less when at max throttle.

5.5.2 Batch dosing systems

Batch dosing can be done on a large or small scale, for example, in a 25m^3 raised storage tank for a water yard, or in individual containers ('bucket dosing') as part of an AWD chlorination campaign, or in household water treatment and safe storage (HWTS) processes. Batch dosing is commonly used in Sudan.

Batch dosing may be undertaken using chlorine in tablet form, or by using 1% solution that has been made up from chlorine-generating products that is put into individual containers using a syringe or poured into a larger container such as a storage tank. It is important to ensure the chlorine is mixed well in the water storage container or tank, so it is good practice to put the chlorine into a storage tank while some of the water is still being poured into the tank as this leads to a swirling motion in the tank.

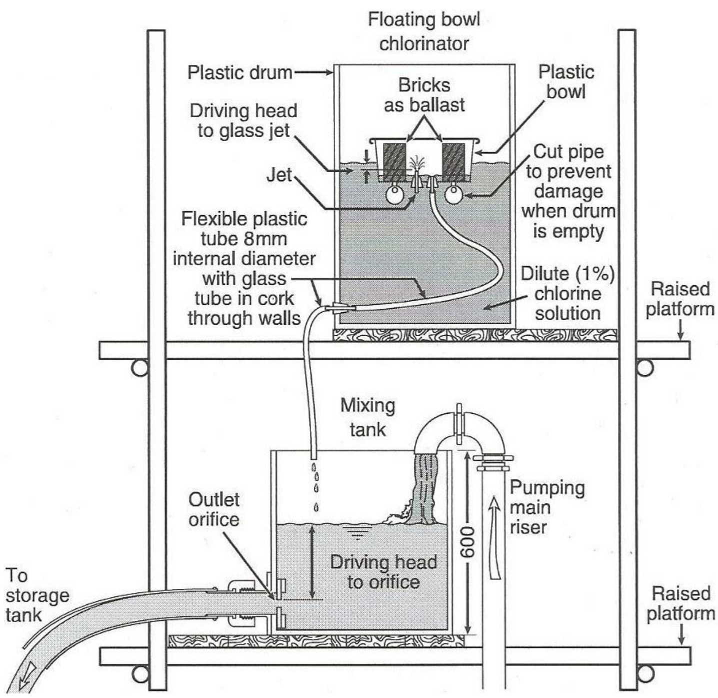
For more information on bucket dosing and HWTS and the use of chlorine tablets see **Protocol 8**.

5.5.3 Continuous constant rate dosing systems

Non-pumped:

Fig. 8 shows two improvised non-pump based continuous constant rate dosing systems. In these systems the chlorine is fed by gravity from a floating bowl. The dose rate from the floating bowl is controlled by the weight of the floating bowl, which is adjusted by adding or removing stones.

Fig 8 - Gravity fed, constant rate chlorine dosing system



(credit: Davis and Lambert, 2002)

(Fig 8 continued)

(credit: E. Fewster / BushProof, CARE)

Pumped:

For pumped systems, chlorine dosing pumps are used to pump the chemical from the day tank to the drinking water pipe. Typically, metering pumps are used, which pump precise adjustable volumes of chlorine liquid over a specified time period (peristaltic- or diaphragm-type metering pumps are commonly used). Some dose pumps may be more manual in operation, where the pumps would be set to dose at that particular flow rate – this would be for situations where the plant flow rate is assumed to be constant (for example, with water pumped from a borehole). See **Fig 9**. This shows an electric pump sucking the chlorine solution from the tank below and pushing it into the tee on the pipe coming from the borehole.

Fig 9 - Electric pump dosing chlorine at constant rate at the borehole

(credit: E. Fewster / BushProof, CARE and DRC)

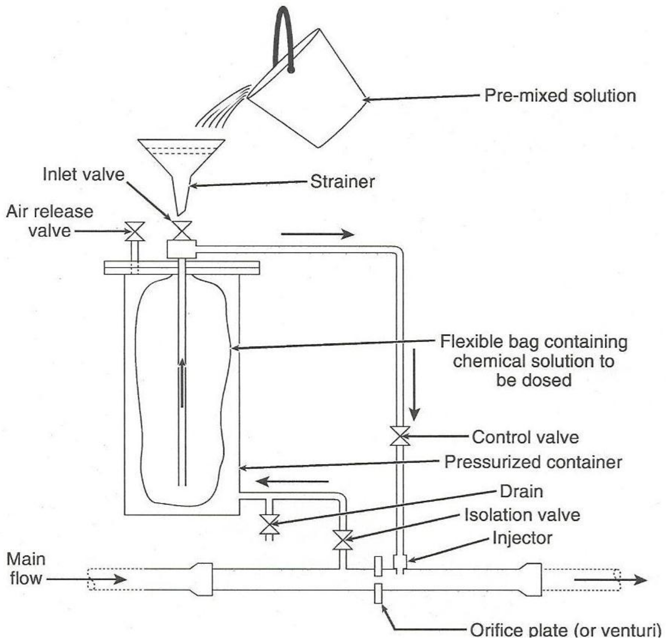
5.5.4 Continuous proportional dosing system

In many cases, water treatment plant flow rates may not be constant, but fluctuating – as such, the risk of chlorine under- or over-dosing with a constant rate dose pump set manually is high. So in these situations the correct choice of dosing pump would be proportional (or flow-paced) – i.e. the pump would automatically adjust the chlorine dose rate to match the flow of water through the water treatment plant (for example, if the plant flow rate increases, the chlorine dose pump output increases to maintain a steady chlorine concentration).

Non-pumped:

Fig 10 - shows a non-pumped proportional doser. Differential pressure if created across the orifice (or alternatively a venturi) displaces solution from the flexible bag and injects it into the flow. Another example of a continuous proportional dosing pump is the Dosatron[15], which uses the flow of the water as the power source.

Fig 10 - Proportional displacement doser



(credit: Davis and Lambert, 2002)

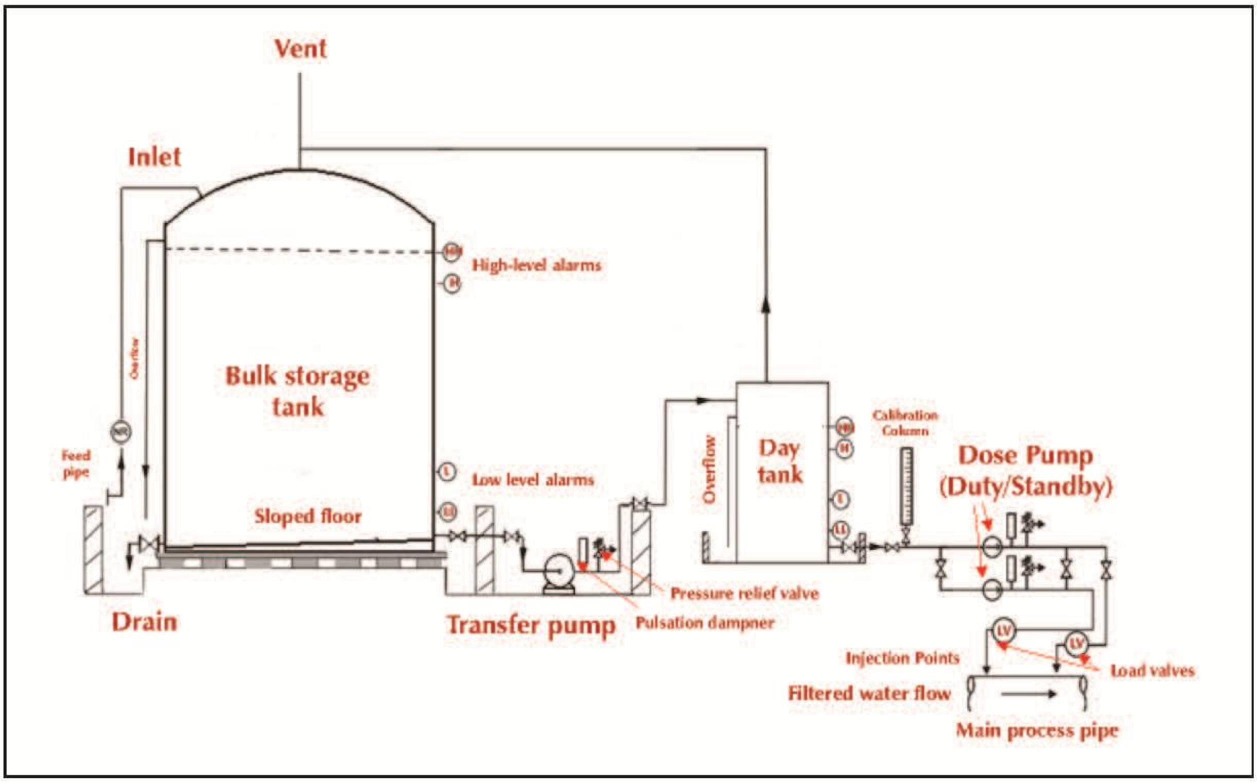
Pumped:

A further level of sophistication involves 'residual trim', where an instrument continually measures the chlorine concentration in the water that has been dosed with chlorine (i.e. the dosed water) and adjusts the chlorine dose rate accordingly.

