Queensland Health

Water Fluoridation Code of Practice

October 2021

Queensland Government

Foreword

Water fluoridation involves the adjustment of the level of fluoride in public potable water supplies to achieve optimal levels for the prevention of dental caries. Queensland Health recognises that this important public health measure must be conducted safely and effectively to ensure continuing health benefits for the community.

The Water Fluoridation Code of Practice (the Code) contains the requirements needed to meet the requirements of the Water Fluoridation Regulation 2020 as well as the relevant workplace health and safety and environmental legislation. This updated edition of the Code identifies criteria to ensure that fluoridation facilities are established and operated in a safe manner. These criteria apply to all new and existing fluoridation facilities in Queensland.

Queensland Health recognises and greatly values the contribution of public potable water suppliers to improving the health of the community. The Code was first published in January 2008 following extensive consultation with major stakeholders. Since then all public potable water suppliers with fluoridation facilities have taken steps to ensure that they comply with the Code. These water suppliers are to be congratulated for their commitment to ensuring this important public health measure is available to their communities.

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An electronic version of this document is available at www.health.qld.gov.au/public-health/industry-environment/environment-land-water/water/fluoridation

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1 Introduction

Fluoridation of drinking water is the most effective community-wide means for reducing tooth decay, particularly in areas with high levels of dental caries. Water fluoridation at optimal levels remains the most significant oral health program in Australia and, in those communities where it is available, provides the most cost-effective and socially equitable means of achieving community-wide exposure to the preventive effects of fluoride. Water fluoridation can reach the entire community regardless of age, socio-economic status, education or individual motivation. Water fluoridation is a very effective public health measure that results in true cost savings as it saves more money than it costs to implement and operate in the majority of communities.

Fluoride occurs naturally in varying concentrations in almost all public water supplies. The optimum level of fluoride in the public water supply is the level associated with the maximum reduction of tooth decay in the population balanced against the potential for dental fluorosis. Water fluoridation involves the adjustment of fluoride in public water supplies to achieve the optimum level of fluoride. This important public health measure must be conducted safely and effectively to ensure appropriate health benefits for the community.

Australian and overseas surveys repeatedly show that people living in communities that receive optimally fluoridated water have less tooth decay than people living in communities without a fluoridated water supply. In 2016, the Australian National Health and Medical Research Council (NHMRC) conducted an evaluation of evidence concerning dental and other human health outcomes associated with water fluoridation and concluded that water fluoridation reduces tooth decay by 26 to 44 per cent in children, teenagers and adults (see NHMRC 2017 in section 10, References). Similarly, a 2015 review of the benefits and costs of water fluoridation in New Zealand found a 40 per cent lower lifetime incidence of tooth decay for children and adolescents living in areas with water fluoridation, a 21 per cent reduction in tooth decay in adults aged 18 to 44 years and a 30 per cent reduction in those 45 years or older (see Moore and Poynton 2015 in section 10, References).

The majority of the Australian population now live in areas where fluoride levels have been adjusted to achieve an optimally fluoridated water supply. Worldwide it is estimated that approximately 370 million people are currently receiving optimally fluoridated water (British Fluoridation Society 2012 in section 10, References) including communities in the United States, the United Kingdom, Ireland, Israel, New Zealand, Canada, Malaysia, Singapore and Hong Kong.

Water fluoridation is supported by Queensland Health and has been endorsed as a safe and effective public health measure by more than 150 science and health organisations, including the NHMRC, the Australian Dental Association, the Australian Medical Association, and the World Health Organization.

1.1 Aim

The aim of the Code is to help public potable water suppliers meet regulatory requirements and to help them achieve best practice in the design, installation and operation of fluoridation facilities in Queensland. The Code is intended to complement, and should be read in conjunction with, the following key legislation:

- *Water Fluoridation Act 2008*
- Water Fluoridation Regulation 2020
- *Work Health and Safety Act 2011*
- *Environmental Protection Act 1994*
- *Water Supply (Safety and Reliability) Act 2008*

The Code does not address de-fluoridation systems where removal of excess fluoride in the water source is undertaken.

1.2 Structure of the Code of Practice

The Code has been designed to provide guidance to assist water providers to meet the statutory requirements of the Water Fluoridation Act and Regulation and to ensure the safe, consistent and accurate operation of fluoridation facilities. This revision of the Code avoids some of the repetition of the previous edition by grouping common requirements for different fluoride delivery methods under single headings. The Code includes mandatory requirements from state laws for water fluoridation, workplace health and safety and environmental protection (which are always indicated by the word “must”) but adds many additional best practice recommendations, generally indicated by the word “should”.

Under each numbered section title there is a numbered sub-heading (e.g. 1.1), plus a requirement or principal recommendation (e.g. shown as 1.1.1). In some cases, additional explanatory information, which may include acceptable solutions, is included (e.g. 1.1.1.1 and shown in italics).

1.3 Terminology

In this document the Water Fluoridation Code of Practice is referred to as “the Code”.

In this document the term *water supplier* means a “public potable water supplier”, as defined in the Act, that fluoridates. In most instances, the water supplier is responsible for the operation of the fluoridation facility and the management of the drinking water reticulation system. However, in some instances the fluoridation facility and reticulation system will be operated by different entities. To provide for this situation, the Code uses the terms:

- **water supplier** for the entity that operates the fluoride dosing facility that adds fluoride to the water supply; and
- **reticulation system manager** for the entity that is responsible for the infrastructure that reticulates the fluoridated water to the customer, *when this is a different entity from the water supplier*.

It should be noted that the Act and Regulation place no responsibilities on the reticulation system manager when this is a different entity from the water supplier.

For further clarification about terms, refer to the Glossary contained in section 9 of the Code.

1.4 Fluoride compounds

The fluoride compounds permitted for use in Queensland are prescribed under Section 3 of the Regulation and are listed in Table 1 below, together with their alternative names. These compounds are all deemed suitable for use in drinking water under the Australian Drinking Water Guidelines (ADWG) (NHMRC/NRMMC 2011).

Table 1: Forms of fluoride permitted for use in treatment of drinking water

Fluoride company	Formula	CAS No	Alternative names
Sodium fluorosilicate	Na_2SiF_6	39413-34-8	Sodium silicofluoride, Disodium hexafluorosilicate
Fluorosilicic acid	H_2SiF_6	16961-83-4	Hexafluorosilicic acid, Dihydrogen hexafluorosilicate
Sodium fluoride	NaF	7681-49-4	Sodium monofluoride
Naturally occurring fluoride contained in water	CaF_2	Nil	Nil

2 Legislative framework

The legislative framework for water fluoridation in Queensland is comprised of the *Water Fluoridation Act 2008* (the Act) and the Water Fluoridation Regulation 2020 (the Regulation). The Act provides for the promotion of good oral health via safe fluoridation of water supplies, while the Regulation prescribes the key requirements relating to the addition of fluoride, and the monitoring of fluoride, in public potable water supplies.

This legislative framework was introduced in 2008 and, at that time, prescribed mandatory fluoridation of all water supplies serving at least 1,000 people. Subsequent amendments to the Act in late 2012 removed the mandatory requirement, instead allowing local governments to determine whether it is in the best interests of their communities to add, not add, or cease to add fluoride to water supplies in their area.

When determining whether it is in the best interests of a community to add, not add or cease to add fluoride to a water supply, one local government must not affect another local government's water security or water supply or the fluoridation of another local government's water supply without the other local government's agreement.

Once a decision to add, or cease to add, fluoride to a water supply is made, the local government must give the Chief Executive of the Department of Health a notice stating that a decision has been made and the nature of the decision. In addition, the local government must publish a notice at least once in a newspaper circulating in the area serviced by the relevant water supply.

In instances where the local government and water supplier are different entities, the local government is obliged to notify the water supplier of a decision to add, not add or to cease adding fluoride. The water supplier is obliged to comply with a decision by a local government to add, not add, or cease adding fluoride. However, the costs incurred in giving effect to the local government's determination must be met by the local government.

Any water supplier adding fluoride to a public potable water supply must do so in accordance with the regulatory requirements spelt out in the Regulation.

Queensland Health is the government agency responsible for the administration and enforcement of the water fluoridation legislative framework. For reference, copies of the Act and the Regulation can be downloaded from the Queensland Legislation website at: www.legislation.qld.gov.au

Water suppliers that have questions regarding the interpretation and application of the legislative requirements under the Act and the Regulation may contact Queensland Health's Water Unit for clarification on telephone (07) 3328 9310 or via email fluoride@health.qld.gov.au.

3 Design criteria for new fluoridation facilities using fluoride compounds

Design criteria in this section apply only to fluoridation facilities using a fluoride compound.

3.1 Risk assessment

3.1.1 A risk assessment should be completed before the fluoridation facility is designed to ensure that risks including safety considerations for operators are addressed appropriately in the design of the facility and systems.

3.1.1.1 The risk assessment should:

- *incorporate hazard identification, risk assessment and risk management strategies to eliminate or minimise the risk of injury or illness to operators throughout the operational life of the fluoridation facility*
- *consider all possible causes of overdosing and effective mitigation strategies to prevent overdosing*
- *include appropriate electrical and or mechanical interlocks and alarms to facilitate timely intervention to avoid overdosing, where feasible.*
- *include consideration of risks related to 'human factors' (see section 8.1 Operator qualifications and training).*
- *follow an accepted risk management methodology, such as ISO 31000.*

3.1.1.2 The risk assessment should be documented and stored and made available upon request by an authorised officer under the Act.

3.1.1.3 The workplace health and safety requirements for plant and structures are defined in Chapter 5 of the Work Health and Safety (WHS) Regulation 2011. Chapter 5 identifies the specific requirements for workplaces that use plant and structures as well as the workplaces that design, manufacture, import, install or supply plant and equipment to workplaces. Workplace Health and Safety Queensland's 'Managing the risks of plant in the workplace Code of Practice 2021' provides supporting guidance for managing the risks associated with plant and equipment at workplaces.

3.1.1.4 Additional work health and safety advice is shown in section 8.13 (Workplace Health and Safety) in this Code.

3.2 The fluoridation facility

3.2.1 The fluoridation facility must be designed to support easy operation and maintenance, as well as safe, consistent and accurate addition of fluoride compounds to the water supply.

3.2.2 A weather-proof building must be provided for the storage of fluoride compounds. Where other water treatment chemicals are also to be stored within the building, separate rooms for these chemicals must be provided.

3.2.3 Fluoridation equipment must be kept separate from other water treatment plant equipment in a separate building or room (the 'fluoridation room').

3.2.4 A laboratory where fluoride analyses can be performed must be located external to the fluoridation room but within or in close proximity to the fluoridation facility.

3.2.5 All dosing equipment must be automated.

3.2.6 The facility should have access to adequate power, water supply and necessary equipment.

3.2.7 The fluoridation room should be purpose designed:

- for the type of fluoridation system that it will house
- to allow easy cleaning and removal of spilt fluoride compound
- to include a hose and stop cock.

3.2.8 The fluoridation facility design should provide the ability to:

- Permit rapid measurement of the fluoride dosing rate
- measure in real time the water flow and fluoride concentration
- conduct a gross check that the estimated concentration of fluoride in water is being achieved to within 5% of the prescribed fluoride concentration.

3.2.9 The floor of the fluoridation room should be made of concrete.

3.2.10 Careful thought needs to be given to the physical layout of equipment within the fluoridation room so that operator safety can be assured. For example, trip hazards and items that people may walk into or hit their heads on should be avoided.

3.2.11 Pipes, conduits and ducts should be identified as referenced in *AS1345 - Identification of the contents of pipes, conduits and ducts*.

3.2.12 The installation of all equipment, valves, controls and access points should facilitate easy access for all expected operational and maintenance requirements (e.g. relative locations, mounting height and general access).

3.3 Electrical controls

3.3.1 Control panels, such as electrical control panels for the fluoridation facility should be located outside of the fluoridation room.

3.3.1.1 Electrical control panels should be located outside the fluoridation room to minimise deterioration due to corrosion and to minimise the need for entry into the room for operational and maintenance staff.

