WATER NEW ZEALAND
Good Practice Guide

HYGIENE PRACTICES TO PREVENT WATER SUPPLY CONTAMINATION

December 2019

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Foreword

Ensuring good industry practice when staff or contractors are working on water supply systems is an essential element of protecting the public from possible infection. At present in New Zealand, there is a range of guidance material used, with some sourced from overseas.

This guide was produced at the request of water service managers employed by local authorities, to provide advice based on best practice overseas and in New Zealand.

Water New Zealand encourages councils operating public water supplies to adopt this document, and to ensure staff and contractors working on their systems adopt the practices it contains.

Water New Zealand
December 2019

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1.0 Background and Statement of Purpose

Contamination of the water supply can occur at source, treatment, in reservoirs, and throughout the reticulation system as a result of poor hygiene practices during the installation of new equipment (including pipes, valves, fittings, and reservoirs), inspections, repairs, and maintenance activities.

The intention of *Hygiene Practices to Prevent Water Supply Contamination, Good Practice Guide* (the Guide) is to provide a user-friendly document for water operations staff, contractors, and their managers working on potable water networks. Using this Guide should facilitate the development of procedures and operational practices that will reduce the risk of water supply contamination.

The Guide describes basic methods of minimising the risks of contamination of drinking water while protecting the health and safety of personnel.

2.0 Principles

This Guide is not a standard. Reference to relevant standards is contained in the document. Some parts of relevant standards are reproduced in the Guide to assist with understanding the context of a statement.

The contents of the Guide do not take precedence over any legislative requirements.

- It is the responsibility of the water supplier to safeguard the health of New Zealand's communities by adhering to the requirements set out in the *Health Act 1956*.
- As described by the Resource Management Act 1991, it is the obligation of regional councils to protect both the natural resource of New Zealand's water and the general environment. Water suppliers are consequently required to ensure sufficient chlorine neutralisation when discharging hyper-chlorinated water.
- Under Section 69S of the Health Act, in the case of maintenance work that involves interruption to a water supply of more than eight hours, it is the duty of the water supplier to inform affected customers and the Medical Officer of Health.
- In the event of a known contamination occurring resulting in water (potable, waste, or storm) not meeting the legal quality requirement, the water provider is accountable for informing the regulatory body and any customers affected.
- It is the responsibility of water operations staff to inform their manager of any concerns they may have regarding the public safety of the water supply post maintenance.
- It is the responsibility of water operations managers to ensure the safety of their staff by understanding both the given situation and the limits of staff capability as discussed in the *Health and Safety at Work Act 2015*.

3.0 Implementation

Good hygiene practices are the key to preventing contamination of the water supply following the installation or renovation of a reticulation system.

In order to achieve this objective, a well-defined hygiene plan should be followed by all staff (including contractors) working on potable water. Such a plan should make clear for workers uniform work processes that will protect the community's health as well as their own.

Well-kept records of hygiene procedures will assist in distinguishing and mediating faults, as well as making sure all correct steps are taken to prevent such faults.

This Guide provides templates that can be used to develop personalised hygiene procedures for staff to follow.

4.0 Definitions

Backflow: An unintended or undesirable reverse flow of water. This could be from property back to the reticulation, or from a yet-to-be disinfected pipe back into the reticulation. Both have the potential to cause a serious health risk.

Contamination: The presence of an unwanted constituent, harmful substance, or impurity into a potable water system.

Dead-ends or dead legs: A section of pipe which has no exit, in which water can remain static.

DWSNZ: Drinking Water Standards for New Zealand 2005 (revised 2018) and subsequent amendments https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

FAC: Free available chlorine. This is the part of the total chlorine measurement that has not yet reacted with contaminants.

Flushing: The process of cleaning, or scouring, the interior of water distribution pipes by sending a rapid flow of water through the mains.

HPC: Heterotrophic Plate Count. Heterotrophs are a group of microorganisms that can be found in all types of water. HPC results are not an indicator of water safety and should not, therefore, be used as an indicator of potential adverse human health effects. The benefit of HPC monitoring is as an indicator of microorganism levels (cleanliness of pipework), and becomes a concern if there is an increase in HPC concentrations above baseline levels.

Ice Pigging: The use of a saline ice slurry to cleanse a pipe. The benefit of this method is that the slurry can be introduced into the pipe through a hydrant, and typically requires less water than pigging as it produces less waste material to manage.

Hyper-chlorination: Also known as super-chlorination, this is the use of high doses of chlorine (above the DWSNZ MAV of 5 mg/L) to disinfect water systems.

MAV: Maximum acceptable value.

mg.min/L: The concentration of disinfectant in mg/L per minute of contact time (C.t.) as pertaining to contact time values.

Pigging: The use of a pig (a cylindrical, typically foam, object with a cone-shaped nose) inside pipelines for a variety of purposes including removing debris and biofilm that can be the source of taste and odour issues.

Spade: A solid plate that is inserted between two flanges to provide an isolation point.

Swabbing: A process of cleaning a water main by inserting a soft material shaped like a bullet, often inserted into a fire hydrant and pushed through the main with water and out of a scour point or another hydrant.

5.0 Scope

This Guide provides water operations staff with the information required to establish a model set of procedures for preventing contamination of a water supply following the installation or upgrade of a pipework, treatment plant, pump station, or reservoir system. Such procedures are necessary to ensure the safety of the water supplied, and to protect the health and safety of workers.

This Guide can be used by personnel working on potable water networks for the disinfection of both reservoirs and mains after maintenance, refurbishment, or installation of equipment.

There are many potential sources of contamination of a water supply network (such as backflow, air valves allowing water from a flooded chamber to enter a pipe during a low pressure situation, vermin entering a reservoir, leaky roof seals in reservoirs, reverse flow in a pipe, dead legs in a pipe network, etc.) which are not covered in this guide. These sources of contamination fall within the domain of regular maintenance and should be covered in a water safety plan.