Where resources allow, a duty pump (i.e. the pump that is normally in use) and a standby pump (i.e. back-up pump, in case the duty pump fails) should be in place. This may minimize the risk of losing chlorine disinfection in the event of a pump failure. In addition, where resources permit, a fuel-powered generator should be available, so chlorine dose pumps may continue to operate in the event of a power failure, to avoid the loss of disinfection.

[15] Dosatron, Water powered dosing technology, http://www.dosatron.com

Fig 11 - Typical pump-based chlorine dosing system



(Credit: WHO SEARO, 2017, adapted from: Adapted from: Environment Protection Agency (2011). Water treatment manual: Disinfection. Wexford, Ireland)

6. Practical chlorination – by context

6.1 Batch chlorination of drinking water in storage tanks, water bladders, water tankers and donkey carts

It is good practice make up a 1% solution of chlorine and use this to dose the drinking water based on calculation of the dosage required for the particular water source.

For the steps to undertake these tasks refer to:

- **Protocol 5** – for how to make up a 1% solution
- **Protocol 6** – for how to do a jar test to establish the dosage required for a particular water source
- **Protocol 7** – for the steps to chlorinate storage tanks, water tankers and donkey carts

6.2 Bucket and household drinking water chlorination

In emergency situations it is sometimes necessary to chlorinate directly into drinking water containers when the water is collected at a source. This is a high maintenance activity which requires a high level of training and supervision, so it is likely to only be possible as a temporary measure.

Household chlorination is also one option for the treatment of drinking water at household level. HWTS is an effective way to keep drinking water safe and reduce risks from any residual pathogens in the water, if the supplier is not able to guarantee an adequate chlorine residual in the water at all times. However it requires discipline from the household members to sustain the processes and also has a cost attached to it on an ongoing basis, through the purchase of the chlorine tablets or liquid. It also requires training for household members.

Refer to **Protocol 8** – for steps to undertake bucket and household drinking water chlorination.

6.3 Cleaning and disinfection of boreholes, wells, storage tanks, tankers and pipelines after installation or repair

After installation of a borehole or well, or after it has been damaged (for example if it has been flooded), cleaning and disinfection will be required. Likewise from time to time storage tanks and tankers also need intermittent cleaning to reduce any build-up of deposits or growth of algae on their surfaces. Pipelines also need disinfecting after installation or repair.

For more information on the steps to take for each of these issues refer to:

- **Protocol 9** – for steps to disinfect boreholes and wells after installation or repair
- **Protocol 11** – for steps to undertake the disinfection of pipelines after installation or repair

6.4 Chlorine mixes for cholera treatment centres and checking the concentration of strong chlorine mixes

In cholera treatment centres, in addition to the standard drinking water with a 0.2 – 0.5 mg/L FRC, other more concentrated chlorine mixes are used for other purposes. This is for hand-washing, cleaning floors, laundry and washing corpses. The concentrations of chlorine used for these various purposes vary from 0.05% for hand-washing to 2% for the washing of corpses.

Refer to **Protocol 12** – for the chlorine mixes used in cholera treatment centres and how to check their strength.

7. Monitoring chlorination processes

7.1 Purpose of monitoring chlorination processes

Monitoring of chlorine processes is needed for:

a) Operational purposes to check the dosages applied and the residuals throughout the treatment system with the aim to optimise the dose.

b) To verify that the resultant FRC from the treatment location will result in the required FRC in the distribution system and will result in the required FRC at the household (0.2 mg/l after 24 hours); and hence to confirm that the water is protected to the point of use and that people will not reject the water due to aesthetic concerns.

7.2 Locations for monitoring

Typical places that the monitoring of FRC should occur at are (see Fig 12):

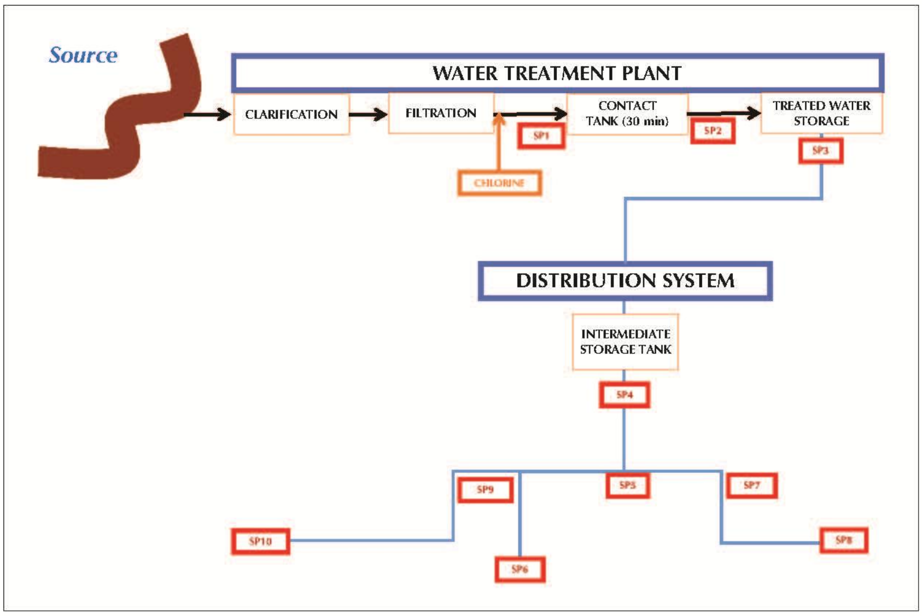
a) **The dosed water** (SP1) – immediately after the chlorine has been added – to check that the dose has been calculated correctly

b) **The dosed water after the required contact time (such as 30 minutes)** (SP2) – to check that effective dosages have been added to the water to result in the required Ct value

c) **After the water storage tank just before the water enters the distribution system** (SP3) – to check that there is optimal FRC to protect the water right through the system

d) **At various locations within the distribution system (SP4 to SP10) –** to check the required FRCs at each stage **-** sample point locations should be representative of the entire distribution network, and should represent: a) The start, middle and end of the distribution network; and b) known water quality trouble spots (i.e. where poor water quality has been historically found, such as low-flow and/or end-points of the distribution network).

Fig 12 - Example of generic operational monitoring sample point locations in a water supply system [16] (SP = sample points)



[16] WHO SEARO (2017)

7.3 Chlorine sampling considerations

Refer to **Section 5.2** for information on testing equipment for FRC. It is vital to process any sample immediately after collection to ensure an accurate chlorine reading is obtained. This is because chlorine is volatile and once exposed to air the chlorine leaves the water and escapes as a gas.

7.4 Corrective action

If operational monitoring identifies that the chlorine concentration is outside of the critical limits, the cause must be investigated immediately and appropriate corrective action should be taken. Assuming accurate chlorine readings are being taken, a high chlorine result will likely be as a result of chlorine over-dosing at the point of chlorine application. However, care must be taken when interpreting a low chlorine result. Low chlorine may occur due to chlorine under-dosing at the point of application, but may also occur as a result of water quality issues downstream in the distribution network (for example, low water flows, increased water age, accumulation of chlorine reactive substances over time or introduction of chlorine reactive substances through asset leakage/damage, backflow, cross connections or illegal connections). As such, the reason for the low chlorine concentration must be carefully and thoroughly investigated, as increasing the chlorine dose at the water treatment plant may not always be the only appropriate course of corrective action.

7.5 Schedule for monitoring

The recommended schedules for monitoring the FRC are:

Through the WTP:

- Where resources permit, continuous on-line monitoring of the chlorine concentration at the water treatment facility should ideally be in place. Alternatively, single (or grab) samples must be taken at a frequency that is appropriate to the specific situation to manage the risk of sub-optimal chlorine dosing. For example, where the raw water quality is constantly changing, monitoring of chlorine concentrations at the water treatment plant should be more frequent (e.g. hourly); whereas, if raw water quality is more consistent, less frequent monitoring may be appropriate (e.g. three times daily).

At water yards:

- Checked daily by the water yard caretaker (once the pH and turbidity are established to be stable).
- Six times a year by the surveillance agency as a routine activity and increased during an outbreak.

In pipe networks:

- The supply agency should test chlorine residual along the supply chain including at distribution points a minimum of 12 times a year including (late stages of the network; sites most vulnerable to contamination; places where there is a lack of persistence of FRC such as loops, low pressure zones, and dead ends).
- This varies depending on the size of the network and the population it covers – varying from 12 times per year for piped systems of <5,000 population; to 12 times per year for every 50,000 population and an additional 600 samples for piped systems for populations of >500,000.