3.3.1.2 The room containing the control panels should have a separate entry door with no interconnecting door or other means by which air can pass between the two rooms. There should be a window in the common wall between the fluoridation room and the control panel room to allow operators to have a clear view of the fluoridation system equipment when operating the control panel.

3.3.1.3 Dosing or blending pumps should be hard-wired to the control system (rather than connected by electrical wall plug).

3.4 Flow measuring devices

3.4.1 The system must have the rate of feed of the fluoride paced to the flow of the water.

3.4.2 The system must have at least two devices that independently monitor the flow of water, one of which must be a flow meter.

3.4.3 The physical indicators of water flow through the fluoridation facility can be via two flow meters or by a combination of a flow meter with a flow-sensing device such as a flow switch.

3.4.3.1 Reliance on a single primary flow-sensing device can significantly increase the risk of overdosing, as a fault or failure could lead to the fluoridation system continuing to add fluoride to the water after the water flow has actually stopped. Care should be taken in selecting the most appropriate devices for this purpose.

3.4.3.2 The flow meter should:

- *be appropriately located to enable the addition of fluoride to be paced to water flow over the full range of flow rates for the water treatment plant or bore and*
- *measure both the rate of flow and total volume of flow.*

3.4.4 The two separate physical indications of water flow through the fluoridation dosing facility should be hard wired in series, either directly or via programmable logic controller (PLC) coding, in the control loop for starting and stopping the fluoridation system. Where possible, the use of electromagnetic flow meters is recommended as they can achieve an accuracy of ± 1-2%. The failure of either one of the devices must stop the fluoridation system from operating. That is, they must be interlocked.

3.4.5 For a gravity flow supply, the first flow signal could originate from a flow meter (upstream location) and the second signal could come from a secondary flow-based measuring device or control device installed on the downstream side of the dosing point. The flow indication or flow measuring device should be positioned to provide a true representation of flow through the plant or from a bore.

3.4.6 For pumped supplies, the fluoridation system pump should be electrically interlocked with the pump supplying water.

3.4.7 The system must be designed in a way that ensures fluoride is not added to the water supply in the event of system failure or when water is not flowing.

3.5 Achieving the prescribed concentration

3.5.1 The fluoridation system must be designed to consistently achieve the prescribed fluoride concentration for the relevant local government area as detailed in Schedule 1 of the Regulation.

3.5.2 The maximum rate for the addition of fluoride which achieves the prescribed concentration at the maximum facility flow must be set in the control system and/or the dosing/blending pump or dry feeder so that it cannot be exceeded. This setpoint should be password protected so that only an authorised person (e.g. the water treatment plant supervisor) can change it.

3.5.3 Fluoridation systems, including pumps, should be sized appropriately so that the dosing pump, running at full capacity, delivers as close as practicable to the desired concentration of fluoride when the plant is running at the maximum flow rate. The size of the fluoridation system should be such that fluoride cannot be delivered into treated water at concentrations that lead to an exceedance of 1.5 mg/L of fluoride in the reticulation system.

3.6 Backflow prevention

3.6.1 It is important that fluoride compound is not siphoned backwards into the solution water system should a failure of the solution water system occur. This possibility could cause problems to other equipment, create a health hazard, or result in an environmental release.

3.6.2 The system should therefore have a backflow prevention device, such as an air gap, that complies with AS/NZS 3500, fitted upstream of the point where the fluoride compound is dissolved (e.g. mixing tanks) or injected (dosing pumps) to avoid contamination of the drinking water supply.

3.7 The fluoride injection point

3.7.1 The point where fluoride is added to the water supply should be located:

- where adequate mixing with water being fluoridated can occur
- where other water treatment processes do not interfere with mixing
- upstream of any treated water storage reservoir.

3.7.2 Where there is no storage reservoir between the point where fluoride is added to the water supply and water service offtakes, at least one online fluoride analyser – interlocked with the fluoridation system – should be provided downstream of the point where fluoride has been added to the water supply at a location where adequate mixing has taken place. In addition, water suppliers should employ at least one additional safeguard such as:

- the adoption of a fluoride solution flow meter with high flow alarm
- the use of a day tank or
- the use of two flow meters (rather than the use of one flow meter and a flow switch) such that discrepancies in flow readings result in shutdown of the fluoride dosing system.

3.7.3 The point where fluoride is added to the water supply should occur after any coagulation, filtration and pH adjustment to avoid substantial losses that can occur if fluoride reacts with other water treatment chemicals such as aluminium, calcium or magnesium. This can cause the fluoride to form a precipitate and thereby cease to be in solution, reducing its effectiveness.

3.7.4 Where the total hardness of the water used for dissolving sodium fluoride compound exceeds 75 mg/L as calcium carbonate the system should include a water softener. This applies only to the water used to make up the fluoride solutions in the mixing tanks and does not apply to the main water supply being treated.

3.7.5 Where a day tank is used the following principles should be adhered to:

- The volume of fluoride solution contained in the day tank should not exceed that required to achieve the prescribed concentration for the maximum volume of treated water produced over a 24-hour period, with reserve capacity necessary to allow a top up.
- The transfer of fluoride solution should be controlled by a pump, be initiated manually and stopped automatically (manual initiation can include initiation via a SCADA system)
- The refilling line should have a motorised valve.
- The pump discharge line should have an anti-siphon motorised valve installed.
- The transfer of fluoride solution should not be repeated within any 24-hour period.

3.7.6 A mixing process designed to achieve adequate mixing should be provided between the point where fluoride is added to the water supply and any sampling point. Without sufficient mixing the validity of results from sampling and analysis cannot be assured.

3.8 Prevention of manual operation

3.8.1 Other than for filling the day tank (see section 3.7.5) equipment should be designed such that it is impossible for it to be switched to manual mode.

3.8.2 The system should be used and operated in automatic mode to prevent possible incorrect operation in manual mode.

3.8.3 No component of the system should be capable of being manually plugged into standard electrical outlets for continuous operation.

3.9 Online monitoring and alarms

3.9.1 All key components should be alarmed with appropriate technology to alert the operator of a failure in the system even if the site is unattended.

3.9.2 The failure of any of the key components of the fluoridation system (including stop/start/pacing signals, feeders, dosing pumps, solution transfer pumps, solution tank levels, mixers and dilution water pumps) should result in an alarm being generated and a response by operational staff.

3.9.3 It is important to provide fluoridation facility operators with the ability to accurately monitor the fluoridation system and equipment performance. Local indicators that should be considered include water flow, fluoride feed rate, pressure and level indicators, storage levels, equipment status, alarms, ammeters and hours run.

3.9.4 Though not a primary control, online monitoring of fluoride concentration in the fluoridated water may also be used as part of the fail-safe system. The online monitoring system can be interlocked with the fluoridation system to shut it down when the concentration of fluoride exceeds a maximum set point.

4 Additional design criteria for new fluoridation facilities using powdered fluoride compounds

The following requirements apply specifically to fluoridation facilities that use either of the powdered fluoride compounds, sodium fluoride or sodium fluorosilicate.

4.1 Dust control

4.1.1 The storage and handling of sodium fluorosilicate and sodium fluoride must comply with requirements under the *Work Health and Safety Act 2011* as well as *AS/NZS 4452 The storage and handling of toxic substances*, which applies to the storage and handling of class 6.1 (toxic) dangerous goods.

4.1.2 An appropriate dust management system should be included in the fluoridation facility design to prevent the escape of fluoride compound dust into the fluoridation room and maintain acceptable internal air quality.

4.1.3 The design of the dust management systems should take into account the total process from unloading the bags into storage hoppers, powder transport from the hoppers to the feeders and from the feeders into the solution feed. Depending on the size of the hopper and fluoridation room, the use of two ventilation systems may need to be considered.

4.1.4 The bag loader for filling a storage hopper should have a dust extraction fan, with an associated dust capture system, vented to an appropriate location outside of the fluoridation room.

4.1.4.1 Systems such as dust exhausts blowing down into external water traps may be used to capture fluoride dust.

4.1.5 The design of the fluoridation room should prevent any potential for the build-up of powder from air deposition including on roof beams and other surfaces.

4.1.6 The internal walls and ceilings of the fluoridation room should have smooth surfaces to prevent dust accumulation and simplify cleaning. A suitable smooth surface for internal walls and ceilings would include gloss paint. Windows should have no ledges.

4.1.7 Dry fluoride compounds should not be allowed to escape from the fluoridation room to the external atmosphere unless a device like a water trap is used.

4.1.8 Doors and walls of the fluoridation room should be flush with no gaps.

4.1.8.1 The use of doors with rubber seals and airtight windows should be considered.

4.2 Hazardous manual tasks

4.2.1 The design of the fluoridation facility should minimise the need for hazardous manual tasks.

4.2.1.1 *The design should consider the use of hand operated pallet forklifts, the matching of the height of the fluoride loading floor with the tray of the delivery truck and use of self-raising pallet systems to maintain the same 'lifting' level as bags are taken off a pallet for loading into the storage hopper. This minimises the need for the operator to bend further as the pallet empties.*

4.2.2 Where the manual lifting of bags is necessary, the distance and height at which they are lifted should be minimised.

4.3 Storage of dry fluoridation chemicals

4.3.1 When bags of powdered dry fluoride compound become damp or wet, they can be very difficult to use in the fluoridation equipment, often leading to increased maintenance and variable fluoride concentrations in the fluoridated water. In more extreme circumstances, the fluoride compound can become unusable and would need to be disposed of (refer to section 8.14 Environmental protection for further guidance on appropriate disposal methods). In some situations, the installation of dehumidifiers or air-conditioning within the fluoridation building can minimise such problems.

4.3.2 Dry fluoride compounds should always be stored in an elevated location. A raised platform is one option for both storage and chemical loading to dry feeders or solution tanks.

4.3.3 The design and construction of the chemical storage areas should consider the relevant Australian Standards (*AS4452 The storage and handling of toxic substances* and *AS3780 The storage and handling of corrosive substances*) to help ensure compliance with the *Work Health and Safety Act 2011* and the *Environmental Protection Act 1994*.

4.4 Continuity of fluoride supply

4.4.1 The capacity of the storage/feed hopper or tank should be no larger than is required to ensure continuity of fluoridation.

4.4.1.1 *Should the capacity of the storage/feed hopper or tank exceed seven days' supply due to operational and/or workplace health and safety concerns, additional control measures should be incorporated into the design and operation of the fluoride dosing system to negate the increased risk of overdosing. Such control measures may include, but are not limited to, the use of online fluoride compound weight-loss monitors and/or online fluoride analysers. Appropriate corrective actions for these additional control measures should also be developed before operation begins.*

4.5 Dry feed systems

4.5.1 Dry fluoride feed systems should include:

- a powder unloading system
- a storage/feed hopper
- a volumetric or gravimetric dry feeder
- a dissolving tank with mechanical stirrer
- a weight loss system to monitor the weight of fluoride compound used
- a potable dilution water source and
- a solution transfer pump (if not gravity fed).

4.5.2 Any water supply used for dissolving sodium fluoride or sodium fluorosilicate should have a fixed flow rate in order to maintain correct dissolving time in solution.

4.6 Fluoride batch solution feed systems

4.6.1 Fluoride batch solution feed systems should include:

- two batching tanks with mechanical mixers
- a dilution water meter
- a potable dilution water source
- a method for calibrating dosage rates
- a metering pump with pressure relief and
- a loading valve on the delivery side of the pump.

4.6.1.1 The two batching tanks containing the dissolved fluoride compound should be located in a bunded area.

4.6.1.2 Suitable methods for calibrating dose rates include a graduated calibration tube or calibrated dipsticks.

4.7 Fluoride saturator systems

4.7.1 A downflow saturator should always contain at least 150 mm of fluoride compound above the top of the filtration support media but should not be filled to the top of the tank where it may impede the flow of water into the tank.

4.7.2 An upflow saturator should never be filled so high that undissolved fluoride compound can be drawn into the suction line.

4.7.3 Fluoride saturator systems should include:

- a saturator tank with powder support media
- a powder unloader system
- a dilution water meter
- a potable dilution water source
- a method for calibrating dose rates, and
- a metering pump with pressure relief and

- a loading valve on the delivery side of the pump.