Sydney Water and Oxyzone have developed a portable trailer-mounted ozone unit for disinfecting water mains which, in theory, could also be used to disinfect reservoirs. This is a recognised method to disinfect and does have some advantages over disinfection with chlorine. This use of portable ozone units to disinfect is not common in New Zealand as yet and is therefore not discussed in this Guide.

6.0 Dosing Chlorine

Chlorination is the most common method for disinfecting both reservoirs and water mains when commissioning new works or during maintenance.

There are three different types of chlorine commonly used for disinfection: chlorine gas, sodium hypochlorite, and calcium hypochlorite (for example High Test Hypochlorite (HTH)).

All forms of chlorine have hazardous substance storage and handling requirements. It is strongly recommended that people using these chemicals are aware of the requirements identified in the material safety data sheets.

6.1 Chlorine Gas

Chlorine gas is the most common form of permanent chlorination used in water supplies in New Zealand. It can be delivered in 90, 100, 920, and 1,000kg volumes at >99.5% chlorine. An ejector is used to create a vacuum system that is then connected to a chlorinator to control the volume released from the chlorine cylinder or drum. The cylinder or drum connections also have heaters fitted to avoid moisture occurring and forming a corrosive hydrochloric acid solution. There are significant hazardous substance requirements associated with chlorine gas installations (*Health and Safety at Work (Hazardous Substances) Regulations 2017*) which constrain the application of chlorine gas for temporary disinfection.

6.2 Sodium Hypochlorite

Sodium hypochlorite is a liquid version of chlorine that can have a solution strength between 0.8% and 17%. The solution strength is significantly affected by heat, light, age, and the presence of contaminants.

Sodium hypochlorite can be generated on site typically in the 0.8-1.0% solution strength range, or be delivered by a chemical supplier at higher solution strengths.

It is relatively easy to use sodium hypochlorite as a method for disinfection in the field, as the amount of product required at the site is easily transportable. It either requires a dose pump arrangement to inject the product into the stream of water as it fills the reservoir or pipe at a fixed flow rate, or a known quantity of product that can be poured into a reservoir and thoroughly mixed.

Sodium hypochlorite loses its strength over time (weeks). As the strength decays, undesirable chlorates are formed, the MAV of which is governed by the DWSNZ.

6.3 Calcium Hypochlorite

Calcium hypochlorite comes in either granules, solid pellets, or slow-release tablets, and dissolves readily in cold or warm water.

Calcium hypochlorite can be stored for a long period of time with only a small loss in strength (3-5% per year) and has a higher solution strength than sodium hypochlorite (typically 65-70%). Consequently, less product transportation is required.

It is best practice to create a disinfection chlorine solution from calcium hypochlorite. Once dissolved, the solution strength is similar to that of sodium hypochlorite.

Calcium hypochlorite can be introduced in similar ways to sodium hypochlorite.

A constant chlorine solution can be created from calcium hypochlorite by small portable feeder systems.

Do not use calcium hypochlorite intended for swimming pool disinfection, as this material may have been sequestered, and it is extremely difficult to eliminate the additional chemicals from the pipe after the required contact time has been achieved.

7.0 Reservoir Disinfection

7.1 Risk Summary

There are three main factors in reservoir maintenance that could compromise the quality of the water supply:

1. **Contamination through equipment:** Reservoir maintenance may require a person or machinery to enter the reservoir. As there may be contaminants on that person or machinery, a strict disinfection procedure must be adhered to.
2. **Intrusion**: When hatches or valves are opened, there is a risk of contamination entering a reservoir. Risk assessments from both a public health and staff health and safety perspective should be carried out prior to work commencing.
3. **FAC deficiency**: This could arise from a miscalculation, unknown disinfection strength, poor mixing practices, or insufficient sampling. Only competent staff should carry out this work.

Proper workforce training and documentation is required to mitigate each of these risks.

7.2 Preliminary Actions

Ideally, before work commences on a reservoir, the facility should be removed from service, and isolated by closing all the inlet and outlet valves. If the reservoir inlet/outlet valves must be inspected in the open position, system valves further upstream (or downstream) should be closed to isolate the section. An alternative method is to install a spade. Some organisations have a practice of requiring double isolation if a person is entering a pipe or reservoir.

If the reservoir is to stay in service while divers or submersibles are used, the water supplier needs to be confident that the contractor’s procedures manage any risks.

To reduce the risk of wind-blown or dropped contaminants entering the facility once a hatch is open, all loose dirt and debris surrounding the hatch should be cleared away prior to opening. The working area in the immediate vicinity of the access hatch should be covered with a protective plastic sheet and, once in place, it should be washed with a disinfectant solution. Wind screens or other protective devices should also be used.

7.3 Free Available Chlorine (FAC)

Chlorination is used to disinfect drinking water by oxidising contaminants. In the case of a diver or submersible being used, the FAC of the reservoir water should be established prior to entry. It is important to have a properly calibrated analyser, which can be achieved through a regular manual calibration check, to ensure accurate measurements are taken.

Representative water samples should be taken from several locations, and analysed for FAC. The results should be recorded for future reference.

The pH of the water being chlorinated greatly impacts the effectiveness and availability of FAC. A pH above 8 means the efficacy of FAC is reduced. Some disinfecting procedures deem the disinfection not valid if the pH of the water is above 9.0, in which case the disinfection process must be repeated once the pH of the water has been lowered. This is of concern when disinfecting new concrete reservoirs or cement-lined pipes, as the pH can easily exceed these values.

For FAC measurements, calibrated portable analysers are most commonly used. Test kits using potassium iodide, which reacts with high concentrations of chlorine to generate yellow colours (following the Beer-Lambert law), are also used.