At household level:

- The supply agency should test chlorine residual along the supply chain to a sample of the households who take the water from the end of the distribution lines a minimum of 12 times a year.

For more details on the recommended schedules for undertaking sanitary investigations / surveys and water quality testing, refer to the Sudan Drinking Water Safety Strategic Framework (SDWSSF) and the FMoH (2016) Manual on Drinking Water Quality and Safety.

Annex I - Protocols for chlorination in Sudan

Protocol 1 – Personal protective equipment for handling chlorine

Purpose	Contact with, or inhalation of, concentrated forms of chlorine may result in irritation, severe chemical burns, breathing complications, blindness and even death. This protocol provides guidance on the personal protective equipment (PPE) is critical to be worn to protect the person handling the chlorine from becoming injured.
Important notices 	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see below.
	PPE that must be provided by employers and always worn when handling chlorine
PPE	1. Use chemical safety goggles and or a full face shield where splashing is possible (for example when using liquid chlorine or mixing powdered chlorine into a liquid). 2. Use a respirator with a dust/mist pre-filter and cartridges appropriate for chlorine, plus goggles (or a full-face respirator with eye shield). 3. Use neoprene or PVC gloves. 4. Wear strong boots that protect the feet and ankles from splashes. 5. Wear an apron or overall to prevent skin contact. 6. Make sure there is a constant flow of water near to the chlorine store or point of use – such as a shower or hose
Face mask types	 (Credit: Health and Safety Executive of the British Government)[17] The image above shows a face mask which has filters suitable for use with chlorine (a respirator with a dust/mist pre-filter and cartridges appropriate for chlorine). It protects the user from damage to the lungs from the vapours released by chlorine gas or powders.
Other PPE	 

[17] Health and Safety Executive (UK) (2013) *Respiratory Protective Equipment at Work, A practical guide*

Protocol 2 – Storing and handling chlorine	
Purpose	To prevent health and safety accidents (explosions, splashing, burns etc) related to the storage and handling of chlorine and to preserve the strength of the chlorine for as long as possible.
Important notices 	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see below and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.
	Actions
Control access	• Keep the chlorine – all types including gas containers when in storage and use – in an area that is fenced and <u>only accessible by trained personnel</u>. • Make sure that unauthorised people including children are not able to access the chlorine supplies including those in tablet form. • Chlorine tablets <u>MUST NOT</u> be swallowed due to the mistaken belief that it would cure an illness (such as Giardia) – as this can lead to serious injury and even death.
Containers for storage	• Keep the product in its original containers. The containers must be corrosion-resistant (for example, light-resistant plastic such as poly vinyl chloride or high density polyethylene). • Keep product containers tightly sealed when not in use and <u>clearly labelled in Arabic</u>.
Storage location and condition	• Store the product in a cool area, since hot and humid conditions lead to reduction in strength. If the average daily temperature exceeds 35^{o}C this can result in rapid decomposition and can lead to the evolution of chlorine gas and heat sufficient to ignite combustible products. • Store in a well-ventilated area (using exhaust ventilation where possible to minimise dust levels and the build up of chlorine gas). • Store in a dry area and keep away from moisture. • <u>No person should be sleeping in the same room</u> where chlorine is stored. • Do not store close to fuel, different types of chlorine together or with nitrogen-containing compounds, dry powder fire extinguishers, oxidizers, corrosive, flammable or combustible materials, ammonium compounds, cyanides, powdered metals, hydrogen peroxide. • Store chlorine, particularly HTH, away from other stock, as the gases can damage other boxes and materials and it can cause a fire with combustible materials. • Chlorine gas containers must be kept in a cool, well-ventilated place outside of the main building and away from exit doors. There must be vents in the walls near floor level as chlorine is heavier than air and sinks to the floor, so if chlorine gas escapes it can lead to someone collapsing and thus exposing themselves to more chlorine gas at floor level.
Handling	• Never use a wet scoop for taking HTH from a drum as this can end up in an explosion followed by a fire. • Never mix more than one type of chlorine together as it can cause an explosion.
Stock records & rotation	• Date and mark all stock upon receipt. • Use first in, first out first stock rotation principles (i.e. always use the oldest stock first).

Protocol 3 – Basic first aid for accidental exposure to chlorine and what to do if a fire occurs	
Purpose	For all personnel working in a location where chlorine is stored and used, to know what to do if an accidental exposure to chlorine or a fire occurs in relation to chlorine products. All staff need this training, not only the handlers of chlorine, as other staff may still have to deal with an accident.
Important notices 	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see below and **Protocol 2**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**. • There should always be a constant supply of water near to the store or point of use if accidents occur – for example a shower or hose and tap.
A – Accidental exposure	
Incident type	**Basic first aid in case of exposure**[18]
IN ALL CASES	• Ensure your own safety before giving assistance to the affected person (such as not entering an area with poisonous fumes without respiratory equipment). • Wear protective gloves to prevent you coming into contact with the chlorine. • Ventilate the area to remove the fumes. • Record the name of the chemical and brand to pass on to the medical staff. • If it is safe to do so, seal the chemical container.
Chlorine makes contact with clothing material	• Gently remove the affected clothing as quickly as possible. • Immediately wash / launder to remove the product before re-use.
Chlorine makes contact with the skin, nose or mouth	• Gently remove contaminated clothing or shoes while flooding the injury with water. • Flood the affected area with running water for a minimum of 20 minutes. • If treating the person lying down make sure that the contaminated water does not collect underneath them. • Seek immediate medical assistance.
Chlorine makes contact with the eyes	• Flood the affected eye with running water for a minimum of 15 minutes. • Occasionally lift the upper and lower eyelids. • Make sure that the contaminated water does not splash the unaffected eye or their face or yourself. • If treating the person lying down, make sure that the contaminated water does not collect underneath them.

[18] St John Ambulance, St Andrew's First Aid and British Red Cross (2016) *First Aid Manual,* Revised 10th Edition, DK Limited; and ARCH Chemicals (2009) *HTH Calcium Hypochlorite, Material Safety Data Sheet*

	• After the eye has been flooded for a minimum of 15 minutes – ask the casualty to hold a clean, non-fluffy pad over the injured eye (or bandage it loosely in position). • Seek immediate medical assistance.
If ingested	• Immediately drink large quantities of water. • DO NOT induce vomiting. • Seek immediate medical assistance. • Do not give anything by mouth if the person is unconscious or if having convulsions.
If inhaled	• Ask the victim to move to fresh air. • Support respiration if needed (artificial respiration or give oxygen). • Seek immediate medical assistance.
B – Fire-fighting measures	
Incident type	**Actions to take if a fire occurs**[19]
Fire occurs	• Cool the exposed containers with water – ideally using a spray - but DO NOT allow direct contact of the chlorine powder with water as it will release chlorine gases. • Firefight from a protected location or the maximum possible distance. • DO NOT use dry extinguishers containing ammonium compounds or carbon tetrachloride – as this can cause explosions. • Do not allow water runoff to enter sewers or waterways.

[19] ARCH Chemicals (2009) *HTH Calcium Hypochlorite, Material Safety Data Sheet*

<table>
<tr><th colspan="2">Protocol 4 – Testing for turbidity, pH and temperature and adjusting the process</th></tr>
<tr><td>Purpose</td><td>To establish the turbidity, pH and temperature to be able to make adjustments to the chlorination process if required.</td></tr>
<tr><td>Important notices</td><td>It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see Protocol 2 and Protocol 3.
It is critical that the user wears appropriate personal protective equipment – PPE – see Protocol 1.</td></tr>
<tr><td>Steps</td><td></td></tr>
<tr><td>Test turbidity and adjust the process</td><td><u>Reasons why you need to check the turbidity:</u>
Chlorine will be used up reacting with non-pathogenic material in the water.
You can get a bad taste / smell when oxidising organic matter.
Pathogens can avoid coming into contact with the chlorine through being shielded by suspended matter in the water.
By-products can occur when chlorine reacts with organic matter (e.g. Trihalomethanes).
<u>Steps:</u>
Test turbidity – you can use a turbidity tube, turbidity meter or photometer (making sure it has been calibrated).
Ideally the turbidity should be less than 1 NTU – but realistically when using a turbidity tube it is only possible to measure down to 5 NTU. Sudanese DWQ standards accept 5 NTU for chlorination.
If the water is too turbid, consider a pre-treatment step.
Then repeat the process.</td></tr>
<tr><td>Test pH and adjust the process</td><td><u>Reasons for testing pH:</u>
If pH is 8 or more, you will need either higher chlorine level and / or more time.
<u>Steps:</u>
Test pH – you can use a comparator, dipsticks or a photometer (making sure the photometer has been calibrated).
Use the following chart to establish the additional contact time required to ensure effective disinfection at higher pH for a range of chlorine residuals.
The alternative would be to use an acid to reduce the pH of the water before chlorinating – an acid that is sometimes used is sulphuric acid (H_2SO_4). However pH adjustment means more chemicals, so more cost and complication, as well as safety issues around the use of acids.</td></tr>
</table>

	Table 6 - Contact time needed for effective disinfection at different pH and chlorine residual[20]

pH	Required FRC at 20°C (mg/L)	Contact time needed for effective disinfection (mins)
8.0	0.5	30
8.5	0.2	206.0
	0.5	82.5
	0.8	52.0
	1.0	41.0
	1.5	27.5
9.0	0.2	412.0
	0.5	165.0
	0.8	103.0
	1.0	82.0
	1.5	55.0

Test for temperature and adjust the process

In Sudan it is unlikely that cold conditions will be reached, so this guidance is not likely to be needed. However it has been included here for completeness of the guidance on how to modify the process if modifying for temperature.