4.7.4 The saturator tank should be designed so that it is possible to observe the level of undissolved fluoride compound in the saturator tank.

5 Additional design criteria for new fluoridation facilities using fluorosilicic acid

Fluorosilicic acid is inherently more hazardous than the powdered fluoride compounds. The following requirements apply to fluoridation facilities that use fluorosilicic acid.

5.1 Corrosive fumes

5.1.1 Corrosive fumes associated with fluorosilicic acid should be removed from the fluoridation room. This can be achieved via mechanical ventilation and venting of fume sources, such as internal storage tanks, to an appropriate location outside the fluoridation room. Acid fumes should be maintained at a level below occupational exposure standards.

5.1.1.1 Fluorosilicic acid is corrosive and will give off acidic fumes. These fumes have the potential to increase corrosion rates of equipment in the fluoridation room and harm operator health and safety, if not managed appropriately. Fumes from internal storage tanks should be minimised through sealing of the tank and extending vents outside the building. Water seals can be used on the tank overflow outlet if the bunded area is internal to the room. An exhaust fan should be installed to remove the fumes from the fluoridation room. The location of the fan and room vents should be chosen to maximise cross flow ventilation of the room. If exhaust fans are used, they should be acid-fume resistant, designed for continuous operation and vented to open air away from doors, windows and air inlets and any area that may be accessed outside the fluoridation room.

5.2 Storage, handling and spills

5.2.1 Storage and handling systems such as carboys, drums, day tanks, indoor bulk storage tanks and graduated calibration tubes should be sealed and vented back to the bulk storage tank or directly to an appropriate location outside of the fluoridation room.

5.2.2 All tanks containing fluorosilicic acid should be inside a compatible spill compound that has the capacity to contain spills or leaks within the work area of the workplace.

5.2.3 Storage and handling of fluorosilicic acid must comply with requirements under the *Work Health and Safety Act 2011.*

5.2.3.1 Spill compounds or bunds can be used to contain any potential leaks and spills from the storage and handling systems. AS3780 The storage and handling of corrosive substances provides recommendations for spill compounds for fluorosilicic acid. Specifically, it states that tanks of fluorosilicic acid should be located within a spill compound large enough to contain 110% of the largest tank within the compound.

5.2.4 No more than 24-hours' supply of fluorosilicic acid should be connected at any time to the suction side of the chemical feed pump. All bulk storage tanks with more than a 7-day supply should have a day tank. A day tank can contain up to 24-hours' supply of acid (with reserve capacity necessary to allow for a top up) and the fluoride transfer from the bulk tank to the day tank should be controlled and not occur more than once in any 24-hour period.

5.2.4.1 Fluoride transfer from the bulk tank to the day tank should be initiated manually and stopped automatically and only occur once in a 24-hour period. Manual initiation can include initiation via a SCADA system. Day tanks should be equipped with online weight management to ensure overdosing does not occur. There should be a motorised valve in the line between the bulk tank and the day tank. Another safeguard is to have an anti-siphon and a motorised valve installed in the metering pump discharge line.

5.3 Acid dosing

5.3.1 Fluorosilicic acid dosing systems should include:

- a day tank equipped with online weight measurement
- a weighing platform for the acid container
- a method for calibrating dose rates
- a metering pump with pressure relief
- a loading valve on the delivery side of the pump, and
- a potable water source.

5.3.1.1 Suitable methods for calibrating dose rates include a graduated calibration tube or calibrated dipsticks.

5.3.1.2 A load cell can be provided for online measurement; the accuracy of load cell measurements should be within ± 1% for the range being measured.

5.3.2 Practical controls should be incorporated into the fluorosilicic acid dosing system to prevent overdosing by rapid release of the day tank's contents into the water being fluoridated. Methods may include anti-siphon pump controls.

6 Additional design criteria for new fluoridation facilities blending naturally occurring fluoride

Although systems that blend water that has naturally occurring fluoride with other, low fluoride water sources are inherently low risk, they must still be designed to maintain a consistent, accurate fluoride concentration.

6.1 Maintaining fluoride concentration

6.1.1 The fluoride concentration of the natural fluoride source water must not vary to the extent that the blending regime cannot be adjusted to accurately achieve the prescribed concentration.

6.1.1.1 As a guide, the variation in fluoride concentration in the source water containing the naturally occurring fluoride should not be more than ±15%.

6.1.2 Flow meters must be installed on both the regular water supply and the water containing naturally occurring fluoride.

6.1.2.1 Sufficient information should be sourced to demonstrate that the particular aquifer being accessed, in terms of its yield and fluoride concentration, represents a long-term source of fluoride. This investigation must be undertaken prior to the completion of the design phase and procurement of any equipment. Historical data for the aquifer should be used but if it is not available, hydrogeological advice should be sought. The evaluation should also consider the future demand from the aquifer.

6.1.2.2 Historical measurements of fluoride concentrations may be adequate to demonstrate security of fluoride supply if they show stability over the long term (i.e. at least 12 samples over a twelve-month period). An alternate source of data (if none is available for the bore in question) could be based on test results from other bores in the area, subject to hydrogeological evidence of the bore in question being in the same aquifer as the other bores.

6.1.3 The fluoridation system for blending should include a metering pump fitted with a pressure relief valve and a loading valve to deliver the source water containing naturally occurring fluoride.

6.1.4 Practical controls should be incorporated into the system to prevent overdosing.

6.1.4.1 Water from the Great Artesian Basin can be very hot (30-100 degrees C) and so consideration should be given to the temperatures range and chemical components of the natural supply when selecting pumping equipment.

6.1.4.2 Pumping equipment should have a non-return valve (or equivalent) arrangement to prevent backflow into the groundwater.

6.1.4.3 Flow should be controlled by a variable speed pump.

6.1.4.4 *Chemicals present in the naturally fluoridated water source (e.g. silica) can precipitate at the blend point due to the rapid temperature change due to mixing liquids with different temperatures. Based on the water chemistry, assess whether precipitation is a likely risk, a Standard Operating Procedure may be needed to monitor the pipework downstream of the blend point for accumulated scale.*

6.1.4.5 *Monitoring of total flow and instantaneous flow measurements can be used to generate an alarm if the pumps generate a daily total flow greater than the maximum daily demand.*

6.1.4.6 *If a bore is the source of naturally occurring fluoride, the prolonged operation of the bore should not change the concentration of fluoride present in that source due to draw down or other effects on the aquifer.*

7 Additional design criteria for upgrades to the water supply or fluoridation facility

This section applies to any fluoridation facility undergoing a system upgrade that will affect the decisions and outcomes of the original risk assessment for the fluoridation facility. It does not apply to new fluoridation facilities.

7.1 Risk controls

7.1.1 Initial design risk control measures are to be maintained if subsequent modifications of the fluoridation facility and/or the water supply system are undertaken, where they are still relevant.

7.1.2 In particular, the fluoridation facility must continue to comply with the provisions of the Act and Regulation and should also comply with the provisions of the Code following any water supply system capacity upgrade or major fluoridation facility upgrade.

7.1.2.1 All changes to the fluoridation facility should be recorded in a plant register or via a maintenance management system.

7.1.3 A new risk assessment should be undertaken if any alteration or modification is made to the fluoridation facility. Control measures should be adjusted or implemented accordingly to control any risks arising from the alterations or modifications.

7.1.4 Any alterations or amendments that result in changes to the operation and/or emergency response plans should be communicated to all staff and contractors involved in the operation, management or maintenance of the fluoridation facility.

7.1.4.1 Modifications to the fluoridation facility should not increase any workplace health and safety risks to the workers or visitors to the plant.

8 Operational performance criteria for fluoridation facilities

8.1 Operator qualifications and training

8.1.1 Operators of the fluoridation facility must be appropriately qualified. This means they must have the necessary training, knowledge and experience to competently operate a fluoridation facility.

8.1.1.1 The necessary skills and knowledge can be obtained through the nationally recognised unit of competency NWPTRT006 – Monitor and operate fluoride addition processes, or an equivalent competency. The unit of competency (NWPTRT006) should be from the Water Industry Advisory Committee Water Training Package NWP or equivalent.

8.1.1.2 However, completion of formal units of training is not sufficient on its own to guarantee competent operation of fluoride dosing facilities. This was shown during the North Pine Water Treatment Plant fluoride overdosing incident in 2009 where a combination of 'human factors' (i.e. human error) led to a breakdown in safeguards (for more information on managing human factors see Cloete et al. 2011 in section 10, References). Operators must be alert to indications that the fluoride dosing system is not operating as it should and respond appropriately.

8.1.2 A sufficient number of competent people must be available to operate the fluoridation facility. A minimum of two fluoridation facility operators should be qualified.

8.1.2.1 The number of qualified people required will depend on the particular staffing arrangements used by a water supplier (e.g. single operator or team based). As a minimum, two competent operators should be available to ensure that periods of sickness, annual leave, weekends and other issues, such as training and meetings, will not result in the unavailability of a competent operator for the fluoridation facility. It is also recommended that the fluoridation facility operators' supervisor (or other appropriate manager) obtain the necessary training, knowledge and experience in order to provide a detailed awareness of the legislative requirements of the Act and Regulation within the management structure of the water supplier (as well as providing operational support in an emergency).

8.1.2.2 Operating staff with prior experience operating a fluoridation facility in Australia or overseas may seek recognition of prior learning from any training provider registered to deliver the unit of competency in Queensland. Recognition of prior learning may include a short skills assessment.

8.1.2.3 Operating staff who are only involved in blending naturally occurring fluoride need not complete the nationally recognised unit of competency for fluoridation. Rather, these staff should have the necessary skills, knowledge and experience to undertake general water operational activities. Examples of appropriate qualifications include a Certificate III or IV in Water Industry Operations.

8.1.2.4 *The water supplier should develop Standard Operating Procedures (SOPs) for all routine operational duties within the fluoridation facility. The water supplier should provide training to all staff on how to carry out these procedures so there is consistency between operators. All operators should be competent in carrying out these SOPs. The use of pictures in SOPs can be useful and effective.*

8.1.2.5 *The SOPs should cover routine daily inspections, management of fluoride compounds (e.g. topping up of day tanks, hoppers, saturators, ordering new stocks), process control decisions, fluoride concentration corrections, record keeping and shut down and start-up where it is likely that the fluoridation system will be taken out of service for any significant period of time.*

8.1.3 All fluoride dosing facility operators should be trained and competent in following all SOPs for the fluoridation facility.

8.2 Maintaining adequate supply of fluoride compound

8.2.1 Sufficient quantities of fluoride compound should be available or kept in storage to ensure continuity of water fluoridation.

8.2.1.1 *The risk associated with ensuring a continuous supply of a fluoride compound is influenced by a number of issues including the quantities involved, transport distance, procurement strategy, general availability of the compound and access to the treatment facility. For some locations, seasonal conditions (e.g. potential for flooding, cyclones) may require the fluoridation facility to store a few months' supply of fluoride compound on site.*

8.2.2 If using a naturally occurring fluoride source, the source should be demonstrated to be a secure supply to ensure continuity of water fluoridation.

8.3 Fluoride compound quality

8.3.1 The water supplier must, on the receipt of each batch of fluoride compound, obtain a copy of the batch analysis certificate from the manufacturer, importer or supplier.

8.3.2 Following amendments to the Regulation in 2020, the batch analysis certificate must be issued by an Australian-based laboratory accredited by the National Association of Testing Authorities Australia (NATA) for analysis of impurities that may be present in fluoride compounds.

8.3.3 The water supplier must not add a fluoride compound to a public potable water supply if the batch analysis certificate indicates a concentration of a particular impurity exceeds the maximum concentration prescribed in Schedule 2 of the Regulation (also listed in Appendix 1 – Table 1).

8.3.3.1 *Metals are the main impurities of health significance found in fluoride compounds. Further guidance on impurities in drinking water chemicals is available in Chapter 8 of the ADWG.*

8.3.4 If a batch analysis certificate cannot be obtained, the water supplier must arrange for a sample of the fluoride compound to be analysed, at an Australian-based laboratory accredited by NATA, to determine the level of any impurities.