7.4 Equipment Disinfection

Disinfection is required for all equipment that will enter an operating reservoir. All equipment used in the disinfection of reservoirs, including air compressors, must be free of oil and dirt, and maintenance records for the equipment must be kept.

Immediately prior to its use, all equipment should be disinfected via submersion in, spraying, or sponging with a disinfectant solution.

If a person will be entering the reservoir, they should be wearing gumboots dedicated solely to potable water work, and a footbath of disinfectant solution should be provided for them to step in immediately before entering the reservoir.

A minimum 1% chlorine solution with a pH value between 7 and 8 should be used for the disinfection of tools, equipment, fittings, and materials. The strength of the disinfectant solution should be verified with a chlorine test kit before use. A new solution should be prepared at least weekly, and the old solution disposed of after it has been dechlorinated.

Between uses, all equipment should be stored in a manner that prevents both chemical and bacteriological contamination. Water supply equipment should be dedicated to water supply use only, and stored away from equipment used for wastewater and stormwater to avoid any contamination. All materials should be stored and handled in a manner that minimises contact with foreign materials.

It is not good practice to use hired equipment for disinfecting reservoirs.

7.5 Post-Work Reservoir Disinfection Procedure

To begin post-work disinfection, the reservoir needs to be thoroughly cleaned. All scaffolding, planks, tools, rags, and other materials that are not part of the structural or operating facilities of the reservoir should be removed. The surfaces of the walls, floors, and operating facilities of the reservoir should be cleaned using a high-pressure water jet, sweeping, scrubbing, or equally effective means. All water, dirt, and foreign material accumulated in this cleaning operation should be discharged or otherwise removed from the reservoir.

Following the cleaning operation, vent screens, overflow screens, and any other screened openings should be reinstated, checked, and/or replaced to ensure they are in a condition to prevent birds, insects, and other animals or vermin from entering the reservoir.

Any equipment required to be in the operating reservoir after the cleaning procedure has been completed should be clean and sanitary when placed in the reservoir. In such instances, care must be taken to minimise the introduction of dirt or other foreign material.

7.6 Contact Time

The concentration of the disinfectant multiplied by contact time (C.t.) value indicates the time necessary to achieve the required percentage inactivation of contaminants at specific disinfectant concentrations. After the water has been dosed with disinfectant, the number of viable organisms remaining is expected to decrease exponentially with time.

$$C.t. = \textit{Disinfectant concentration } (mg/L) \; x \; minutes$$

The required C.t. value varies with the temperature of the water and the expected pathogens being inactivated. The following table from the World Health Organisation (2004) shows the C.t. value required to achieve a 2-log disinfection (99% of pathogens suspended in water at different temperatures).

Chlorine C.t. values for 99 percent inactivation (2 logs)

Microorganism	C.t. value	Conditions
Bacteria	0.08 mg.min/L 3.3 mg.min/L	1–2°C; pH 7 1–2°C; pH 8.5
Viruses	12 mg.min/L 8 mg.min/L	0–5°C; pH 7–7.5 10°C; pH 7–7.5
Giardia	230 mg.min/L 100 mg.min/L	0.5°C; pH 7–7.5 10°C; pH 7–7.5
Cryptosporidium	Not inactivated	

WHO 2004

Higher values are required to treat pathogens that are not in suspension.

Selecting the appropriate C.t. value depends on the conditions in each individual reservoir. Aspects such as temperature and pH levels can impact the efficiency of the disinfection process, so these must be accounted for when selecting a C.t. value.

The C.t. value must also be appropriate for both the work planned and the pathogens to which the asset has potentially been exposed. It is expected that a new reservoir or pipe being put into service for the first time would have been exposed to significantly more pathogens than a reservoir in a chlorinated system being drained for a short period of time for inspection.

The size of the contact area must also be considered when determining the best disinfection method. For reservoirs or large-diameter pipes, spraying a disinfectant onto the potentially contaminated area may be more effective than dosing the incoming water via an injection method.

The effectiveness of the disinfection process is reduced if there is inadequate mixing of the disinfectant with water in the reservoir. Poor mixing may result in a pathogen not being exposed to an effective disinfectant concentration for the required time.

There is no set method for mixing, so each water utility must use a thorough procedure to ensure proper contact time occurs. Options include introducing the disinfectant with the inlet water as the reservoir is filled in such a way that ensures through mixing with the incoming water, and hanging a submersible pump in the reservoir to ensure sufficient mixing occurs within the reservoir through circulation. Note that aeration of water will reduce FAC levels. Allowance should therefore be made for a reduction of FAC if chlorinated water can free-fall into a reservoir while filling, or a submersible pump is positioned such that water creates a fountain within the reservoir.

It is up to each individual utility to determine its preferred approach for C.t. values in different circumstances. Some examples are described below.

7.7 Dosing Methods

When considering the following example C.t. values and methods in order to determine which approach best suits your situation, it is better to take a precautionary approach. Choose a solution that is in excess of your requirements, rather than risk inadequately disinfecting a reservoir and creating a public health issue.

- Example Approach A

Watercare has a C.t. value of 2,880 mg.min/L. This is achieved by filling the cleaned reservoir with potable water to a depth of two metres, adding enough chlorine to result in a concentration of 2 mg/L, and leaving it to stand for 24 hours. The chlorine concentration is then measured and, if required, additional chlorine is added as the reservoir is filled to capacity. The final chlorine concentration should be between 0.5 and 1.0 mg/L.

- Example Approach B

American Water Works Association has three methods of reservoir disinfection:

1) The first method has a C.t. value of 3,600 mg.min/L and involves filling the reservoir to its overflow level with potable water, then adding enough chlorine to provide a FAC content of no less than 10 mg/L at the end of a 6-hour period. The reservoir is then drained (the water being dechlorinated in the process) and refilled with potable water before being returned to service.
2) The second method has a C.t. value of 6,000 mg.min/L. This method consists of leaving a sprayed coat of 200 mg/L chlorine solution for a minimum of 30 minutes, after which the reservoir is filled to overflow level with potable water and then drained.
3) The third method has a C.t of 18,000 mg.min/L. The reservoir is filled to approximately 5% with a 50 mg/L chlorine solution for no less than 6 hours. Following this 6-hour period, the reservoir is filled to overflow and left to stand for another 24 hours.