- If temperature of water is under 20°C, the Ct factor needs increasing
- Ct combines free residual (C) and contact time (t)
- For every 10°C drop, the Ct factor needs to be doubled
- This can be done by adjusting either residual, or time or both

Example:

- *Water is at freezing point 0 °C, therefore the Ct needs quadrupling*
- *With a chlorine residual of 0.5 mg/L, what is the normal Ct at 20°C and what is the new Ct at 0°C?*
  - ✓ *Normal Ct = (0.5 x 30 mins) = 15*
  - ✓ *New Ct = 15 x 2 x 2 = 60*

Table 7 - Modifying the treatment process to respond to colder temperatures

Options		FRC	Time	Ct factor
Option 1	Increase FRC	2.0 mg/L	30 min	60
Option 2	Increase the contact time	0.5 mg/L	120 min	60
Option 3	Increase both the residual and time	0.6 mg/L	100 min	60
		1.0 mg/L	60 min	60

[20] Oxfam (no date) *Oxfam Guidelines for Water Treatment in Emergencies*

Protocol 5 – Making a 1% solution

Purpose	To make a 1% solution that can be used for the jar test and / or the disinfection of the water supply.
Important notices	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.
Steps	
General notes	• Make the 1% solution in a container that is not reactive to chlorine, for example in a plastic bucket and use a wooden or plastic stirring implement. • Make up a 1% solution, regardless of original product used. • The amount of chlorine product to use per litre depends on % available chlorine in product you have. • It is often useful to make up 10 litres, which fits safely into a 20 litre bucket. • There are different opinions on whether you should add chlorine powder to water or water to powder based on health and safety risks – two recommendations include: a) Add the chlorine powder to the water - but only where there is a large volume of water (not a small amount such as a wet bucket as it can cause an explosion) b) Add water to the powder to first make a paste and then add more water • Keep stirring until most of the powder has dissolved – this may take up to 5 minutes (a small amount of precipitate may remain – this is normal, depending on the quality of the chlorine powder). • Once made: ✓ Allow any undissolved material to settle particularly when using a dosing pump as it may block the pump. ✓ Once it settles, carefully transfer the chlorine liquid solution into a clean chlorine resistant container, taking care not to disturb the settled sediment. ✓ Keep it in a non-transparent container out of sunlight. ✓ The container should also be airtight. ✓ As a guide, keep the 1% solution for a maximum of 2 weeks – this is to ensure that not too much potency is lost in storage, but also for practical reasons around storing large volumes of chlorine on site. ✓ Store it safely – as it emits a dense gas that is hazardous to health.
Two different options have been given below for making a 1% solution – one is determining the weight of chlorine powder from first principles and the second provides a simplified equation for calculating the same. Following this is a table with estimated weights for different types of chlorine.	
Steps and calculation option 1	1. A 1% solution has the following amount of active chlorine for a given volume of water – note that grams are equivalent to millilitres (i.e. 100 ml = 100 g):

Table 8 - Weight of available chlorine in different volumes of water for a 1% solution

Weight of active chlorine	Volume of water
1 g	100 ml
10 g	1,000 ml
10,000 mg	1,000 ml
10 mg	1 ml

2. So to make 1% solution with product with n% available chlorine:
   - For every litre of water 10 x (100/n) grams is needed
   - *For example: if using HTH with 70% available chlorine = 10 x (100/70) = 14g / litre*

Steps and calculation option 2

1. Use the following calculation to establish the amount of powder required to prepare 1 litre of 1% chlorine solution from HTH 70% active chlorine

$$\text{Powder required (g)} = \frac{\text{1,000 x volume of chlorine liquid required (litres) x desired liquid chlorine concentration (\%)}}{\text{Active chlorine concentration in chlorine powder (\%)}}$$

Example:

$$\textit{Powder required (g)} = \frac{\textit{1,000 x 1 litre x 1\%}}{\textit{70\%}} = \textit{14 g of HTH per litre of water}$$

So if you want to make a 10 litre batch of 1% chlorine you will need 10 x 14g of HTH.

Measuring chlorine if you don't have weighing scales

If you do not have weighing scales an approximate measure can be used (as long as you are consistent and use the same measure each time you make your stock solution):

- *For example: 14g = approx. 1 tablespoon, so for 10 litres of 1% use 10 spoons*

The following is a simplified table of quantities for preparing a 1% solution.

Table 9 - Preparation of a litre of 1% chlorine solution[21]

Chlorine source	Active chlorine %	Quantity required	Approx. measure
High test hypochlorite (HTH) granules	70	14g	1 tablespoon
Bleaching powder	35	30g	2 tablespoons
Liquid household disinfectant	10	100ml	
Liquid laundry bleach	5	200ml	

(1 tablespoon, slightly rounded = approximately 15ml; 1 teaspoon = approximately 5ml)

[21] Davis, J and Lambert, R (2002, 2nd Edition) *Engineering in Emergencies, A Practical Guide for Relief Workers,* Register of Engineers for Disaster Relief and Practical Action Publishing

Protocol 6 – Jar test to establish the required chlorine dosage and chlorine quantity

Purpose

To establish the required chlorine dosage rate for the particular water and the quantity of chlorine for the application.

Important notices

- It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure of a fire occurs – see **Protocol 2** and **Protocol 3**.
- It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.

Steps

Undertaking a jar test[22]

1. Line up 6 buckets or jerrycans and mark them on the side with the volume of water to be added to each.
2. Add 1% solution in the quantities in the following table to buckets or jerrycans (with a syringe) – *in this example using 15 litres of raw water.*

Table 10 - Examples of volumes to be added to 15 litres of water for the jar test

Bucket 1	1 ml
Bucket 2	1.5 ml
Bucket 3	2 ml
Bucket 4	2.5 ml
Bucket 5	3 ml
Bucket 6	4 ml

3. Wait for 30 minutes = usual contact time.
4. Measure FRC in each bucket using a pooltester and DPD1 tablets.
5. Choose the bucket with a residual closest to the required residual:
   a. *For this example assume we want a residual of 0.5 mg/L*
6. Multiply volume of 1% solution needed for larger quantity.
   a. *For this example - How many litres of 1% needed to treat a 5,000 litre bowser if the correct dose (that gave us a residual of 0.5 mg/L after 30 minutes) was found to be bucket 4?*
      i. *2.5 ml was added to bucket 4. This was diluted in the 15 litres of water contained in the bucket.*
      ii. *So 2.5/15 = 0.167 ml per litre required for this specific water*
      iii. *Therefore a 5,000 litre water truck needs 0.167 ml x 5,000 = 835 ml of 1% solution*

Important note

- It is important to remember that the following are <u>not the same things</u>:
  - <u>ml/L - of 1% chlorine solution added into the bucket</u> (as above)
  - <u>mg/L - free residual</u> (as measured after 30 minutes)
  - <u>mg/L - dosage rate</u> (as calculated below)

[22] This protocol has been developed from: Fewster, E (2017)

- From the previous jar test example:
  - *The dosage rate in mg/L = ranging between 0.67 and 2.67 mg/L*
  - *For example with bucket 4:*
    - *We know that a 1% solution has 10 mg active chlorine in 1 ml (see* **Protocol 5***)*
    - *So in 2.5 ml we know that there is 25mg of active chlorine*
    - *When this is which diluted into 15 litres means there is 1.67 mg/L as the dosage rate (25 / 15 = 1.67)*

Table 11 - Differences between dosage and free residual

	Dose of active chlorine for 15 litres of water (in syringe)	**Dose volume for 15 litres of water (in syringe)**	**Dose of active chlorine per litre of water under test** (i.e. dose in syringe / volume of water)	**FRC in the water under test**
Bucket 1	10 mg	1 ml	0.67 mg/L	
Bucket 2	15 mg	1.5 ml	1 mg/L	
Bucket 3	20 mg	2 ml	1.33 mg/L	
Bucket 4	25 mg	2.5 ml	1.67 mg/L	In the range 0.2 – 0.5 mg/L
Bucket 5	30 mg	3 ml	2 mg/L	
Bucket 6	40 mg	4 ml	2.67 mg/L	