8.3.5 The specifications for fluoride compounds detailed in Appendix 1 - Table 1 must be treated as the minimum standard for water suppliers using sodium fluoride, sodium fluorosilicate or fluorosilicic acid.

8.3.6 It is recommended that fluoride compounds comply with the specifications in Appendix 1 - Table 2 to minimise potential operational issues.

8.3.7 The water supplier should ensure that the physical characteristics of the fluoride compound or variations in fluoride compound strength do not lead to excessive variability in the prescribed fluoride concentration in the fluoridated water or cause excessive workplace health and safety hazards.

8.3.7.1 Insoluble matter can increase turbidity levels in the final water.

8.3.8 It is recommended that the water supplier develop an SOP for the receipt of fluoride compounds. An SOP for the receipt of fluoride chemicals could include checks against chemical specifications, checks that the product is accompanied by the necessary paperwork (a batch analysis certificate issued by an Australian-based laboratory accredited by NATA and an SDS), and checks on the integrity of packaging and that the product has not been tampered with.

8.4 Quality of naturally occurring water for blending

8.4.1 The blending of a naturally occurring fluoride source should not result in any ADWG health or aesthetic parameters being exceeded in the final, treated water.

8.5 Prescribed fluoride concentration for the applicable local government

8.5.1 The water supplier must ensure the average measured fluoride concentration over a quarter meets the prescribed fluoride concentration, as per Schedule 1 of the Regulation.

8.5.2 Water suppliers must focus their efforts on the supply of safe drinking water at all times. Accordingly, if there are legitimate concerns regarding the safety of the fluoridation facility, the obligation to meet the prescribed concentration, when averaged over a quarter, should be viewed as of secondary importance. However, water suppliers should notify their local Public Health Unit (refer to section 11) if they consider that they are unlikely to meet the prescribed concentration, when averaged over a quarter, due to legitimate safety concerns.

8.5.3 The ADWG maximum health guideline value for fluoride is 1.5 mg/L. Under the provisions of the *Water Supply (Safety and Reliability) Act 2008*, drinking water service providers are required to report any exceedance of ADWG health guidelines immediately. If the concentration of fluoride in the fluoridated water exceeds 1.5 mg/L, the water supplier must immediately take corrective actions and notify Water Supply Regulation within the Department of Regional Development, Manufacturing and Water.

8.5.4 The water supplier should aim to achieve a consistent and accurate measurement of the fluoride concentration in the water supply.

8.5.4.1 *Some water supplies have fluctuating naturally occurring fluoride concentrations in their source water, or they may rely on multiple water sources that may have differing natural fluoride concentrations. This may present a risk of fluoride overdosing if not managed properly. Regular raw water sampling may be necessary during the initial operating period of the fluoridation facility to gain a better understanding of the presence and concentration of any naturally occurring fluoride. It is the responsibility of each water supplier to assess this risk as part of the risk assessment process discussed in section 3.1 of this Code. Online fluoride monitors may be needed to consistently monitor the raw water fluoride concentration where fluctuations in naturally occurring fluoride concentrations could affect the ability of the water supplier to maintain the prescribed fluoride concentrations in fluoridated water.*

8.5.4.2 *Best practice in fluoridation involves the application of an accurate concentration of fluoride at a constant rate to ensure an optimal fluoride concentration is maintained. In terms of fluoride dosing accuracy, best practice is achieved when at least 95% of the daily samples (when the fluoridation facility is operational), obtained over a 12-month period, fall within the ranges detailed below:*

- *Local government listed in part 1 of Schedule 1 of the Regulation: 0.4 – 0.7 mg/L*
- *Local government listed in part 2 of Schedule 1 of the Regulation: 0.5 – 0.8 mg/L*
- *Local government listed in part 3 of Schedule 1 of the Regulation: 0.6 – 0.9 mg/L*

8.5.4.3 *The water supplier should aim to meet these operational targets on a consistent basis. Note: This is an operational target and does not negate the water supplier's regulatory obligation to meet the prescribed fluoride concentration (+/- 0.1 mg/L) when averaged over a quarter.*

8.5.4.4 *Water suppliers operating a reticulation system that can be supplied by multiple water treatment plants/bores may shut down individual water treatment plants/bores for maintenance or during periods of low demand. In these situations, the water supplier should develop SOPs for shut down and start-up operations to ensure safe and accurate dosing or blending is maintained.*

8.5.4.5 *In some instances, the water supplier and the reticulation system manager may be different entities resulting in the reticulation system manager having no direct control over the fluoride concentration in the water. The water supplier should have a notification arrangement with the reticulation system manager in relation to an under dosed supply, such that they are notified of any disruptions that affect the supply of optimally fluoridated water. For overdosing events, clearly articulating and establishing these communication procedures is an essential part of Emergency Response Planning (see section 8.11 of this Code) and is also important for effectively communicating other water fluoridation issues in a timely manner. Wherever possible, these communication procedures should be integrated into existing plans and procedures.*

8.6 Analysis of fluoride in treated water

8.6.1 The water supplier must analyse the concentration of fluoride in the fluoridated water each day, from a location where the fluoridated water would have a consistent concentration of fluoride. The sampling point location should be far enough downstream from the point where the fluoride is added to the water supply to ensure the fluoride is well mixed, but prior to any customer connection, reservoir or tank.

8.6.1.1 Daily sampling serves two purposes: to monitor fluoride levels in water distributed to customers and to verify the correct operation of the fluoridation system.

8.6.1.2 Where fluoride is added to a single main, it is often the case that one sampling point can be used for both purposes.

8.6.1.3 In such cases it is important to ensure that the sample point is far enough downstream so that the fluoride is well mixed with the treated water but not too far downstream, or after a service reservoir.

8.6.1.4 Complex supply networks will require at least two sampling points. Where long sample lines are used it is good practice to carry out regular checks to ensure the sample line is not affecting the sample water quality (e.g. compare results taken from each end of the sample line).

8.6.2 The water supplier must use a method of analysis that has been prescribed under the Regulation. Prescribed analysis methods include the following (see Glossary for further information):

- ion-selective electrode (ISE) method
- SPADNS method
- ion chromatography method.

8.6.2.1 Each of the above methods for measuring fluoride in water are included in the Standard Methods for the Examination of Water and Wastewater (see AWWA/WEF 2017 in section 10 References).

8.6.2.2 The ISE method is preferred as it is reliable, easy to perform and less affected by interfering substances in the water.

8.6.2.3 It is essential that measurements be carried out as described with the use of appropriate, calibrated equipment and reagents of appropriate quality. Failure to do so may lead to inaccurate results and unnecessary concern (see sections 8.7 and 8.9 for guidance on quality assurance and calibration respectively).

8.6.2.4 The minimum requirements for equipment and reagents to carry out bench-top ISE analyses are:

- *a meter that can be used with fluoride and temperature probes, and that displays millivolts, fluoride concentration and temperature in degrees Celsius*
- *fluoride electrodes (either a combined electrode, or separate measuring and reference electrodes)*
- *temperature probe (for measuring temperature of sample being tested)*

- *a magnetic stirrer with insulated top, moveable arm stand with probe holder for fluoride and temperature probes, and Teflon coated stirrer bars*
- *laboratory plastic ware (beakers, measuring cylinders and sample/storage bottles)*
- *a timer*
- *Total Ionic Strength Adjustment Buffer (TISAB), and electrode filling solution (potassium chloride), which should be of analytical grade.*

8.6.2.5 Only plastic should be used for fluoride samples as the use of glassware (such as bottles or beakers) may lead to lower results due to adsorption of fluoride ions onto the glass surface.

8.6.2.6 Online analysers will only produce accurate and reliable results when they are properly maintained and regularly calibrated. Investigations of poorly maintained ISE probes have shown that the instruments can produce an erroneous estimate of fluoride concentration (see sections 8.7, 8.9 and 8.10 for guidance on quality control measures, calibration and maintenance).

8.6.2.7 Online analysers utilise the ISE method and as such are susceptible to analytical interferences that may either increase or decrease the apparent fluoride concentration. Interferences are caused when fluoride forms complexes with metal ions, such as aluminium and iron. Variations in ionic strength can also affect the accuracy of ISE measurements.

8.6.2.8 The extent to which fluoride complexes are formed depends on solution pH, fluoride concentration and concentration of complexing metal ions. If interferences cause errors in the measurement of the fluoride ion of 0.05 mg/L or greater, the use of online analysers that utilise a buffering agent – such as TISAB – is recommended.

8.6.2.9 The use of a free fluoride online analyser – an online analyser which does not utilise TISAB – may be considered appropriate if the water to be dosed and monitored:

- *is consistently low in aluminium and iron (i.e. consistently below the aesthetic guidelines values in ADWG – 0.2 mg/L for aluminium and 0.3 mg/L for iron) and*
- *has a relatively stable pH between 5.5 and 8.5.*

8.6.2.10 All ISE analyses, including online ISE analyses, should be performed at a constant temperature, or results corrected for temperature, as ISE measurements are temperature dependent.

8.6.2.11 SOPs should be developed for sampling and analytical procedures and should specify any areas that may be problematic (e.g. adding reagents, timing or interfering substances).

8.6.2.12 ISE electrodes should be cleaned and stored appropriately.

8.6.2.13 The meter attached to the fluoride ion selective electrode should be checked regularly for sensitivity (following manufacturer's instructions).

8.6.3 The method should conform to the latest edition of Standard Methods for the Examination of Water and Wastewater (see AWWA/WEF 2017 in section 10 References).

8.6.4 Staff should be appropriately trained in the method used to analyse fluoride and must follow any SOPs associated with fluoride analysis.

8.6.5 The analysis SOP should ensure that the fluoride calibration standard(s), quality control samples and the routine fluoride samples are at the same temperature before proceeding with the analysis.

8.6.6 The laboratory where fluoride analysis is performed should contain appropriate resources to ensure accurate fluoride concentration analysis.

8.6.7 Analytical equipment should be permanently set up. Bench space should be adequate for analysis and sufficient storage available for consumables (such as plastic ware, reagents and spare parts). The area should not be exposed directly to sun or high temperature. Air conditioning is preferred. A small fridge for storing samples and reagents at a constant low temperature should be provided.

8.6.8 Appropriate spare equipment/parts for the laboratory should be available on site.

8.7 Quality assurance of fluoridated water supply

8.7.1 On one day each month the water supplier must split a daily sample into two parts and analyse one part using a prescribed analysis. The other part must be forwarded to an Australian-based laboratory that is NATA accredited for fluoride analysis, and the results of analysis provided to the water supplier.

8.7.1.1 The sampling and analysis of a quality control sample each month is required under the Regulation to provide confirmation of the accuracy of the analytical procedures employed on site. This must be performed by an accredited laboratory.

8.7.2 A daily quality control sample should be analysed by the water supplier along with the mandatory daily samples of fluoridated water. This sample should be analysed using the same prescribed analysis as the routine samples.

8.7.2.1 The daily quality control sample is a sample of known fluoride concentration. This daily quality control sample provides a means to ensure that any analysis performed by the fluoridation facility operator is providing accurate results. The daily quality control sample should be prepared separately from the calibration standards as it is used to check on the accuracy and precision of the analysis performed.

8.7.2.2 The daily quality control sample can be prepared in the on-site laboratory from analytical reagent grade chemicals or can be purchased from an external provider.

8.7.2.3 Plotting the results of quality control analyses over time will allow the water supplier to check any trends that may be developing (e.g. fluoride concentration of quality control samples may be gradually dropping over time, in which case corrective action may be required).

8.7.2.4 If there is a greater than 0.2 mg/L difference in fluoride concentration between the locally and externally analysed monthly control samples, then the reason for the discrepancy should be investigated.