8.0 Mains Disinfection

8.1 Risk Summary

Possible contributors to contamination of the water supply during mains maintenance include:

Intrusion: When blanking plates, end caps, or outside valves are opened, there is a risk that contamination in the form of vermin, contaminated water, dirt, or debris could enter a pipe.

FAC deficiency: This could arise from either a miscalculation, or a contaminant not being accounted for.

Contamination through equipment: There is a risk of contamination from equipment, such as CCTV cameras used to inspect water mains, or tools used by staff. The staff working on the reticulation system also pose a contamination risk (see Section 12).

Unsuitable material choices: These can lead to permeation or leaching.

Backflow: This can occur if suitable prevention devices are not installed or maintained.

Proper workforce training and documentation is required to mitigate each of these risks.

8.2 Preliminary Actions

A typical sequence for new mains is: inspecting the pipe prior to flushing; flushing the pipe; pressure-testing to confirm there are no leaks and no additional work required; and disinfecting.

A new main should be hyper-chlorinated, subsequently dechlorinated as the pipe is drained, refilled with potable water, and placed into service after clear bacteriological test results.

Some utilities have a practice of inspecting new mains with an internal diameter ≥150mm via CCTV, with the CCTV report verifying that the pipe is completely free of debris and any pipe shavings before starting disinfection. Other Utilities have a practice of skipping this step and going straight to flushing.

Maintenance on a reticulation system may require a temporary interruption of service to customers due to the necessary isolation of certain parts of the system. For planned maintenance, it is good customer service practice to notify affected customers at least one day prior to supply interruption.

Excavations should be at least 400mm deeper than the bottom of the pipe being worked on. Consider using pea metal, which has already had the fines washed out of it, as draining material for a cleaner work site. Also make provision prior to starting for sump pumps in order to mitigate contamination due to the work site becoming submerged.

Openings in the pipeline should be closed with watertight plugs when work is interrupted or stopped for any reason. Rodent-proof plugs may be used when watertight plugs are not practicable. A thorough cleaning practice such as pigging, flushing, or disinfection must be carried out before the pipe is put into service.

Fittings should be boxed, capped, or sealed with plastic wrapping prior to installation.

It is good practice to have all pipes capped. Pipes delivered for construction should be stored in a manner that minimises the entrance of foreign material.

Pipe deliveries should be scheduled as close as possible to installation dates to reduce the risk of contamination.

Only potable water shall be used for disinfection, flushing, and hydrostatic pressure testing.

If an adjacent reticulation network is used as the source of potable water, and is directly connected to the work site (including via fire hydrants), then the use of an approved backflow device is highly recommended to prevent contamination of the reticulation network. Tankers are an alternative source of water.

8.3 Backflow

The water supplier should have a clear and easily obtainable policy covering backflow prevention. Best practice guidance to minimise the risk of backflow is outlined in *Boundary Backflow Prevention for Water Supplies* (Water New Zealand, 2013).

All temporary connections of reticulated water to mains under construction and/or maintenance shall incorporate testable double-check backflow devices to prevent contamination of the source reticulation network. This includes water being used for hydrostatic pressure testing, flushing, and disinfection.

8.4 Equipment Disinfection

Immediately prior to its use, all equipment should be disinfected via spraying, sponging, or submersion in disinfectant solution. A minimum 1% solution with a pH value between 7 and 8 should be used for the disinfection of tools, equipment, fittings, and materials. The strength of the disinfectant solution should be verified with a chlorine test kit before use. A newly prepared solution should be made available at least weekly and stored out of direct sunlight if possible. The old solution should be disposed of after it has been dechlorinated.

8.5 Mains Disinfection Procedure

The main should be thoroughly flushed in sections through hydrants and scours, producing a minimum 0.91m/s flow velocity (AWWA 2014) to remove all foreign matter. The volume of flushing water used should be equivalent to at least three pipe volumes.

The flow of water shall be from one direction at a time. Depending on the position of the flushing point/s, flushing in alternating directions may be required to ensure all sections of the pipe have been completely flushed, and no unflushed dead-ends exist.

For pipes that have been in service and are being flushed, be aware that flushing the pipe in a reverse flow direction or at higher flow rates than normal service may dislodge biofilm and sediment at quantities higher than expected.

If dirt remains in the pipe following flushing operations, the interior of the pipe should be cleaned using mechanical means such as a hydraulically propelled pig, or other suitable methods such as ice pigging.

Following cleaning, the pipe should be drained completely, then slowly filled with chlorinated potable water. Using an approved/registered water tanker pre-mixed with chlorine is a common method and is easier to manage as a controlled batch process than using a reticulated water network with backflow prevention. For larger pipes, a chlorine injection to fill water approach is common due to the quantity of water required.

When using an injection method, the chlorine solution must be injected at a continuous flow-proportional rate to ensure a uniform concentration is in contact with every part of the main. This can be achieved by pumping in the chlorine solution, or by using a chlorine injector while the main is being filled with water.

The chlorinated water should be introduced at the lowest point of the section of pipe being disinfected to ensure that no air is trapped. This will ensure all surfaces encounter the disinfectant.

After the requisite contact time, the pH of the water should be recorded. The effectiveness of chlorine as a disinfectant is greatly reduced above pH 8.0. A pH level greater than 9.0 is not accepted as compliant with disinfection requirements, and disinfection must be repeated using a solution producing a pH less than 9.0. This is particularly applicable when disinfecting new or refurbished cement-lined pipes, as the pH can easily exceed these values.