- For drinking water, normal dosage rates tend to be between 1 – 5 mg/L:
  - For clear water, usually 0.5 – 2 mg/L
  - For water with some turbidity this can be higher and up to 4 or 5 mg/L

Calculate the chlorine quantity required for the application

- Based on the calculation of dosage rate established using the jar test, calculate the required kg of chlorine for a set time period to ensure you have enough in stock and in the supply pipeline.
- It is important to consider if your water consistency is likely to change and hence to add on some additional volume of chlorine to the estimate to ensure you do not run out – how much additional will depend on how reliable your logistics supply chain and processes are.
- If you undertake the jar test regularly you should be able to establish with more accuracy the likely variations in chlorine requirement.
- *Example: Based on the previous example, for budgeting & stock planning, how many kg of HTH do you have to order for 3 months if the daily water demand is 80,000 litres?*
  - *0.167 ml of 1% required to treat 1 litre*
  - *80,000 litres x 0.167 ml = 13,360 ml of 1% per day (13.36 litres)*
  - *13.36 litres x 90 days = 1,202 litres of 1% in 3 months*
  - *14 grams of HTH makes up 1 litre of 1%, so 14 g x 1,202 litres = 16,828 grams = 16.83 kg*

<table>
<tr><td rowspan="2">What should you do if you don’t find any chlorine residual when doing the jar test?</td><td>Why might the problem have occurred?</td><td>1. The chlorine may have expired – which can be quite likely with liquid chlorine products like bleach
2. The chlorine may not be 70% HTH? Could be you have been using 30% chlorine if there is no label?
3. The DPD1 tablets may have expired
4. You left the jar test buckets out in strong sunlight – even 30 mins in the sun can reduce residual
5. There is some turbidity that has been using up the chlorine
6. You have been chlorinating water that is affected by seawater – sometimes DPD tablets do not work well in such conditions with delayed colour reaction, or none at all</td></tr>
<tr><td>What should you do?</td><td>Try and check the following:
1. Ask where the chlorine was stored – how hot, for how long?
2. Check if the DPD1 tablets have expired or try another batch
3. If you find you have been using a weaker chlorine solution you may need even twice as much powder per litre to make the 1% solution and you will have been dosing with too weak a solution
4. If you were doing the jar test in the sunlight – repeat the test in the shade
5. If the turbidity has been using up the chlorine, preferably find ways to decrease the turbidity. You could also repeat the jar test and increase the chlorine dose (but in this case you will have more by-products and taste/odour produced as a result).
6. If you suspect the water may be saline, test the Electrical Conductivity or the chloride levels to check
7. Repeat the jar test</td></tr>
<tr><td>Calculation of dosage rate for continuous dosing</td><td colspan="2">Example of how to calculate the flow of 1% solution into the dosing line:
• You have a flow of 18,500 litres/hour pumped in a pipeline and you want to do on-line dosing
• The jar test showed you needed 2.5ml of 1% solution per 15 litres for the residual required
• So 2.5/15 = 0.167 ml/L
• Multiply 0.167ml/L x 18,500 L/h= 3,090 ml of 1% solution dosed per hour
• Calibrate your dosing machine for something measurable like 1 to 5 mins:
    o For one minute you need 3,090/60 = about 52 ml per minute
    o This is then what you need going through the dosing line when calibrating the dosing pump</td></tr>
</table>

Adjusting the chlorine dose with continuous dosing	Once you have set up the chlorine dose for the continuous flow dosing system, if you find that the chlorine residuals are not adequate, it is best to repeat the jar test to reset the flow rate for the dosing system. ⇨ **See Protocol 5 for making a 1% solution and Protocol 6 (above) for how to undertake a Jar Test**. <u>A second less accurate option would be to:</u> 1. Adjust the dose in a step-wise fashion - that is gradual (little by little). 2. Do not make large adjustments all at once or you risk over- / under-dosing. 3. Always consider the time taken for newly dosed water to flow through (or turn over) in the tank or pipe before additional adjustments are made – for example it may take two days for a higher chlorinated water to reach a particular point in the distribution system. 4. Always increase chlorine monitoring following changes in the chlorine dose to ensure the dose has been optimized and under- or over-dosing is not occurring. 5. Adjustments to the chlorine dose may be required following the use of a fresh batch of chlorine, due to batch variation with regards to the strength of the new chlorine liquid solution.

Protocol 7 – Chlorination of drinking water in storage tanks, tankers and donkey carts	
Purpose	To provide guidance on how to chlorinate drinking water storage tanks, bladders and tankers.
Important notices	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.
Cleaning and disinfection of storage tanks, tankers and donkey carts	See **Protocol 10**.
Chlorination of drinking water in storage tanks and tankers	<u>Calculating the dosage:</u> 1. Undertake a jar test to establish the required dosage for the size of storage tank or tanker – see **Protocol 6**. **See Protocol 5 for making a 1% solution and Protocol 6 for how to undertake a Jar Test**. <u>Dosing the drinking water:</u> 1. Make a 1% solution – see **Protocol 5**. 2. Dose the tank when the water is still being filled to help to mix the tank 3. Leave the tank to stand for a minimum of 30 minutes after dosing before allowing it to be supplied (or the required amount of time considering the pH and turbidity - see **Protocol 4**) 4. Check the residual of the water leaving the tank – **it should be a minimum of 0.5 – 1.0 mg/L** at the point of supply (see **Section 5.1**)
Chlorinating drinking-water in a donkey cart with 1.67g NaDCC tablets	1. It is important to start by reading the manufacturer's instructions for the dosage for drinking water – this may however take the worst case scenario so you may need to modify the dosage to suit the water you are using. 2. For example – the manufacturer of a common brand of 1.67g chlorine tablets in Sudan suggests to dose at 2 tablets per 400 litre tanker. This leads to a starting dose of 5 mg/L. It is assumed that the manufacturer will have assumed for this dose that the water will have a degree of turbidity and there is no testing/control/calibration. 3. But if the water is from a groundwater source or the water has already been treated before being supplied to the Water Yard, the water should have limited contamination a lower dosage would be applicable. For example:

- In Kassala, the starting dosage that is being used (0.5 tablets per 400 litre drum) is equivalent to 1.25 mg/L
- In Khartoum the starting dosage that is being used (1 tablet per 400 litre drum) is equivalent to 2.5 mg/L

4. It suggested to start with a test of ¼ tablets per 400 litres, then ½ tablet, then 1 tablet, checking the FRC at each step.
5. To check that you have dosed the tanker appropriately, test the chlorine residual:
   - Aim for a minimum of 0.2mg/L at the household after 24 hours of water storage
   - If you are getting less or more than this, then increase or decrease the dosage accordingly to suit the water you are using

Chlorinating a donkey cart with HTH (70%) chlorine powder

1. Make a 1% solution – see **Protocol 5**.
2. Undertake a jar test to establish the required dosage for the size of the donkey cart tank – see **Protocol 6**.

See Protocol 5 for making a 1% solution and Protocol 6 for how to undertake a Jar Test.

It is always best to do a jar test, but if the jar test is not possible, a rough method that could be used by trial and error would be:

3. A 1% solution has 10 mg of active chlorine / 1 ml (and so 1 mg of active chlorine is in 0.1 ml.)
4. Try the dosages in the following table for 200 or 400 litre drums starting from the dosage of 1mg/L and test the chlorine residual at the households who use the water after 24 hours – aim for 0.2 mg/L FRC after 24 hours.
5. If the dosage does not result in the required residual adjust the dosage up (or down if the dose produces too much residual) accordingly.
6. Repeat the process until the required FRC is obtained at household level after 24 hours.

Table 12 - Dosages of 1% solution to chlorinate donkey tanker drums

Dosage	Calculation of the number of ml of 1% solution to be added	Volume of 1% solution (ml) to be added to:	
		200 litre drum	400 litre drum
1 mg/L	0.1 x size of tank in litres	20 ml	40 ml
2 mg/L	0.2 x size of tank in litres	40 ml	80 ml
3 mg/L	0.3 x size of tank in litres	60 ml	120 ml
4 mg/L	0.4 x size of tank in litres	80 ml	160 ml

Protocol 8 – Bucket and household drinking water chlorination

Purpose

To provide guidance on how to undertake bucket and household drinking water chlorination.

Important notices

- It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**.
- It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.

Bucket chlorination using a 1% solution

Steps:

1. Individual containers are dosed using a 1% chlorine solution and a syringe.
2. Ask the owner to not drink the water for a minimum of 30 minutes.