8.7.2.5 *It is good practice to record the details of fluoride standards and reagent chemicals, as well as the results from daily quality control samples. This will help ensure the results of fluoride analyses are accurate. In terms of reagent chemicals and fluoride standards, the following records should be kept:*

- *batch numbers*
- *expiry date*
- *comparison of results when changing from one batch to another*
- *quality assurance documentation from the manufacturers.*

8.7.2.6 *Where online analysers are used, water suppliers should conduct daily bench-top or laboratory analysis of the fluoridated water – using TISAB – and compare the results of this analysis with the results from the online analyser. The SPADNS method may be used as an alternative to the TISAB ISE method. Where significant differences are observed between the two sets of results, investigations should be undertaken to determine the cause of the discrepancy.*

8.7.2.7 *Water suppliers should ensure TISAB and sample flow rates to the online analyser are stable and within established limits. For online analysers using TISAB, this can be checked by measuring the pH of the waste stream.*

8.7.2.8 *When a free fluoride online analyser is used, the water supplier should adopt the following additional quality control practices to ensure the system produces accurate results:*

- *water suppliers should check the performance of the online analyser using a quality control sample prepared by spiking unfluoridated water with a known concentration of fluoride and*
- *plot the results of the quality control samples on a chart (with the date on the x-axis and the concentration on the y-axis) to monitor any adverse trends.*

8.8 Records and reporting requirements

The Regulation contains mandatory record keeping and reporting requirements for water suppliers that supply fluoridated water. This information should be recorded electronically or in hard copy for auditing purposes.

8.8.1 For fluoridation facilities using a fluoride compound the water supplier must record, on the approved form, the daily:

- volume of fluoridated water
- amount of fluoride compound added even if the amount is zero
- calculated fluoride concentration of fluoridated water
- measured fluoride concentration in the fluoridated water from a point where the fluoride has a consistent concentration (see section 8.6.1)

8.8.2 The water supplier must record the fluoride concentration in the locally analysed monthly quality control split sample as well as the fluoride concentration in the other split sample analysed by an Australian-based laboratory (which is NATA accredited for the prescribed analysis) as noted in section 8.7.1 and the Glossary.

8.8.3 The results of the measured fluoride concentration in the monthly quality control samples ("prescribed tests") must be kept for a minimum of five years.

8.8.4 Where online fluoride analysers are used, the water supplier should record the average fluoride concentration at pre-determined periods throughout the day.

8.8.5 Records should also be kept of the following:

- results from the chemical analysis of fluoride compounds
- results from analysis of fluoride concentration in raw water
- maintenance and calibration records of plant and equipment.

8.8.6 All other fluoride results from NATA-accredited laboratories should be recorded, maintained and made available for auditing.

8.8.7 Records documenting fluoridation facility operation, particularly those relating to regulatory requirements, must be available to persons authorised under the Act for inspection.

8.8.8 When the fluoridation facility ceases operation for a continuous 14-day period, the water supplier must notify Queensland Health, using the approved form (Form 2 Notice-Period of non-operation), within 1 business day of the end of the 14-day period.

8.8.9 When the fluoridation facility resumes operation after a period of non-operation for a continuous period lasting 14 days or more, the water supplier must notify Queensland Health, using the approved form (Form 3 Notice – Resumption of operation), within 5 business days of operation resuming.

8.8.10 The water supplier must complete Fluoridated Water Quarterly Reports in the approved form (Form 5 Notice – Fluoridated Water Quarterly Report). The completed form must be submitted to the Chief Executive of the Department of Health within 30 business days of the completed quarter.

8.8.11 The quarterly report must contain the following information:

- the number of samples taken for the reporting period
- the quarterly average measured fluoride concentration in the fluoridated water
- the maximum measured fluoride concentration
- the minimum measured fluoride concentration in the fluoridated water
- the prescribed concentration for the local government area
- the number of times the fluoride concentration exceeded 1.5 mg/L, and
- in instances where the average measured fluoride concentration is not within 0.1 mg/L of the prescribed concentration, an explanation as to why the prescribed concentration was not met.

8.9 Equipment calibration

All fluoride dosing facility operators involved in fluoride analysis should follow an SOP when calibrating equipment and analysing fluoride samples.

8.9.1 An SOP should be established for the calibration of analytical equipment.

8.9.1.1 It is essential that calibration standards are kept at the same temperature as the fluoridated water sample. This can be achieved by either keeping the calibration standards at room temperature and waiting for the fluoridated water sample to come to room temperature before analysis or keeping the calibration standards in a water bath using a continuously running fluoridated water sample, in which case the analysis can be done immediately. The potential impact of this issue is greatest where the diurnal temperature range is large, and the laboratory area is not air-conditioned.

8.9.1.2 Calibration standards should include at least three points between 0.5 and 2 mg/L (e.g. 0.5, 1.0, 2.0 mg/L).

8.9.1.3 Calibration records should be maintained. Information from instrument calibration, such as slope, can identify changes in performance, such as sensitivity changes, in fluoride meters and electrodes. Calibration records will identify when instrumentation needs servicing or replacing.

8.9.1.4 It is important to follow manufacturer's instructions with regard to the process of calibrating the equipment for the method used for fluoride analysis. Instructions should indicate any interference likely to affect the fluoride reading.

8.9.1.5 Water suppliers should calibrate both bench top and online analysers at least daily unless it can be demonstrated a reduced frequency is appropriate. Water suppliers should also ensure the slope and the instrument zero are within the limits recommended by the manufacturer.

8.9.1.6 When a free fluoride online analyser is used, the water supplier should prepare the relevant calibration standard solutions with representative, unfluoridated water (that is, representative of the water to be dosed). Calibration of the online analyser should always be undertaken with these specially prepared standard solutions to eliminate interference caused by differing pH or ionic strength. The natural background level of fluoride in the unfluoridated water should be taken into account when preparing the calibration standard solutions. New standard solutions should be prepared in response to significant changes in water chemistry.

8.9.2 Standards used for calibration should be the same temperature as the fluoride sample being analysed.

8.10 Equipment maintenance

8.10.1 Daily inspections should be conducted to assess the condition of equipment in the fluoridation facility.

8.10.1.1 *If a water supplier faces particular difficulties having an operator attend the site each day of the week - to fulfil the daily sampling and analysis requirements and to inspect the equipment in the fluoridation facility, the water supplier may wish to approach their local Queensland Health Public Health Unit to discuss the possibility of less frequent site visits. Water suppliers wanting to reduce the frequency of site visits by operators should be able to demonstrate a history of appropriate operation, that risks managed through daily site visits will be managed through alternative risk management practices and that appropriate quality control procedures are in place for online analysers used at the site. See section 11 for a link to contact details for Public Health Units.*

8.10.2 The fluoridation facility and associated equipment should be adequately maintained to achieve reliable operation.

8.10.3 Saturator tanks should be periodically cleaned out to remove the build-up of insoluble cinders.

8.10.3.1 *Insoluble cinders result from the accumulation of insoluble material present in sodium fluoride, and precipitates that can form when sodium fluoride is dissolved in a saturator tank. The accumulation of insoluble cinders can lead to saturation not being achieved and, consequently, underdosing. Table 2 below provides recommended cleaning frequencies based on the following assumptions:*

- *The water used to dissolve the sodium fluoride has a hardness of less than 75 mg/L, and*
- *The operating volume of the saturator tank is, or is approximately equal to, 210L.*

Table 2: Recommended cleaning frequency for saturator tanks

Number of 25kg bags used per week	Recommended cleanout frequency
Up to 2 bags	Annually
2 to 4 bags	6 monthly
4 to 7 bags	4 monthly
>7 bags	2 monthly

8.10.3.2 *Once removed, water suppliers should dispose of the solution and insoluble cinders in accordance with relevant regulations and guidelines (see section 8.14 for guidance regarding the relevant environmental protection regulations and guidelines).*

8.10.3.3 *Further information on the accumulation of insoluble cinders, and recommended management strategies, is available in American Water Works Association Standard B701-18 – Sodium Fluoride.*

8.11 Emergency response planning

8.11.1 Emergency response planning for overdosing incidents should be developed and documented as part of the risk management plan discussed in section 3.1 of this Code.

8.11.1.1 Ideally, the risk assessment conducted during the planning of the fluoridation facility should have identified all possible causes of overdosing and appropriate control measures will have been developed and implemented to deal with each one. These controls should be integrated with existing risk management documentation and should form part of the water service provider's Drinking Water Quality Management Plan.

8.11.1.2 The ADWG maximum health guideline value for fluoride is 1.5 mg/L. If this value is exceeded, corrective actions should be taken and the incident must be reported immediately to Water Supply Regulation within the Department of Regional Development, Manufacturing and Water.

8.11.1.3 Water Supply Regulation will in turn notify the relevant Public Health Unit and the Department of Health.

8.11.1.4 Appendix 3 details actions which may be appropriate in the event of an overdosing incident.

8.11.2 An overdosing event can be defined as when the fluoride concentration in treated water or the reticulation system is over 1.5 mg/L.

8.11.3 Where one or more online analysers are used, and are interlocked with the fluoridation system, fluoride concentration readings greater than 0.3 mg/L above the prescribed fluoride concentration for a significant period of time should result in an automatic shutdown of the fluoridation system and generate an alarm. The treatment plant supervisor should be notified, and the cause of the elevated concentration should be investigated and rectified before recommencing fluoridation system operations.

8.11.3.1 Shutting the fluoridation facility down in such circumstances will help ensure that the limit of 1.5 mg/L is never exceeded.

8.11.4 The water supplier's emergency response plan should also contain details on how to ensure that customers serviced before a storage reservoir are not exposed to elevated levels of fluoride in the event of an overdosing incident.

8.11.5 Emergency response planning for fluoridation should include:

- procedures for shutting down fluoridation equipment in the event of overdosing
- actions required to identify and rectify problems
- actions required to advise and protect the health of the public in the event of an overdosing event
- reporting protocols including a clear chain of command and designated responsibility.

8.12 Plant security

8.12.1 Maintenance staff, including contractors, must not be permitted to be in charge of or operate the fluoridation facility unless they have the appropriate skills, knowledge and experience as detailed in section 8.1.

8.12.1.1 Entry to the fluoridation facility by untrained persons (staff and public) needs to be controlled both for the protection of the fluoridation equipment and for personal safety. Maintenance workers need to be supervised to prevent impacts on the fluoridation process. The fluoridation facility manager and competent operators are responsible for ensuring maintenance staff do not put themselves, the fluoridation process, or the environment at risk. Best practice could involve the use of a work permit system that includes a systematic risk assessment of the potential impact on the fluoridation process from the work being done.

8.12.2 The water supplier should ensure that visits by any personnel to the fluoridation room are authorised and a qualified operator accompanies visiting personnel.

8.12.2.1 The operator and the maintenance staff should assess the risks together and agree on any special controls required while the work is being carried out (e.g. for work carried out while water flow is off, maintenance staff will not switch dosing equipment on or off for testing without the knowledge of the operator). The degree of control required will depend on the knowledge, training and experience of the maintenance staff.

8.12.3 Once visitors have entered the fluoridation room, the presence of the competent operator may not be required, provided that the competent operator is satisfied that:

- The visitors have been adequately instructed and will not be in contact with the fluoride compound or any part of the fluoridation equipment; or
- The visitors have been given appropriate instruction and provided with the appropriate personal protective equipment if contact with fluoride compound is likely when maintaining specific items of the fluoridation equipment.

8.12.4 The building housing the fluoridation facility should be a solid lockable construction and kept locked when unattended to prevent unauthorised entry.

8.12.4.1 The fluoridation facility (plant room/building, fluoride compound storage areas, dosing lines etc) should be of sufficiently solid construction to minimise the risk of damage to equipment due to vandalism. The plant design should minimise the risk of accidental damage to equipment such as dosing lines, valves etc. where feasible.

8.13 Workplace health and safety

This section applies to all fluoridation facilities. All activities relating to fluoridation facilities must be undertaken with maximum regard for the health and safety of workers. Factors to consider include (but are not limited to) plant, exposure to hazards, ergonomics and hazardous manual tasks.

8.13.1 All safety obligations under the *Work Health and Safety Act 2011* (WHS Act 2011) must be met.

8.13.1.1 Water suppliers need to regularly review the safety requirements of the WHS Act and associated Regulations to ensure compliance. General Risk and Workplace Management provisions are contained within Chapter 3 of the Work Health and Safety Regulation 2011 (WHS Regulation 2011).