The residual chlorine concentration must be recorded after the contact time period. If the required concentration is not achieved, the chlorination procedure must be repeated.

Once the required pH level, chlorine concentration, and contact time are achieved, the main and service connection pipes should be flushed with potable water until the chlorine concentration of the water meets the utility's requirements. The flush water should be dechlorinated before being released into the environment (see Section 9.0).

The disinfection process typically takes 36 hours to complete. If there is a delay putting the main in service (days) following disinfection, sampling for FAC and bacteria should be carried out. If the results of this sampling are unacceptable, repeating the disinfection process will be required.

The dumping of calcium hypochlorite powder, granules, or tablets into the pipe or through hydrants without mixing is not an acceptable form of disinfection under any circumstances, as it will not instantly dissolve, and will be pushed away from the work area as the pipe is filled. Consequently, the area that is potentially contaminated will not be disinfected, and a slug of water with a high dose of chlorine (probably above the Drinking Water Standard limits) will result, potentially creating further customer issues.

8.6 Contact Time

See Section 7.6 for a description of how C.t. values are calculated, and what concentrations and times are required to treat different pathogens.

Selecting the appropriate C.t. values depends on the conditions in each individual network. Aspects such as temperature and pH levels can impact the efficiency of the disinfection process, so these must be accounted for.

The contact time must also be appropriate for the work planned. Maintenance activities of short duration typically require a shorter contact time than disinfecting a new or refurbished section of network.

In addition, pipe size must be considered when determining the best method of application in each situation. Disinfection methods suitable for reservoirs may be most effective for larger-diameter pipes, while an injection method may be adequate for smaller pipes.

The effectiveness of the disinfection process is reduced if there is inadequate mixing of the disinfectant with water. Poor mixing may result in the microorganisms not being exposed to the disinfectant, which would nullify the purpose of disinfecting.

There is no set method for disinfecting. Each utility must apply a thorough procedure to ensure proper C.t. values.

It is up to each individual utility to determine its approach for C.t. values in different circumstances and ensure these are recorded in procedures.

8.7 Dosing Method Examples

When selecting an appropriate C.t. value and method, it is better to take a precautionary approach. Choose a solution that is in excess of your requirements rather than risk inadequately disinfecting a main and creating a public health issue.

- **Example Approach A**

For new networks, Watercare has a C.t. value of 36,000-72,000 mg.min/L. This is achieved by dosing the water with chlorine at 25-50 mg/L and leaving it for 24 hours, after which the minimum allowable chlorine concentration for the water to be deemed uncontaminated is 20 mg/L. Due to the nature of chlorine, this method becomes ineffective at a pH level of 9.0 or above.

For temporary connections, Watercare accepts a C.t. value of 3,000 mg.min/L. This is achieved by dosing the water with chlorine at 100 mg/L for 30 minutes, after which the minimum allowable chlorine concentration for the water to be deemed uncontaminated is 20 mg/L.

- **Example Approach B**

The AWWA continuous-feed method has a C.t. of 36,000 mg.min/L. This involves completely filling the pipe to remove air pockets, flushing, and refilling with potable water dosed at 25 mg/L. After a 24-hour period, the residual chlorine level must be not less than 10 mg/L.

Hydrants and fittings are operated to ensure disinfection of these devices also occurs.

- **Example Approach C**

The AWWA slug method has a C.t. value of 18,000 mg.min/L. The slug method requires the pipe to be completely filled to remove air pockets, then applying, at a slow, metered constant rate, a slug of water dosed with chlorine at a concentration of not less than 100 mg/L. The slow flow rate ensures that all parts of the main are exposed to the chlorine for no less than 3 hours. If the slug FAC drops below 50 mg/L at any measuring point along the pipe, then the flow is stopped, the chlorination equipment is relocated to that point, and enough chlorine is added to restore the FAC in the plug to greater than 100 mg/L. This method is suitable for use in large-diameter mains where the volume of water makes the continuous-feed method impractical and difficult to achieve for short attachments.

The slug method is useful for large-diameter pipes, as it uses less chlorine and has a considerably lower volume of heavily chlorinated water to treat before discharging to waste.

- **Example Approach D**

The AWWA spray method has a C.t. value of 6,000 mg.min/L. The spray method consists of spraying a coat of 200 mg/L chlorine solution and leaving for a minimum of 30 minutes. This method is suitable for use in large-diameter transmission lines where spray equipment can be used to disinfect all surfaces of the pipe.

- **Example Approach E**

Scottish Water has a C.t. value of 6,000 mg.min/L for simple cases in rehabilitated networks, achieved by dosing with chlorine at 50 mg/L for two hours.

A C.t. value of 28,800 mg.min/L is required for more difficult maintenance cases and new systems, achieved by dosing with chlorine at 20 mg/L for 24 hours.

- **Example Approach F**

The *Guidelines for Drinking-water Quality Management for New Zealand* (Ministry of Health 2017) require a minimum C.t. value of 5,000 mg.min/L for disinfecting new mains. For repairs where pressure is lost or the line is drained and contamination of water is likely, the guidelines suggest applying chlorine with a C.t. value of 500 mg.min/L and notifying consumers to boil water or supplying separate drinking-water.

The procedure for mains cleaning and restoration to service should be fully documented. An example template is provided in Appendix C.

It is not recommended to leave high doses of chlorine in a pipe following the completion of the disinfection period, as the pipe, linings, and fittings may become damaged with prolonged exposure to hyper-chlorinated water.

8.8 Disinfection Procedures when Cutting into or Repairing Existing Pipe

The planned, unplanned, or emergency repair of a water main is typically time sensitive due to the disruption of water services to customers. The repair still needs to be made using sanitary and safe procedures by well-trained crews, however, in order to minimise possible public health issues caused by contamination of the potable water occurring at the repair site.