Notes:

- Different sizes of water containers need different doses.
- Requires recruitment, training and close support supervision of "chlorinators".
- Could be expensive if there are many water points to cover.
- Short term solution only.
- Effective and fast method if properly implemented.

Dosages:

3. Ideally undertake a jar test to establish the required dosage for a specific volume (see **Protocol 6**) and adjust according to commonly used container sizes.

See Protocol 5 for making a 1% solution and Protocol 6 for how to undertake a Jar Test.

It is always best to do a jar test, but if the jar test is not possible, a rough method that could be used by trial and error would be:

1. The following table provides an example starting point for the ml of 1% solution to be injected into each container.
2. The water in some of the containers should then be tested for FRC and the volumes adjusted to get as near as possible to 0.5 mg/L FRC in each container.
3. If the dosage does not result in the required residual adjust the dosage up (or down) accordingly.
4. Repeat the process until the required FRC is obtained.

Table 13 - Approximate dosages by container size

Container size	Example starting point for water with very little turbidity (At an initial 2mg/L dose aiming to result in 0.5 mg/L FRC)	
	Aiming for the following mg of chlorine per container	**ml of 1% solution to be injected into the container** (1% solution contains 10 mg/ 1 ml)
1 litre	2 mg	0.2 ml
5 litre	10 mg	1 ml
10 litre	20 mg	2 ml
20 litre	40 mg	4 ml
30 litre	60 mg	6 ml

Household drinking water chlorination

It is critical that any distribution of chlorine tablets or liquid for household use must be undertaken with training and back-up monitoring and support to check they are being correctly used.

In general the steps for chlorinating a household drinking water container or a container at a distribution point would be as follows:

1. Wash your hands with water and soap.
2. Check if your water is clear.
3. If the water is clear:
    a. Put a single dose of the tablets or liquid into the container with the water in
    b. Close the container and wait for 30 minutes
    c. The water is then ready to drink
4. If it is not clear:
    a. Filter the water through a cloth
    b. Put in double dose of the tablets or liquid into the container with the water in
    c. Close the container and wait for 30 minutes
    d. The water is then ready to drink
5. Make sure the treated water is stored safely in a clean container with a well-fitted lid. The container should either have a tap or can be poured so that no implement is put inside the container to draw out the drinking water.

The number of tablets or volume of liquid to put into the container will depend on:

1. The size of the container
2. The % of active chlorine in the tablets

Check the manufacturer's instructions to calculate the dosage for the particular brand of tablet or liquid, and make sure that all chlorinators / hygiene promoters understand the correct dosage. One brand of tablets has the following options for sizes (but noting that various brands exist):

Table 14 - Variations in tablet sizes from the Aquatabs brand of chlorine tablets (NaDCC)[23]

"Emergency" Usage Dosage: 4 - 6 mg/l free available chlorine (FAC)			
Aquatabs Strength	**NaDCC Content Per tablet**	**FAC Content Per Tablet**	**Litres of Water Treated Per Tablet**
Strip-packed Tablets (10 tablets per strip)			
Aquatabs 8.5mg	8.5mg	5mg	1
Aquatabs 17mg	17mg	10mg	2
Aquatabs 33mg	33mg	20mg	4 - 5
Aquatabs 67mg	67mg	40mg	8 - 10
Aquatabs 167mg	167mg	100mg	20 - 25
Tubs			
Aquatabs 1.67g (200 tablets per tub)	1.67g	1000mg	200
Aquatabs 8.68g (60 Tablets per tub)	8.68g	5000mg	1000 - 1250

[23] Medentech (no date) *Aquatabs,* Medentech Ltd.

Protocol 9 – Cleaning and disinfection of boreholes and wells

Purpose	To provide guidance on how to clean and disinfect boreholes and wells.
Important notices 	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.
Rehabilitation, cleaning and disinfecting boreholes and wells	Steps to be taken to clean and disinfect a well or borehole: The amount of rehabilitation and cleaning required will depend on the amount of damage to the well or borehole. Typically it will include the following steps: 1. Remove and repair/replace the pumping mechanism or lifting device. 2. Remove polluted water and debris from the well or borehole using either buckets or pumps. 3. Repair/reline the well walls to reduce sub-surface contamination, if needed. 4. Clean the well lining using a brush and chlorinated water. 5. If needed a 150 mm layer of gravel could also be added in the base of the well to protect it from disturbance. 6. If the top of the well or borehole does not have a clay sanitary seal, this should be added. 7. Construct a drainage apron and head wall around the well or borehole if it does not already have one to prevent surface water from entering the well. 8. Provide a cover for the well ideally with a pump of some kind to stop buckets and hands contaminating the water. Disinfection and de-watering the well 1. Take out the pump, measure the water volume in the well or borehole. 2. Calculate the amount of 1% needed based on a 50-100mg dose (see below). 3. Add the chlorine to the well and wait for a minimum of 30 mins (or ideally 2-3 hours). 4. Dewater the well to ensure all of the highly chlorinated water has been removed. 5. This process will clean the well, but will not leave a residual disinfectant and so water treatment and safe storage at the household should also be encouraged. 6. Calculate the amount of chlorine needed for disinfection of the well or borehole. See below for the calculation. Two issues need extra care when dewatering the wells: a. Water with high concentration of chlorine should not flow into streams or wetlands; b. When dewatering on coastal areas salt water intrusion should be avoided.

Calculating the amount of chlorine needed for disinfecting a well or borehole

To calculate the amount of chlorine for disinfecting a well or borehole:

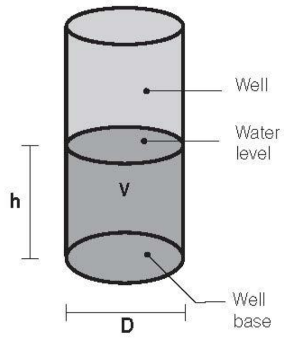
1. Make up some 1% solution (**Protocol 6**).
2. Estimate the volume of water in the well or borehole using the following formula (you will need to use a string and weight to physically measure):

Fig 13 - Estimating the volume of water in a well or borehole

$$V = \frac{\pi D^2 h}{4}$$

Where

V = volume of water in the well (m^3)
D = diameter of the well (m)
h = depth of water (m)
π = 3.142



(credit: WHO/WEDC, 2013)

Example: The well has a diameter of 0.95m, and the depth from the well base to water level is 1.4m. What is the volume?

- *Diameter = 0.95m*
- *Volume = $\Pi D^2 h/4$ = (3.24 x (0.95 x 0.95) x 1.4)/4 = 0.99m^3*
- *0.99m^3 x 1,000 = 990 litres*

3. The concentration of chlorine needed to disinfect a well or borehole is usually between 50 to 100 mg / litre of water in the well or borehole. Use the lower dosage rate if you are just disinfecting the water or the higher dosage rate if in addition you are scrubbing down the walls. You should then add the amount of chlorine according to the dosage rate and volume in the well.

Example: If the lower rate of 50 mg/L is used, how much is that in terms of 1% solution that is needed to add to the well water?

- *See* **Protocol 5** *– 1 ml of 1% solution contains 10 mg of active chlorine*
- *So 5ml contains 50 mg*
- *So if you add 5ml of 1% chlorine to 1 litre you will have a dose of 50mg/L*
- *Therefore the amount of 1% chlorine to add in order to disinfect 990 litres at a rate of 50 mg/L is 990 x 5 ml = 4,950 ml (4.95 litres).*

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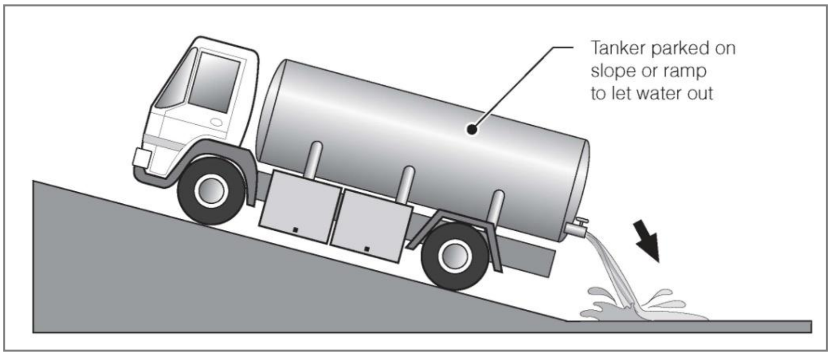
The above steps have been adapted from:

Reed, R.A. (Series Editor.) (2013) ***Technical Notes on Drinking water, Sanitation and Hygiene in Emergencies,*** **WHO and WEDC, UK: No 1 - Cleaning hand dug wells; and No 2 - Cleaning and rehabilitating boreholes**