8.13.1.2 A risk assessment, as described in section 3.1 of this Code, should include all safety aspects of the design, commissioning, operation, testing, maintenance, repair and decommissioning of a fluoridation facility. The risk assessment process should involve a range of stakeholders such as plant operators, managers and technical experts. Hazards and control mechanisms should be identified in the risk assessment and incorporated into the design. Appropriate control measures should be implemented. Based on the hierarchy of controls, hazards should be eliminated wherever possible, followed by use of substitution, isolation and engineering controls. The use of personal protective equipment should not be relied upon as a sole control measure and will often be used in conjunction with other controls.

8.13.1.3 Water suppliers using fluoride compounds that are hazardous chemicals also need to comply with Chapter 7 – Hazardous chemicals of the WHS Regulation.

8.13.1.4 Under the above legislative provisions, water suppliers must identify foreseeable hazards associated with handling, storing, or using fluoride compounds at their workplace, manage their risks including applying the Regulation’s hierarchy of controls, and maintain and review all of the corresponding controls.

8.13.1.5 Water suppliers must ensure the airborne concentration of fluoride compounds does not exceed the exposure standard and, where the water supplier is not sure if the exposure standards are being exceeded or not, conduct measurements of the airborne concentrations. The current exposure standard for fluorides is 2.5 mg/m^3.

8.13.2 Water suppliers must provide workers handling fluoride compounds and/or storage and handling systems with adequate information, training and instruction on how to handle hazardous chemicals and how to operate storage and handling systems.

8.13.3 Water suppliers with >250 kg or L of fluorosilicic acid or >1000 kg of sodium fluoride or sodium fluorosilicate must comply with the placarding requirements of Schedule 13 of the WHS Regulation. Placarding quantities referred to in this section are based on general chemical classifications given at HCIS (Hazardous Chemical Information System - http://hcis.safeworkaustralia.gov.au/HazardousChemical). Always check the manufacturer’s Safety Data Sheet (SDS) Section 2 for the correct hazard classification.

8.13.4 Water suppliers with >2,500 kg or L of fluorosilicic acid or >10,000 kg of sodium fluoride or sodium fluorosilicate must have a manifest. These water suppliers must provide Queensland Fire and Emergency Services with a copy of their emergency plan and notify Workplace Health and Safety Queensland using 'Form 73' that they are a manifest quantity workplace, as well as provide them with the manifest. More information about preparing a manifest and notification can be found at: https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/hazardous-chemicals/Working-with-large-quantities-of-hazardous-chemicals/are-you-a-manifest-quantity-workplace. Manifest quantities referred to in this section are based on general chemical classifications given at HCIS (Hazardous Chemical Information System - http://hcis.safeworkaustralia.gov.au/HazardousChemical). Always check the manufacturer's SDS Section 2 for the correct hazard classification.

8.13.5 Safety Data Sheets (SDSs) must be available on-site for all fluoride compounds.

8.13.5.1 An SDS is essential for providing information on fluoride compounds such as effects from exposure and details on safe storage and handling and how to manage leaks and spills. SDSs must be available to workers and any other person that could be exposed to the chemicals. E.g. emergency services staff.

8.13.6 Appropriate personal protective equipment (PPE) must be available for operator protection.

8.13.6.1 Depending on the activity being performed, PPE for fluoride dosing facilities may include:

- *elbow length impervious rubber or plastic gloves, long sleeve shirt, trousers, full length impervious rubber or plastic apron for protection of skin*
- *impervious rubber or plastic boots*
- *for plants using dry fluoride compounds, a full-face mask with type P3 respiratory filters (as per 'AS/NZS 1715 Selection, use and maintenance of respiratory protective equipment')*
- *for plants using fluorosilicic acid, where there is a risk of exposure to acid fumes, a full-face respirator fitted with an acid gas filter and/or a full-face shield or splash-proof safety goggles.*

8.13.7 If a worker is exhibiting a symptom that could be related to acute occupational fluoride exposure, they should consult a medical practitioner with a copy of the relevant SDS. Symptoms of acute occupational fluoride exposure include increasing stiffness in the back, nausea, vomiting, abdominal pain, diarrhoea, fatigue and drowsiness.

8.13.8 Emergency eyewash and showers, that comply with AS/NZS 4775, and adequate routine washing facilities should be available wherever fluoride compounds are stored and handled.

8.13.9 Appropriate equipment for cleaning up and disposing of spills or leaks must be provided at the workplace and used solely for this purpose. Water suppliers must also provide workers handling fluoride compounds with adequate information, training and instruction on how to clean up spills and leaks, including how to use clean up and disposal equipment.

8.13.10 Dry clean up, when managed safely, may be a more effective method of removing the bulk of larger spills than hosing the spilt powder or granules into a sump or drain. The collection, treatment or disposal of the resulting contaminated water may be more difficult to manage than dry chemical waste.

8.13.11 Small spills, or the final clean-up of larger spills, could be undertaken with the use of a mop or wet rag.

8.13.12 Clean up procedures should address the correct use of PPE and ways of minimising dust creation.

8.13.13 The water supplier must consider how it will dispose of spilt fluoride compound once contained as part of its procedures and instruction, information and training of its workers.

8.13.14 The obligations applicable under the WHS Act and Regulation are determined by the quantity of hazardous chemicals at the facility. Every facility holding hazardous chemicals has obligations under WHS legislation.

8.13.14.1 The quantities of fluoride compounds and other chemicals stored or handled at the facility may invoke specific requirements under the WHS Act including safety signage and warning placards. For guidance on warning placards refer to Appendix 4.

8.13.14.2 A number of documents including codes of practice, guidelines and Australian Standards are available to assist with complying with the legislative requirements for operator safety including:

- *Managing the risks of plant in the workplace - Code of Practice 2021 (Workplace Health and Safety Queensland 2021)*
- *Electrical safety Code of Practice 2020 – Works (Workplace Health and Safety Queensland)*
- *Managing risks of hazardous chemicals in the workplace Code of Practice 2021 (Workplace Health and Safety Queensland)*
- *Hazardous manual tasks Code of Practice 2021 (Workplace Health and Safety Queensland)*
- *AS3780 The storage and handling of corrosive substances (relevant to hydrofluorosilicic acid)*
- *AS/NZS4452 The storage and handling of toxic substances (relevant to powdered fluoride compounds)*
- *AS1319 Safety signs for the occupational environment*
- *ISO 31000 Risk Management – Principles and guidelines*
- *ISO 45001 Occupational health and safety management systems-Requirements with guidance for use.*
- *AS/NZS 1715 Selection, use and maintenance of respiratory protective devices.*
- *Australian Code for the Transport of Dangerous Goods by Road & Rail (National Transport Commission).*

8.13.14.3 Further information on workplace health and safety requirements can be found at the Workplace Health and Safety Queensland web site - www.worksafe.qld.gov.au/laws-and-compliance/codes-of-practice.

8.14 Environmental protection

Water suppliers must consider environmental protection laws and take all reasonable and practicable steps to prevent environmental harm from occurring.

8.14.1 The water supplier must comply with the *Environmental Protection Act 1994* (EP Act) and associated regulations, policies and approvals.

8.14.1.1 The Environmental Protection Regulation 2019 (EP Regulation) places a number of obligations on generators, transporters and receivers of regulated and trackable wastes. These include, but are not limited to, recording prescribed information about the waste, providing copies of the prescribed information to the transporter and the Department of Environment and Science (DES), and only using a licensed transporter to transport the waste. The water supplier should therefore prepare, document and implement an SOP that addresses the disposal of fluoride waste that is consistent with the trackable waste requirements of the EP Regulation and outlines the disposal plans for contaminated fluoride compound and fluoride compound containers. The options for disposal of fluoride compound/s may include returning it to the supplier, disposal through a waste disposal contractor or disposal in the local waste landfill (if permitted by the operator of the landfill). Concentrated fluoride compounds (powder or solution) are hazardous to wildlife and disposal options should be considered carefully. Further guidance on the management of trackable wastes can be found on the DES website at: https://environment.des.qld.gov.au/management/waste/business/tracking.

8.14.1.2 The water supplier has a general environmental duty under the EP Act not to carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm. If clarification of EP Act requirements is necessary, water suppliers should consult DES.

8.14.2 The disposal of analytical solutions containing TISAB must comply with applicable regulatory requirements.

8.14.2.1 The most common methods for disposing of analytical solutions containing TISAB are discharging to sewer and, where there is no access to a sewer, storing the solutions in a holding tank for later disposal by waste management services. Where it is anticipated that TISAB-containing solutions will be discharged to sewer, the water supplier should consult with the operators of the relevant sewage treatment plant in the design phase to ensure this disposal option will comply with local regulations. Less frequently, water suppliers may prefer to discharge these solutions to the environment. In such cases DES should be consulted in the design phase to ensure all applicable regulations and guidelines are complied with.

8.14.3 The plant risk assessment discussed in section 3.1 should consider the potential for environmental impacts associated with unloading and spill containment of fluoride compounds.

8.14.4 The water supplier should prepare, document and implement an SOP for an emergency response to a spill of fluoridation chemical including emergency contact numbers. This should ensure that appropriate spill kits are located in key areas of the facility to enable safe and effective management of minor spills and leaks and that safety procedures detailed in the SDS are followed when a large spill of fluoride compound occurs.

8.14.5 Empty fluoride compound containers and contaminated fluoride compounds are considered ‘regulated’ and ‘trackable’ waste under the EP Regulation. The water supplier should therefore prepare, document and implement an SOP consistent with the requirements of the Regulation for the disposal of these items.

9 Glossary

Australian Standards (AS/NZS)

Standards are published documents setting out specifications and procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they were intended to. They establish a common language which defines quality and safety criteria. Where standards are referred to in the Code, it is recommended that the most recent version of the standard be consulted, unless otherwise prescribed under legislation.

Australian Drinking Water Guidelines (ADWG)

The Australian Drinking Water Guidelines (2011) provide a risk management framework to assure the consistent supply of safe drinking water to protect public health. They include maximum health guideline values for a range of water quality parameters, including fluoride.

Batch analysis certificate

Batch analysis certificate, for a fluoride compound, means a certificate stating the concentration of impurities in the fluoride compound issued by an accredited laboratory to the manufacturer, importer or supplier of the fluoride compound.

Blending

Blending is a method of fluoridating water supplies whereby a source water, containing elevated levels of naturally occurring fluoride, is added to the water supply in a ratio such that the prescribed fluoride concentration is achieved in the blended water.

Calculated fluoride concentration

The calculated fluoride concentration (CFC) is the theoretical concentration of fluoride ions in the water after addition of the fluoride compound. It is calculated in mg/L using the following:

a) the amount (kg) of fluoride compound added to water calculated using the loss of volume from a tank (day tank or otherwise) or loss of weight from a tank (day tank or otherwise)

b) % of fluoride ion in the fluoride compound (NaF = 45.2%; H2SiF6 = 79.1%; Na2SiF6 = 60.6%)

c) Purity of the fluoride compound (% purity). This information can be obtained from the batch analysis certificate

d) volume of water treated in ML

e) fluoride concentration in the raw water before treatment (F in raw water in mg/L)

Equation

Using a) to e) above, the equation is as follows:

$$CFC = \frac{(a \text{ x } b \text{ x } c)}{(d \text{ x } 100 \text{ x } 100)} + e$$

Or written in full, the equation is as follows:

$$CFC\ mg/L = \frac{(amount\ of\ chemial\ added\ (kg) \text{ x } \%\ of\ fluoride\ ion \text{ x } \%\ purity)}{(Volume\ of\ water\ treated\ ML \text{ x } 100 \text{ x } 100)} + F\ in\ raw\ water\ mg/L$$

The calculated fluoride concentration should equal the measured fluoride concentration. It will also be a 24-hour average fluoride dose rate.

Calibration standard

A solution with a known concentration of the pure fluoride compound used to evaluate the concentration of fluoride present in the sample solution. Generally, at least three calibration standards, of increasing fluoride concentration, are used to plot a calibration curve with fluoride concentration on the x-axis and instrument response on the y-axis.

Chief Executive

Chief Executive means the Director-General of the Department of Health, Queensland.

Daily quality control sample

The daily quality control sample is a sample of known fluoride concentration that is analysed alongside the routine treated water sample using the same analytical equipment. This sample is intended to alert the operator to any problems with the analytical method procedure and/or problems with analytical equipment.