If depressurising the pipe is necessary, it is ideal to delay the depressurisation until the site has been excavated to prevent contamination from trench soil and water.

The exterior of the pipe around the repair site should be cleaned and disinfected with a minimum 1% chlorine solution. If the interior of the pipe is exposed to the environment, it should be inspected and, if debris is present, flushed into the trench. All interior surfaces should be disinfected by either spraying or swabbing with a 1% chlorine solution.

If a new section of pipe is required, then the new pipe should be inspected, cleaned, and disinfected by swabbing with a minimum 1% chlorine solution.

Flushing and scouring, ensuring the flushed water is visually clear, should occur immediately on returning the main to service. If the supply is normally chlorinated, flushing should also continue until the normal chlorine residual is present.

If disinfection procedures identified in section 8.7 cannot be carried out, boil water notices and/or alternative water sources should be provided until clear *E.coli* test results have been obtained for three consecutive days.

In the case of contamination due to pipe breakage, a variant of the slug chlorination (e.g. Example Approach C under 8.7 above) method may be used. All service connections should be isolated, and the section of pipe with the break isolated and disinfected with an appropriate method from Section 8.7 above. After disinfection, the individual service connections should be flushed.

If the pipe has been contaminated with chemicals such as hydraulic oil or petrochemical products, the pipe section should be replaced and not used for potable water again.

9.0 Testing

Water main disinfection verification: samples should be tested and recorded along the length of the main where collecting a sample is practicable (every hydrant, etc.) to ensure even and effective distribution of the chlorine.

Reservoir disinfection verification: samples should be collected from as many locations around the tank as practicable (most reservoirs have two hatches), and from different depths at each location, to ensure adequate mixing has occurred.

It is recommended that an approved laboratory be used for sampling and analysis. Each sample should be analysed for Chlorine Residual, pH, turbidity, *E.coli*, Total Coliforms, and HPC.

E.coli test samples taken from a chlorinated source are only valid if the requisite additives (i.e. sufficient dechlorinating agent) are present in sterile sample bottles. There is also a risk of contamination during sample taking, so only trained personnel should collect samples. An NZQA unit standard and training courses on sampling are available.

E.coli testing must be completed within 24 hours of sample collection. Seek the laboratory's guidance for information about sample handling, preservation, transportation, etc.

E.coli testing should be undertaken when pressure is lost during main repairs.

A clear *E.coli* test result is a recognised verification that the disinfection has been effective, however a pH above 9.0 renders the effectiveness of the disinfection process questionable, and it is recommended that the system be flushed again and the disinfection process repeated.

A sample with a turbidity value greater than 2 NTU also renders the effectiveness of the disinfection process questionable, and should result in flushing and repeating the disinfection process.

The *Drinking Water Standards New Zealand* have a Maximum Acceptable Value for Free Available Chlorine of 5 mg/L. Customer complaints are likely at FAC levels approaching the MAV. Staff and contractors should, therefore, test for FAC in the field following all maintenance activities to ensure the efficacy of disinfection practices.

10.0 Neutralising Chlorine

In some areas, regional councils may require a plan to be submitted for approval outlining how the utility intends to comply with the permitted activities rules of that council in terms of discharging chlorinated water following a disinfection operation. Discharge consent requirements may need to be complied with, and these are likely to include a requirement to dechlorinate the water as it is discharged.

There are many methods to dechlorinate water, but chemical neutralisation using sodium thiosulphate is the most common. This involves the water being dosed as it is being discharged.

At least one New Zealand utility has a temporary magnetic flow meter that is attached to a scour so that chlorine neutralisation can be controlled and monitored for accuracy.

Alternatively, the chlorinated water can be captured on site (e.g. in a tanker) prior to discharge. It is suggested that the water be kept contained on site for a minimum of two days until the FAC concentration is reduced to <1 mg/L. It can then be discharged to a sewer. Another acceptable practice is to dechlorinate the water in the tanker prior to discharge.

Where water is discharged to a sanitary sewer, a minimum airgap of 300 mm is required in order to reduce the risk of recontamination of the disinfected pipework.

10.1 Chlorine Neutralisation Solution

To prepare 15% w/v solution of sodium thiosulphate, the following steps should be taken:

a) Fill the solution tank approximately 2/3 full of water.

b) Add sodium thiosulphate to the tank in accordance with the required ratio of additive to tank capacity (e.g. 15 kg sodium thiosulphate to 100 L water).

c) Mix the solution until the additive has dissolved.

d) Add the remainder of water, and mix.

e) Stir periodically to avoid the solution stratifying.

10.2 Chlorine Neutralisation Method

To add the neutralisation chemical to the hyper-chlorinated water, the following steps should be taken:

a) Calculate the flow rate required for adding the sodium thiosulphate using the formula below.

b) Use a calibrated dosing pump to achieve the calculated required flow rate by adjusting the speed or stroke setting of a calibration chart.

c) Verify successful neutralisation by testing for FAC.

NB: Most regional plans have a maximum allowable discharge concentration of FAC to the environment. Typically, this is 0 or less than 0.3 mg/L.

The required ratio of sodium thiosulphate to chlorine can vary depending on temperature and pH. Rather than introduce a level of complexity, a conservative approach is to use a ratio of 3.

$$Flow(L/hr) = \frac{FAC(g/m3) \times 3 \times draining\ flow\ rate\ of\ chlorinated\ water\ (L/min) \times 60(min/hr)}{\%\ Strength\ of\ the\ neutralising\ solution \times 10{,}000}$$

Example:

The FAC of the hyper-chlorinated water to be neutralised is 20 mg/L.

The hyper-chlorinated water is being discharged from the main at a flow rate of 100 L/min.