Protocol 10 – Cleaning and disinfection of storage tanks, tankers and donkey carts	
Purpose	To provide guidance on how to clean and disinfect storage tanks and tankers
Important notices	<u>Health and safety</u> • It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3** • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1** • Gaining access and working inside a water tank can be difficult and dangerous. There is often only a small access hatch on the top of the tanker through which to climb in and out. • Cleaners should be aware that some liquid held in tanks can give off hazardous gases which may remain even when the liquid has been removed. The liquids may also pose physical hazards such as slippery surfaces. Corrosive liquids can cause burns. • Always blow fresh air into the tank for a period before allowing a person to enter. The cleaner should wear protective clothing, including gloves, boots, a hat and goggles as well as having the appropriate respirator mask. • Make sure someone remains outside the tank, next to the access hatch all the time in case the cleaner has an accident. • The use of portable ventilators would be a positive advantage.
Cleaning and disinfecting storage tanks and tankers	<u>Selection of tanks for use for water storage:</u> • Tanks should be selected based on three considerations: normal use; ease of cleaning and water storage hygiene. • Selected tanks should only have been previously used for holding food-grade liquids, for example, milk, cooking oils, fruit juices, wines and spirits or vinegar. Tanks previously used for holding non food-grade liquids such as fuel and sewage should *not* be used. Tanks that previously held water but have been out of use for some time must also be cleaned and disinfected. • Tanks must be easy to clean. This means they must be accessible for cleaning and have no sharp corners that may hold dirt and so prevent the removal of food deposits. • Water will only remain clean if stored safely. Tanks must therefore be covered and fitted with an access point with a lockable lid. <u>Steps to be taken to clean a storage tank or tanker</u>: <u>Empty the tank</u> 1. Open the outlet valve or tap and drain out any remaining liquid. 2. Collect the liquids so that they can be safely disposed of. 3. In the case of tankers, outlet valves are usually located at the back so parking it on a slope

will help to ensure that all the liquid can be discharged.

Fig 14 - Parking a tanker on a slope to facilitate emptying[24]



4. Permanent storage tanks are usually fitted with a washout valve that draws liquid from the base. Use this, rather than the normal outlet valve, for emptying.

<u>Scrub the internal surfaces of the tank</u>

5. Use a mixture of detergent and hot water (household laundry soap powder can be used) to scrub and clean all internal surfaces of the tank. This can be done with a stiff brush or a high pressure jet. Attaching the brush to a long pole may make it possible to clean the tank without entering it.
6. Take special care to clean corners and joints so that no small amounts of the original liquid remain. Even minute amounts of some liquids can give the water a bad taste and people may refuse to drink it.
7. Leave the outlet valve open while cleaning and collect the liquid for safe disposal.

<u>Wash and flush the tank</u>

8. This is most easily done with a high pressure hose pipe or water jet but if they are not available the tank can be filled with (preferably hot) water and left to stand for a few hours.
9. Drain all the water from the tank and collect for safe disposal as before.
10. Continue flushing the tank until there are no longer traces of detergent in the water.

<u>Calculate the volume of the tank</u>

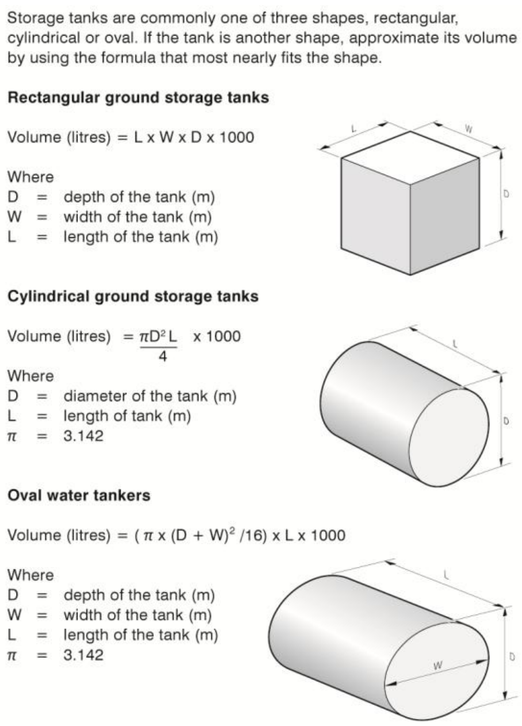
11. The amount of chlorine needed to disinfect the water tank will depend on its volume. See below for details of how to calculate the amount of chlorine needed.
12. Tank cleaning should take place in open areas away from houses to avoid possible health problems resulting from the disposal of the wastewater.

<u>Clean hoses</u>

13. The hoses, pumps and pipes used for filling and emptying the tank must also be cleaned. Flush a mixture of hot water and detergent through the pipes and pump to remove deposits and other waste material.

[24] Reed, R.A. (Series Editor.) (2013) No 3

	14. Once cleaned, flush the system with clean water to remove the detergent. <u>Add the disinfectant</u> 15. Fill the tank a quarter full with clean water. Pour in the required volume of concentrated chlorine liquid solution while the tank is filling. Fill the tank completely with clean water, close the lid and leave to stand for 24 hours. 16. If the tank is required for use urgently, double the quantity of chlorine added to the tank. This will reduce the time of disinfection from 24 to 8 hours. <u>Disinfecting the hoses and pump</u> 17. If the tank is fitted with a pump, connect the hoses so that water is drawn from and returned to the tank. 18. With the tank full of water and disinfectant, start the pump so that the mixture passes through the hoses and pump. Run the pump for about an hour. Repeat this procedure with the tank full of clean water. 19. If no pump is fitted, use some of the disinfectant from the tank and gently fill the hoses to full capacity. You will have to block one end of the hose and fill it from the other end. Allow to stand for 24 hours. 20. Empty out the disinfectant and connect the hoses to the tank outlet so that when the clean water in the tank is discharged it passes through the hoses. The hoses are now ready for use. <u>Prepare for use</u> 21. Completely empty the tank and carefully dispose of the disinfecting water as it will contain a high concentration of chlorine. Fill the tank with drinking-water, allow to stand for about 30 minutes then empty the tank again. The tank is now ready for use. <u>Safely dispose of liquid waste</u> 22. Care must be taken when disposing of all liquids used for cleaning and disinfecting the tanks. Sudden discharge of water will cause localized erosion or flooding. Make sure the water follows a channel to its final disposal point. 23. Liquid waste should not be disposed of in rivers and ponds as the organic materials and high chlorine levels may kill fish and plant life. Wastewater should be disposed of to a sewer network, carried in tankers to a sewage treatment plant or disposed of in an underground soakage system. The above steps have been adapted from: **Reed, R.A. (Series Editor.) (2013) *Technical Notes on Drinking water, Sanitation and Hygiene in Emergencies,* WHO and WEDC, UK: No 3 – Cleaning and disinfecting water storage tanks and tankers**
Calculating the amount of chlorine needed for disinfecting a storage tank or	To calculate the amount of chlorine for disinfecting a storage tank or tanker: 1. Estimate the volume of water in the tank using the formulas on the following page 2. The concentration of chlorine needed to disinfect a storage tanks is approximately 50 to 100 mg/ litre of water in the storage tank or tanker 3. Mix approximately 114g of HTH for every 1,000 litres of the total capacity of the tank (this is a dosage of approximately 80 mg/L)

<table>
<tr>
<td>tanker</td>
<td>


(credit: WHO/WEDC, 2013)
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<tr>
<td>Cleaning the donkey cart and making sure that they have a well-fitted lid</td>
<td>
When providing the chlorine tablet for disinfecting the donkey cart, take the opportunity to provide hygiene education to the donkey cart operator. This should include:

The need to clean the inside of the donkey cart on a regular basis:

Use hot water to clean the internal surfaces of the tank.
Brush with a medium sized handle (or a brush attached to a stick) and brush as much of the surface inside the tank as possible to reach.
If you have access to a high pressure hose this can clean the inside of the tank.
Flush out the tank until it is empty and waste the water from the tank.
Fill the tank with water and add chlorine at a higher dosage to disinfect the tank – for example a dose at 5 times the usual dosage for the drinking water.
Also fill the hose with the same water (after blocking the end).
Leave it in the tanker for a few hours.
Empty the tanker to waste taking care of where the wastewater is disposed of as it will contain a high concentration of chlorine – <u>DO NOT</u> allow this water to be drunk.
Refill the tanker one more time and leave it to stand for 30 minutes.
Empty it to waste and then the tanker is then ready to use.

The need to clean the outside of the donkey cart and the donkey cart has a well fitted lid.
How to instruct the household members to clean their jerry cans or containers, keep them covered with a lid, and to not dip a cup inside the container but to pour the water from the container or use a tap.