Dangerous goods

Dangerous goods are defined under the Australian Dangerous Goods Code and are classified on the basis of immediate physical or chemical effects, such as fire, explosion, corrosion and poisoning affecting people, property or the environment.

Dosing

Dosing refers to the process of using a fluoride compound to fluoridate the drinking water supply.

Dry Fluoride feed system

Feed system where dry chemical, sodium fluoride or sodium fluorosilicate, is metered at a predetermined rate.

Externally analysed fluoride concentration

A fluoride sample analysed at an external laboratory, not at the fluoride dosing facility site. This laboratory must be NATA accredited for fluoride analysis.

Fluoride compound

There are three prescribed fluoride compounds referenced in the Water Fluoridation Regulation 2020: fluorosilicic acid (H_2SiF_6), sodium fluoride (NaF) and sodium fluorosilicate (Na_2SiF_6).

Form of fluoride

The four forms of fluoride prescribed under the Water Fluoridation Regulation 2020 are: fluorosilicic acid (H_2SiF_6), sodium fluoride (NaF), sodium fluorosilicate (Na_2SiF_6) and naturally occurring fluoride contained in water.

Fluoridation

Fluoridation is the addition of a prescribed form of fluoride to drinking water for the purpose of oral health benefit. Fluoridation involves the controlled addition of a form of fluoride to a public water supply to achieve the prescribed fluoride concentration for the local government area.

Fluoridation facility

Relates to facilities that include dosing or blending fluoridation systems.

The building and equipment involved in the fluoridation of drinking water, including chemical storage areas, dosing and control equipment, safety equipment and any other fixtures used for, or associated with, the purpose of fluoridation.

Fluoride dosing system

The dosing and control equipment involved in the fluoridation of drinking water with a fluoride compound.

Fluoride concentration

Fluoride concentration means the concentration of fluoride ion in water. Where fluoride concentration is mentioned in the Water Fluoridation Regulation 2020 or this Code of Practice, it refers to the concentration of the fluoride ion.

Hazardous chemicals

Hazardous Chemicals are defined in Schedule 19 of the Work Health and Safety Regulation 2011.

Interlocked

An interlocked fluoridation system is interconnected in such a way that the failure of any one part of the fluoridation system results in the shutdown of the entire fluoridation process and cannot be automatically restarted. An interlocked system must also ensure that the automatic fluoridation equipment cannot operate unless it receives confirmation of water flow through the fluoridation system via a water flow measuring device.

Ion chromatography method

The fluoride ion can be analysed by ion chromatography. This method can be automated and is generally used in larger laboratories that handle large numbers of samples. It is not a bench top system found at most water treatment plants. Ion chromatography is an analytical technique in which the negatively charged fluoride ions in the sample are separated from the other anionic species in the sample by an anion exchange column. The conductivity of fluoride ions is measured and is directly proportional to the concentration of fluoride in the sample.

Ion-selective electrode (ISE) method

The fluoride ion in a water sample can be detected by an electrode sensitive to the fluoride ion. This method can be adapted to field or online instrumentation as well as a laboratory instrument. It is generally the method of choice for most on-site laboratories.

Local government area

Local government areas are listed in Schedule 1 of the Water Fluoridation Regulation 2020. Section 4 of the Water Fluoridation Regulation 2020 prescribes optimal fluoride concentrations for particular local government areas.

Locally analysed fluoride concentration

Fluoride sample analysed at the on-site laboratory.

Manifest

A written summary of the hazardous chemicals used, handled or stored at a workplace.

Measured fluoride concentration

The concentration of fluoride measured using one of the prescribed analyses in the Water Fluoridation Regulation 2020.

Monthly quality control sample

The monthly quality control sample is a sample that is taken from the fluoridated water or the reticulation system and split into two portions. One portion is analysed at the on-site laboratory using the fluoride method routinely used at the treatment plant and the other portion is sent away to a laboratory that is NATA accredited for fluoride analysis.

National Association of Testing Authorities (NATA)

NATA is the authority responsible for the accreditation of laboratories, inspection bodies, calibration services, producers of certified reference materials and proficiency testing scheme providers throughout Australia. See: www.nata.com.au.

Naturally occurring fluoride

Some groundwater sources in western Queensland that draw their water from the Great Artesian Basin have concentrations of fluoride above the level required under the Water Fluoridation Regulation 2020. This means that this water can be blended with water containing low fluoride concentrations to achieve the appropriate concentration for the location specified in Schedule 1 of the Water Fluoridation Regulation 2020.

Programmable Logic Controller (PLC)

A computerised device used in the automation of electromechanical processes.

Prescribed fluoride analysis

The Water Fluoridation Regulation 2020 lists three approved methods for undertaking prescribed fluoride analyses. These are ion selective electrode, SPADNS and ion chromatography.

Prescribed fluoride concentration

The prescribed fluoride concentration is specified in Section 4 of the Water Fluoridation Regulation 2020 is:

- if the water supply is located in a local government area listed in Schedule 1, part 1 – 0.6 mg/L
- if the water supply is located in a local government area listed in Schedule 1, part 2 – 0.7 mg/L

- if the water supply is located in a local government area listed in Schedule 1, part 3 – 0.8 mg/L.

Quarter

Quarter in the Water Fluoridation Regulation 2020 means each of the following:

- 1 January to 31 March of each year
- 1 April to 30 June of each year
- 1 July to 30 September of each year
- 1 October to 31 December of each year

Quarterly average measured fluoride concentration

This is a single value that is calculated by adding up all the measured fluoride concentrations for samples taken during the quarter and dividing this number by the number of samples. For example, for a 5-day period, 5 samples are taken and fluoride is measured. The results are 0.7, 0.6, 0.7, 0.8 and 0.7 mg/L. The average measured fluoride concentration in this example is 0.7 mg/L {(0.7 + 0.6 + 0.7 + 0.8 + 0.7) ÷ 5}.

Reticulation system manager

The entity that is responsible for reticulating the fluoridated water to customers.

SCADA

Supervisory Control and Data Acquisition. A SCADA system is a control system that receives signals from components in the water treatment system. An operator can usually monitor any aspect of the treatment system such as levels of chemical tanks and water reservoirs or operation of pumps. SCADA systems generally alert an operator when a component in the system fails. The operator can generally access the SCADA system via a computer to see why an alarm was generated.

SPADNS method

The SPADNS (Sodium 2-(parasulfophenylazo)1,8-dihydroxy-3,6-naphthalene disulfonate or other synonyms) method is a colourimetric method for determining fluoride concentration in water. Fluoride ions react with the zirconium-SPADNS dye lake resulting in a loss of colour. The residual colour of the dye is then measured at 570 nm in a spectrophotometer. The concentration of the fluoride ion is inversely proportional to the intensity of the colour. This method is suitable for fluoride ion analysis in on-site laboratories.

Slope

The slope is the gradient of the ISE calibration curve (see definition for calibration standard above). It is a constant and describes how the response from the analytical equipment changes in response to changes in fluoride concentration under the conditions in which the calibration curve is constructed.

Note: the slope is temperature dependent. Most ISE instruments measure the slope automatically as part of the instrument calibration.

Water Supplier

The entity that operates the fluoride dosing facility that adds fluoride to the water supply.

Water Supply Regulation

The state government agency in the Department of Regional Development, Manufacturing and Water that administers the *Water Supply (Safety and Reliability) Act 2008*.

Water Fluoridation Act

Water Fluoridation Act means the Queensland *Water Fluoridation Act 2008*.

Water Fluoridation Regulation

Water Fluoridation Regulation means the Queensland Water Fluoridation Regulation 2020.

10 References

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11 Public Health Unit contact details

Note that an up-to-date list of contact details for Public Health Units is maintained at:

www.health.qld.gov.au/system-governance/contact-us/contact/public-health-units

12 Appendices

12.1 Appendix 1 – Guidance on quality of the prescribed forms of fluoride

Water suppliers are required to ensure that the forms of fluoride used in water fluoridation are of an appropriate quality to ensure public health is not jeopardised and to minimise workplace health and safety risks and operational issues which could contribute to periods of non-operation.

Fluoride compounds

For the purpose of determining impurity specifications for fluoride compounds, it is appropriate to think of fluoride as a water treatment chemical and adopt the methodology for water treatment chemicals detailed in section 8.8 of the ADWG. In essence this methodology requires that when a certain water treatment chemical is dosed, the concentration of any impurities in the treated water, as a result of that dosing, should not exceed 1/10th of the relevant ADWG guideline value.

Maximum Impurity Content values (MICs) have been calculated and are provided in Table 1. Water suppliers must compare the results detailed in the 'batch analysis certificate' or 'certificate of analysis' accompanying a delivery of fluoride compound with the specifications detailed below in Table 1 to determine if the fluoride compound is of an appropriate quality. It is important to note that these are maximum allowable levels, and in practice the concentration of residues is much lower than these values. Water suppliers are encouraged to adopt more stringent impurity limits where these can be achieved cost-effectively.

Table 1

Impurity	Sodium Fluorosilicate	Sodium Fluoride	Fluorosilicic Acid
	MIC mg/kg[1,2]	MIC mg/kg[1,2]	MIC mg/kg[1,2]
Antimony	180	130	47
Arsenic	590	440	160
Barium	20,000	30,000	32,000
Beryllium	3,600	2,600	950
Cadmium	120	88	32
Total Chromium[3]	3,000	2,200	790
Copper	20,000	30,000	32,000
Lead	590	440	160
Mercury	59	44	16
Nickel	1,200	880	320

Impurity	Sodium Fluorosilicate	Sodium Fluoride	Fluorosilicic Acid
	MIC mg/kg[1,2]	MIC mg/kg[1,2]	MIC mg/kg[1,2]
Selenium	590	440	160
Uranium	1,000	750	270

Table notes

1. Assuming fluoride ion dose rate of 1 mg/L.
2. The MIC data are derived assuming 97% purity for Sodium Fluoride, 98% for Sodium Fluorosilicate, and 20% for fluorosilicic acid. If the fluoridating compound contained impurities at the levels shown here, the contribution of the impurity to the water supply after dosing (at 1 mg/L fluoride) would be 10 times lower than the ADWG drinking water guideline. For example, if a batch of sodium fluoride powder contained 440mg/kg of lead (Pb), the contribution to the water supply after dosing at a level of 1 mg/L fluoride, would be 0.001 mg/L. Note that the ADWG guideline value for Pb in drinking water is 10 times higher than this value i.e. 0.01 mg/L.
3. Relates to Total Chromium. It is recommended that a "total" chromium determination in the fluoridating compounds is initially performed and if the concentration equals or exceeds the MIC value, Cr(VI) analysis should then be conducted.

Further to these MICs, batches of fluoride compound should also comply with the specifications in Table 2.

Table 2

Fluoride compound	Minimum Purity (%)	Moisture %w/w	Insoluble Matter %w/w	Maximum free acid content (%)
Sodium Fluorosilicate	98	0.5	0.5	N/A
Sodium Fluoride	97	0.5	0.6	N/A
Fluorosilicic Acid	20-30	N/A	N/A	1 (expressed as HF)

Naturally occurring fluoride

The ADWG should be used as a guide to determine the quality of the water source containing naturally occurring fluoride. The water source should be sampled to verify its quality and suitability for blending. The blending of a naturally occurring fluoride source should not result in aesthetic or health guideline values in the ADWG being exceeded

Workplace Health and Safety and Operational Concerns

In addition to addressing public health concerns, it is also important to ensure that the fluoride compound used is of suitable physical quality such that it is not likely to create additional workplace health and safety issues and/or operational issues that could lead to unnecessary periods of non-operation.

Therefore, dry fluoride compounds should be free flowing and free of lumps or debris that could interfere with efficient feeding, dosing or other handling equipment.

Industry standards, such as the relevant American Water Works Association (AWWA) standards, provide useful guidance in these respects. It is therefore highly recommended that water suppliers obtain a copy of the relevant standard for their reference.