The required flow rate of the 15% neutralising chemical solution is:

$$\text{Flow} = \frac{20\ \text{mg/L} \times 3 \times 100\ \text{L/min} \times 60}{15 \times 10{,}000}$$

$$= \frac{360{,}000}{150{,}000}$$

$$= 2.4\ \text{L/hr}$$

A dose pump is required to apply the 15% w/v solution to the discharge at a rate of 2.4 L/hr.

To calculate the required volume of neutralising chemical solution if the pipe is 450 mm in diameter and 220 m long:

volume = π (3.14) x radius (half diameter in meters) squared x length in meters

= $3.14 \times (0.225)^2 \times 220$

= 3.14 x 0.05 x 220

= 34.989 m^3 or 35,000 litres (1 m^3 = 1,000 litres)

In this example the discharge rate is 100 L/min.

Time to discharge will take: $\frac{\text{pipe volume (litres)}}{\text{flow rate (litres/minute)}}$

$$= \frac{35{,}000}{100}$$

= 350 minutes or 5.83 hours (/60)

With the chlorine neutralising solution dosing at 2.4 L/hr for 5.83 hours, the volume of chlorine neutralising solution required is:

2.4 x 5.83 = 14 litres

In this example, making a 15 litre batch of neutralising solution (2.25kg of sodium thiosulphate added to 15 L of water) would be a better option than a batch of 100 litres.

Just as throwing a handful of HTH granules into a pipe repair is not an approved method to disinfect a pipe, having the discharge water fall on to a sack of sodium thiosulphate and then flow on into the environment is not an approved method to dechlorinate.

If too much sodium thiosulphate is added to the water, the water will be become de-oxygenated and consequently unable to support aquatic life.

Water that has had the chlorine neutralised with sodium thiosulphate should not be consumed.

11.0 Hygiene

11.1 Equipment

Actions of staff working on water reticulation systems are a potential source of contamination. Supervisors must ensure that the appropriate safeguards are rigorously applied to each situation. They should only assign work to employees who are free of illness or disease, and who have the appropriate training and competencies.

Ideally, staff, tools, and vehicles used on a potable water supply would never encounter a contaminated site such as a wastewater site. It is recognised that for some organisations and specialist roles this is not possible, so the following general guidelines are strongly advised to minimise contamination risks:

- It is not acceptable to use the same equipment, protective clothing, or tools for the maintenance of both potable water and wastewater reticulation systems. Staff who work on both potable and wastewater assets should have separate protective clothing and tools for each system.
- If personnel are required to work on a potable water system after working on a wastewater system, they should shower and change into clean overalls and boots between jobs.
- If the same vehicle is used to travel between potable water and wastewater sites, the potable water tools and personal protective equipment (PPE) must be stored separately from, and not come into contact with, wastewater tools and PPE.
- Provisions such as dedicated cleaning water supply, sanitary wipes, and antibacterial liquid soap must also be available for workers to cleanse and sanitise their hands in the field.
- Equipment such as breakers and excavators that have previously been used on a wastewater site should be steam-cleaned and disinfected with a 1% chlorine spray before being transported and used on a potable water site. The equipment may be rinsed off with potable water after disinfection.

Records should be kept of equipment used for repairs. This includes contractor equipment, which should be available for inspection. A record template is included in Appendix B.

There are several portable field instruments available for measuring FAC. It is becoming common practice for service crews to use these instruments to determine FAC results in the field.

11.2 Personnel

Personal hygiene levels must be high when working on potable water networks.

Water treatment facilities and reticulation networks must be treated as the food grade factories and delivery systems that they are.

Personnel working on wastewater facilities and sewerage networks may be exposed to a wide range of diseases and pathogens occurring in the communities connected to the networks. They must take measures to protect both their own health and the health of the community.

Those working on both potable water systems and wastewater systems obviously pose a high risk of being the conduit for contamination of the potable water system. Such personnel must be highly cognisant of the risks, and diligently pursue the following safe work practices:

- Any personnel suffering diarrhoea or any notifiable disease or gastrointestinal illness, with or without vomiting, shall not undertake works that involve or potentially involve direct contact with drinking water (treatment and/or network) until a medical clearance certificate has been obtained stating that they are clear of the disease. Any further tests prescribed by the doctor to determine evidence of infection shall be carried out. All staff should be encouraged to report medical issues without prejudice to ensure the potable water system is not placed at risk.
- Both staff and contractors should have appropriate training for pathogen awareness and correct hand-cleansing practices.
- No person who knowingly has an abnormal temperature or symptoms of illness shall work in a water supply facility.
- All staff must wear clean overalls.
- All staff are personally responsible for thoroughly washing their hands, forearms, and fingernails prior to the commencement of work on a drinking water system. Where this is not practicable, clean, disposable gloves should be worn. This is critical to good hygiene practice.
- Managers need to allow for conditions where a staff member does not feel well or is waiting on a medical clearance to undertake works that involve or potentially involve direct contact with drinking water.

10.3 Diseases

Legislation exists that prohibits employers from force-medicating employees. Vaccinations, therefore, must be encouraged. This requires advocacy and education, along with a certain amount of delicacy.

Hepatitis A can be transmitted from both faecal and oral sources. It is a virus with a long infectious period (2-3 weeks) before symptoms become evident. Hepatitis A should consequently be of high concern to all personnel. The Hepatitis A virus is very susceptible to chlorine, so good disinfection and personal hygiene practices significantly reduce the risk.

Hepatitis B can only be transmitted via blood to blood contact. If an employee has no open wounds, therefore, there is a lower level of risk. Vaccines and booster shots are typically given for both Hepatitis A and B together. As every person is unique in their past exposure and immunity to Hepatitis A and B, some people may require more booster shots than others in order to build up immunity.

All staff should receive a Tetanus vaccination booster at a minimum interval of 10 years.

Typhoid fever is a water-borne disease that can also be transferred person to person. While it is uncommon in New Zealand, it is more common in several Pacific Island nations, and should therefore be of concern to staff if it exists in the community in which they are working.