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</table>

Protocol 11 – Disinfection of pipelines after installation or repair	
Purpose	To provide guidance on how to clean and disinfect pipelines after installation or repair.
Important notices	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3**. • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**.
Cleaning and disinfection of pipelines after installation or repair	Steps to bring a new distribution main into service[25]: A new main after installation should be pressure tested, flushed to remove all dirt and foreign matter and disinfected prior being placed in service. Different methods can be applied in the chlorination of a distribution system: Continuous method: 1. The continuous method involves supplying water to the new main with a chlorine concentration of at least 50 mg/L. Either a solution-feed chlorinator or a hypochlorite feeder injects chlorine into the water that fills the main. 2. The chlorinated water should remain in the pipe for a minimum of 24 hours while all valves and hydrants along the main are operated to ensure their disinfection. 3. At the end of 24 hours, no less than 25 mg/L chlorine residual should be remaining. Batch method with continuous feed to replace leakage: 1. Acquire a tanker of volume equal to, or higher than, the calculated volume of the pipe. 2. Fill it with water with at least 50 mg/L of chlorine and connect the water tanker to the upstream valve. 3. Open the valves between the tanker and the pipe. 4. Gradually open the downstream washout so that the chlorinated water replaces the clean water in the pipe (or pump the water into the pipe). 5. Continue feeding water into the pipeline until chlorine can be smelt in the water coming out of the washout. 6. Close the washout valve but leave the inlet valves open so that chlorinated water can still enter to replace leakage. 7. Leave the pipeline for 24 hours. Slug method with a higher dosage – for use where 24 hour contact is impractical, often for large mains: 1. In the slug method of chlorination, a continuous flow of water is fed to the main with a chlorine concentration of at least 300 mg/L. The rate of flow is set so that a column of chlorinated water contacts the interior surfaces of the main for a period of 3 hours.

[25] MoWRIE/DWSU (2009, draft) Technical Guideline and Manual for Drinking Water Distribution Networks for Field Staff and Practitioners; and Reed, R.A. (Series Editor.) (2013) *Technical Notes on Drinking water, Sanitation and Hygiene in Emergencies,* WHO and WEDC, UK: No 4 – Rehabilitating small-scale piped water distribution systems

	2. As the slug passes, other connections, the valves are operated to ensure disinfection of all parts of the system. Following disinfection by any of the above methods: 1. The chlorinated water should be flushed to waste by using potable water until the water coming out no longer smells strongly of chlorine. 2. A microbiological test should then be conducted before placing the main into service. Disinfecting a broken main: 1. When disinfecting a broken main, it is isolated by closing the nearest valves. 2. The first step in repair involves flushing the broken section to remove contamination while pumping the discharge out of the trench. 3. Minimum disinfection includes swabbing the new pipe sections and fittings with a 5% hypochlorite solution before installation and flushing the main from both directions before returning the system to service. 4. Where conditions permit, the repaired section should be isolated and disinfected by any of the procedures described above.

Protocol 12 – Chlorine mixes for use in cholera treatment centres and determining the strength of a chlorine solution	
Purpose	To provide guidance on how to make up chlorine mixes for use in cholera treatment centres and how to test the concentration of a strong chlorine mix.
Important notices 	• It is critical that a person who will be handling chlorine is trained to understand how to store and handle chlorine safely and what to do if there is an accidental exposure or if a fire occurs – see **Protocol 2** and **Protocol 3** • It is critical that the user wears appropriate personal protective equipment – PPE – see **Protocol 1**
Chorine mixes used in cholera treatment centres	The table on the following page provides an overview of the different chlorine mixes commonly used in cholera treatment centres. Note that the World Health Organisation, Médecins Sans Frontières and UNICEF promote a different concentration of chlorine for the mid-range concentration (0.2% and 0.5%). Both options have been included below for use when in centres operated with the support of any of these organisations. Both concentrations are acceptable. The amount of chlorine powder to be used in each mix can be calculated using the following equation, or **Table 15** at the end of this Protocol can be used for approximations. $\text{Powder required (g)} = \dfrac{\text{1,000 x volume of chlorine liquid required (litres) x desired liquid chlorine concentration (\%)}}{\text{Active chlorine concentration in chlorine powder (\%)}}$ *<u>Example:</u> HTH powder required (g)* $= \dfrac{\textit{1,000 x 1 litre x 2\%}}{\textit{70\%}}$ *= 28 g of HTH per litre of water*
Determining to strength of a strong chlorine solution	
Purpose	To establish the strength of chlorine before dosing. This is only normally important where there is a need to know the concentration of high strength solutions such as are used on cholera or Ebola treatment centres. It can also be used to check the strength of a batch of chlorine that has been stored for a long period of time; noting however that if undertaking a Jar Test the actual concentration of the chlorine does not need to be known, just the quantity of chlorine that needs to be added to reach a specific FRC.
WATA Test	For the high percentage of chlorine mixes (from 0.05% to 2% chlorine), a test kit called the **'Wata Test'** is now available[26]. It is used by putting a number of drops into a 2ml sample of the chlorine and mixed until a colour change occurs. The resulting chlorine concentration is then established in grams per litre by dividing the number of drops by half. For example if you use 10 drops then it is established that the concentration of the chlorine mix is 5 g/L (10 / 2 m = 5). Since we know that a 1% solution of chlorine has 10 g/L, then 5 g/L = 0.5% chlorine.

[26] The Wata Test can be purchased from Antenna Water; email: wata@antenna.ch; website: https://antenna.odoo.com/shop/product/kwt-kit-watatest-wata-3

Modified Horrocks method	An alternative method known as the 'Modified Horrocks' method can also be used. This involves making up a number of buckets of distilled or unchlorinated bottled water (which will have very low chlorine demand) and adding different volumes of chlorine to result in a range of concentrations of chlorine residual. As it is possible to calculate what the chlorine residual is expected to be at a specific concentration (for example when using HTH at 70% active chlorine), when the results are different from this, the modified strength can then be determined. For example if the residual proves to be 50% less than was expected, it can be assumed that the chlorine has lost 50% of its strength. This test has been superseded by the arrival of the Wata Test, which provides a simple and quick tool for checking strong chlorine solutions that might be used in cholera or Ebola treatment centres. But has been included in case the WATA test is not available.

Table 15 - Approximate chlorine mixes for use in cholera treatment centres[27]

	0.05%	**0.2%** (MSF & UNICEF)	**0.5%** (WHO)	**2%**
Uses	Hands, showering, washing utensils and dishes, clothes	Disinfection of shoes, floors, walls, beds		Faeces, vomit (the resultant fluid will not be 2%) Dead bodies (2% used without dilution)
How often to make solutions?	Make daily	Make daily	Make daily	Stable for one week if stored properly
Grams of <u>active chlorine</u> in 1 litre	0.5 g	2 g	5 g	20 g
Calcium hypochlorite (HTH) at 70% active chlorine	0.7 g / litre 7 g / 10 litres Half (0.5) tablespoon / 10 litres	3 g / litre 30 g / 10 litres 2 level tablespoons / 10 litres	7 g / litre 70 g / 10 litres 5 level tablespoons / 10 litres	28 g / litre 2 level tablespoons / 1 litre
Bleaching powder at 30% active chlorine	1.7 g / litre 1 level tablespoon / 8 litres	7 g / litre 70 g / 10 litres 4 level tablespoons / 10 litres	17 g / litre 1 level tablespoon / 1 litre	67 g / litre 4 level tablespoons / 1 litre
Sodium dichloro-isocyanurate (NaDCC) 1.67g tablet (with 1g active chlorine per tablet)	0.5 tablets / litres	2 tablets / litre	5 tablets / litre	20 tablets / litre

[27] WHO (2004) *Cholera Outbreak: Assessing the outbreak response and preparedness*, WHO/CDS/CPE/ZFK/2004.4; UNICEF (2013) *Cholera Toolkit; and* Médécins Sans Frontières (2004) *Cholera Guidelines*

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- 1 - *Cleaning hand dug wells*
- 2 - *Cleaning and rehabilitating boreholes*
- 3 - *Cleaning and disinfecting water storage tanks and tankers*
- 4 - *Rehabilitating small-scale piped water distribution systems*
- 11 – *Measuring chlorine levels in water supplies*
- 12 - *Delivering safe water by tanker*
- 15 – *Cleaning of wells after seawater flooding*

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- *Disinfectants*. Fact Sheet 2.16
- *Chlorine gas or liquid in cylinders*. Fact Sheet 2.18
- *Calcium hypochlorite*. Fact Sheet 2.19
- *Sodium hypochlorite*. Fact Sheet 2.20
- *Continuous chlorination of dug wells*. Fact Sheet 2.21
- *Dosing hypochlorite solutions*. Fact Sheet 2.22
- *Dosing chlorine for cylinders*. Fact Sheet 2.23
- *Chlorine Monitoring at Point Sources and in Piped Distribution Systems; Chlorination in epidemic and disaster situations.* Fact Sheet 2.30
- *Chlorine testing*. Fact Sheet 2.31

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