While polio is no longer a significant risk in New Zealand, one utility receives significant numbers of overseas tourists, and considers that polio is of sufficient risk to their staff that it recommends vaccination.

Where personnel working on drinking water systems have been to countries with significant levels of typhoid or cholera, they need to check their health status to ensure the potable water system is not at risk.

12.0 Staff Management

Employed staff and contractors should adopt the same best practices to minimise the risks to both themselves and the public's health.

12.1 Site Facilities

It is imperative that a lack of toilet facilities or alternative arrangements does not lead to contamination of water supplies. Satisfactory toilet arrangements must, therefore, be made for all personnel working on water supply activities, and hands must be washed thoroughly after using any toilet facilities. Where permanent or temporary toilet facilities are provided on site, these must be maintained in a clean and hygienic condition, and arrangements made for regular and safe disposal of toilet wastes. For work on sites where there are no toilet facilities, alternative hygienic arrangements must be agreed locally, and all personnel concerned formally told of the arrangement. In all situations involving water supply work, adequate hand-washing facilities, using soap and water or a suitable anti-septic hand cream, must be provided.

12.2 Requirements of Contractors

An in-depth process is covered in *A Principal's Guide to Contracting to Meet the Health and Safety in Employment Act 1992* (MBIE, 2010).

Contractual requirements to minimise contamination may include (but are not limited to) processes such as lines of communication, responsibilities, accountability, safe systems of work, method statements, and use of client services. These details may provide a deeper understanding of what is expected of the contractor/staff member. Periodic feedback to the contractor may also help with this.

12.3 Audits

It is important to remember that work on the water network provides a public health service. The entity in charge, therefore, needs to be sure that correct procedures are being followed in order to gain and retain the community's trust. One way of doing this is through audits.

The frequency of such audits is at the discretion of the controlling entity; however, six-monthly is a typical time frame.

An example audit template is provided in Appendix D.

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World Health Organisation (2004)

Appendix A: Example Equipment/Clothing Information Sheets

<table>
<tr><td colspan="3">Wastewater Equipment/Clothing</td></tr>
<tr><td colspan="2">Item: Saw</td><td>Equipment Code: WWS04</td></tr>
<tr><td>Date:</td><td>Disinfection procedure after work:</td><td>Operation manager</td></tr>
<tr><td>10/08/2019</td><td>Swabbed with 1% chlorine solution</td><td>John Smith</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Wastewater Equipment/Clothing		
Item: 2.5 T Excavator	Equipment Code: WWD07	
Date:	Disinfection procedure **after** work:	Operation manager
10/08/2019	Steam cleaned by Fred Flintstone on 9/08/2019	John Smith

Potable Water Equipment/Clothing		
Item: Saw	Equipment Code: PWS01	
Date:	Disinfection procedure **before** work:	Operation manager
15/12/2019	Submerged in 1% chlorine solution	John Smith

Appendix B: System Disinfection Report

Disinfection Report						
All utility staff names						
All contracted staff names						
Location/pipeline details						
Time of work commencement	Date:			Time:		
Time of work completion	Date:			Time:		
Maintenance job description						
Equipment required (i.e. tools, cameras, robots, specialised clothing) – Attach necessary equipment disinfection forms						
Initial FAC details	Location 1:		Location 2:		Location 3:	
	pH:	[Cl]:	pH:	[Cl]:	pH:	[Cl]:
Form of chlorination	Type		Conc.		Volume on site	
Method of disinfection (incl. calculations for Cl added)						
Time of water testing #1	Date:			Time:		
[Cl] of test #1	Location 1:		Location 2:		Location 3:	
	pH:	[Cl]:	pH:	[Cl]:	pH:	[Cl]:
E. coli test results #1						
Volume of Cl added						
Time of water testing #2	Date:			Time:		
[Cl] of test #2	Location 1:		Location 2:		Location 3:	
	pH:	[Cl]:	pH:	[Cl]:	pH:	[Cl]:
E. coli test results #2						
Volume of Cl added (if						

required)						
Time of water testing #3 (if required)	Date:			Time:		
[Cl] of test #3	Location 1:		Location 2:		Location 3:	
	pH:	[Cl]:	pH:	[Cl]:	pH:	[Cl]:
E. coli test results #3						
Neutralising chlorine and wastewater disposal method (if required)						
Supervisor Approval						

Appendix C: Audit Sheet

<table>
<tr><th colspan="5">Staff Audit</th></tr>
<tr><td>Utility Name</td><td colspan="4"></td></tr>
<tr><td>Staff/Contractor Name</td><td colspan="4"></td></tr>
<tr><td>Period of contract</td><td colspan="2">Start Date:</td><td colspan="2">End Date:</td></tr>
<tr><td rowspan="2">Intended work for utility</td><td colspan="4">Position:</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Relevant training</td><td colspan="4"></td></tr>
<tr><td>Previous experience in field</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Do you have your own tools? (Please circle one)
If yes, please describe disinfection methods used including conc. of disinfectant.</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="4">Disinfection Method:</td></tr>
<tr><td>Vaccines (Please circle all that are valid & provide medical certification.)</td><td>Hep A.</td><td>Hep B.</td><td>Typhoid</td><td>Polio</td></tr>
<tr><td>Any injuries that may prevent capacity to work (please describe)</td><td colspan="4"></td></tr>
<tr><td rowspan="3">For utility manager ONLY: Comments from in-job review</td><td colspan="4">Review Date:</td></tr>
<tr><td>Quality of work performed (Please circle one)</td><td>Poor</td><td>Satisfactory</td><td colspan="2">Excellent</td></tr>
<tr><td colspan="4">Further Comments:</td></tr>
</table>

water
NEW ZEALAND
The New Zealand Water & Wastes Association Waiora Aotearoa