Fluoride compound	Relevant standard
Sodium Fluorosilicate	ANSI/AWWA B701-18
Sodium Fluoride	ANSI/AWWA B702-18
Fluorosilicic Acid	ANSI/AWWA B703-19

12.2 Appendix 2 - Approved forms

The following forms are approved under the Water Fluoridation Regulation 2020 (the Regulation).

- Form 1 – Fluoridation notice. This form must be used to notify the Chief Executive of the Department of Health that a water supplier intends to add, or cease to add, fluoride to a public potable water supply from a stated date. This notice must be submitted at least 30 days prior to the stated date. This fluoridation notice must also be published at least once in a newspaper circulating in the area of the state serviced by the water supply.
- Form 2 – Notice of non-operation. This form must be used to notify the Chief Executive if a fluoride dosing facility is continuously non-operational for a period of 14 days. This form must be submitted to the Chief Executive within 1 business day after the end of the 14-day period.
- Form 3 – Notice of resumed operation. This form must be used to notify the Chief Executive when operation of fluoride dosing equipment resumes after a notifiable period of non-operation. This form must be submitted to the Chief executive within five business days of operation resuming.
- Form 4 A, B, C & D – Recording requirements. These forms must be used to ensure that the recording requirements of the Regulation are met. If these forms are filled in correctly, the requirements of section 22 of the Regulation will be fulfilled. Only one form, either A, B, C or D needs to be used depending on the fluoridation system being used at the treatment plant.
  - Form A is for dry feeder systems.
  - Form B is for acid feed systems.
  - Form C is for batch solution feed systems.
  - Form D is for saturator systems.
- Form 5 – Quarterly reporting form. This form must be used when submitting the quarterly reports as required under section 23 of the Water Fluoridation Regulation. The completed form must be submitted to the Department of Health within 30 business days of the completed quarter.

A copy of all approved forms can be found at www.health.qld.gov.au/public-health/industry-environment/environment-land-water/water/fluoridation.

12.3 Appendix 3 - Actions in event of overdosing

If fluoride concentration in treated water is:	Perform the following Actions:
> 1.5 mg/L	1. Manually shut down fluoridation facility immediately, if not already done so. 2. Immediately notify your supervisor 3. Immediately notify Water Supply Regulation within the Department of Regional Development, Manufacturing and Water by phoning 1300 596 709. 4. Immediately implement your Emergency Response Plan. This Plan should include, at a minimum, the following actions: i. Allow the water treatment plant to run without the fluoridation facility operating to dilute the water in the treated water reservoir (unless there are connections to the main before a service reservoir in which case immediately notify affected residents and provide alternative drinking water supplies) ii. Sample within the reticulation system to determine the extent of the overdosing event. iii. Work with the relevant Public Health Unit(s) to ensure public health is not jeopardised. Complete and submit the relevant incident notification form to Water Supply Regulation as soon as reasonably practicable. See: www.dnrme.qld.gov.au/__data/assets/pdf_file/0010/45595/wsr017-noncompliance.pdf iv. Determine the reason for the overdose and implement appropriate corrective actions to ensure overdosing doesn't happen again. 5. Once the problem has been rectified, restart the fluoride plant. 6. Closely monitor treated water. 7. The overdosing incident must be recorded on the relevant fluoridated water quarterly report – "Number of samples exceeding 1.5 mg fluoride/L" (See Appendix 2 – Form 5).

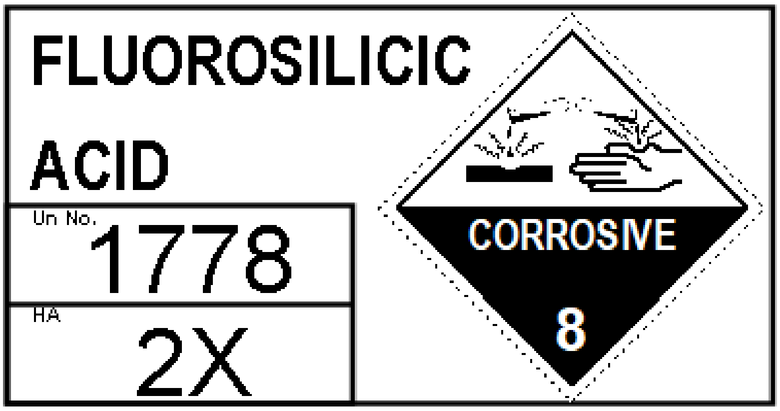
12.4 Appendix 4 - Information placards

Placards provide visual warning of the hazards associated with hazardous chemicals present at the premises and are a requirement under the Work Health and Safety Act 2011. The form and dimensions of the placards are specified in Schedule 13 of the Work Health and Safety Regulation 2011. Premises storing hazardous chemicals must display an Outer Warning Placard at all entrances to the facility as shown below.

In addition to the outer warning placard for the facility, placards are required at each individual chemical storage area.

Placards for hazardous chemicals in tanks

Placards for the storage of hazardous chemicals in tanks are essentially the same as the full-size Emergency Information Panels (EIP) required by the Australian Code for the Transport of Dangerous Goods by Road & Rail (ADG Code) for bulk transport but without the bottom row showing emergency contact details, as shown below.



Example of a placard for a storage tank for Fluorosilicic acid.

The example above displays the form identifying the Proper Shipping Name, the dangerous goods class, the UN number and the Hazchem code. This information is taken from the ADG Code. The placard for the bulk storage of hazardous chemicals must be located on, or adjacent to, each tank or vessel.

Placards for hazardous chemicals in packages

Storage and handling areas for packages containing fluoride compounds must be placarded with the class label ('diamond') if the quantity in the area exceeds the quantity specified below:

For Sodium fluoride or Sodium fluorosilicate in packages such as 25 kg bags where the aggregate amount exceeds 1000 kg, the following class label is required:

For fluorosilicic acid in packages such as drums where aggregate amount exceeds 250L, the following class label is required:

A placard is also required in the area where the fluoride compound is stored. The placard must be displayed at the main point of entry to the building where the store is located, and either at every point of entry to the storage room or enclosure or adjacent to the fluoride compound.

For further information refer to Work Health and Safety Regulation 2011, Schedule 13.

12.5 Appendix 5 - Calculations for fluoridation facilities

This appendix contains a number of calculations intended to assist in the design and operation of fluoride dosing systems. Section 1 provides detailed workings for the calculations required to complete the daily record sheets while Section 2 provides the workings for a number of equations which may assist in the design of fluoride dosing systems, developing standard operating procedures, and configuring SCADA systems.

Section 1 - Daily Calculations

Calculate the fluoride ion content in fluoride compounds

Note: All worked examples rounded to 2 significant figures, unless carried forward to further calculations.

The fluoride ion content (F^-) of a fluoride compound, expressed as a percentage, is the molecular weight fraction of the fluoride ion in the dosing chemical (P) multiplied by the purity fraction of the dosing chemical (K) multiplied by 100. K, the purity fraction, is derived by dividing the % purity by 100. For example, if the purity of sodium fluoride in a particular batch is stated as 98%, then K = 0.98. For fluorosilicic acid, the molecular weight fraction of the fluoride ion in the dosing chemical is multiplied by the solution concentration.

Equation 1

$$F^- = P \times K \times 100\%$$

Where:

F^- Is the fluoride ion content in the fluoride compound
P is the proportion of fluoride in the molecular formula of the compound
K is the purity of the chemical as indicated on the batch analysis certificate (powder) or concentration (liquid), expressed as a fraction

The following P values apply:

Sodium Fluoride (NaF)	0.452
Sodium Fluorosilicate (Na_2SiF_6)	0.606
Fluorosilicic Acid (H_2SiF_6)	0.791

K values for the dosing chemicals should conform to the minimum purity percentages in Table 2 of Appendix 1.

Worked example 1 of Equation 1

The batch analysis certificate for sodium fluoride indicates that purity is 98%, so K is 0.98. The fraction of fluoride ion (P) in sodium fluoride is 0.452.

$$F^- \text{ (in NaF)} = P \text{ x } K = 0.452 \text{ x } 0.98 \text{ x } 100\% = 44\%$$

Worked example 2 of Equation 1

Fluorosilicic acid in supplied as a 20% WW solution, so K is 0.20. the fraction of fluoride in fluorosilicic acid (P) is 0.791.

$$F^{-}(H_2SiF_6) = P \text{ x } K \text{ x } 100\% = 0.791 \text{ x } 0.20 \text{ x } 100\% = 16\%$$

Calculate the strength (S) of fluoride compound in solution

The strength of a fluoride compound in a solution (S) is determined by dividing the mass of fluoride compound (m) used to make the solution by the amount of water used to dilute the fluoride compound in a solution tank (Equation 2), expressed as a percentage.

Equation 2

$$S(\%) = \frac{(m \times K)}{V} \times 100$$

Where:

S is the solution strength (%) of the fluoride compound in a solution tank
m is the mass of the fluoride compound added to the solution tank in (kg)
K is the purity of the fluoride compound as indicated on the batch analysis certificate (powder) or concentration (liquid) expressed as a fraction
V Is the volume of water in the solution tank (L)

Worked example of Equation 2

5 kg of sodium fluoride with a purity of 98% (K = 0.98) is dissolved in water and made up to a volume of 250 L in a holding tank.

$$S\ (\%) = \frac{(5\,kg \times 0.98)}{250\,L} \times 100\% = 1.96\%$$

S can also be expressed as 1.96 g/100mL, or 19.6 g/L

Calculate the amount of fluoride ion added to the water supply in one day

Dry feed systems and solution feed systems using fluorosilicic acid:

It is a requirement to record, each day, the amount of fluoride added to the water supply. For dry feed systems, and solution feed systems that use fluorosilicic acid, the amount of fluoride ion added to the water supply can be calculated from the mass of fluoride compound added and the fluoride ion content (Equation 3).

Equation 3

$$m_{F^-} = m \times F^-$$

Where:

m_{F^-} is the amount of fluoride ion added in a day in (kg)
m is the mass of fluoride compound added in a day (kg)
F^- is the fluoride ion content (from Equation 1)

Worked example of Equation 3

5 kg of sodium fluoride with a fluoride ion content of 0.44 is added to the water supply over the course of one day.

$$m_{F^-}\,(kg) = 5kg \times 0.44 = 2.2\ kg$$

Calculate the fluoride ion content for solution feed systems using sodium fluoride or sodium fluorosilicate

For solution feed systems using either sodium fluoride or sodium fluorosilicate, the amount of fluoride ion added to the water supply can be calculated from the volume of the fluoride solution dosed into the water supply, the strength of the solution and the fluoride ion content (Equation 4).

Equation 4

$$m_{F^-} = V_s \times S \times P \times cf$$

Where:

m_{F^-} is the amount of fluoride ion added in a day (kg)
V_s is the volume of fluoride solution added in a day (L)
S is the strength of the fluoride solution (from Equation 2) (% or g/100mL)
P is the proportion of fluoride in the molecular formula of the compound (see P values listed in Equation 1)
cF is the conversion factor for grams to kilograms (0.001kg/g) and grams/100mL to grams/L (1,000mL/L)

Worked example of Equation 4

200 L of a 1.96% (1.96g/100mL) sodium fluoride solution is added to the water supply over the course of one day.

$$m_{F^-}(kg) = 200L \times \frac{1.96g}{100mL} \times\ 0.452\ \times 0.001kg/g \times 1{,}000mL/L =\ 1.8\ kg$$

Calculate the fluoride ion content for saturator systems using sodium fluoride or sodium fluorosilicate

For saturator systems using either sodium fluoride or sodium fluorosilicate, the amount of fluoride ion added to the water supply can be calculated from the volume of fluoride solution dosed into the water supply, the strength of the solution, and the fluoride ion content (Equation 5).

Equation 5

$$m_{F^-} = V_S \times S \times F^- \times cf$$

Where:

m_{F^-} is the amount of fluoride ion added in a day (kg)
V_s is the volume of fluoride solution added in a day (L)
S is the strength of the fluoride solution (% or g/100 mL)
The solubility of sodium fluoride is 4% and the solubility of sodium fluorosilicate is 0.64%.
F^- is the fluoride ion content expressed as a fraction (0.452 for sodium fluoride, 0.606 for sodium fluorosilicate, 0.452 for sodium fluoride)
Cf Is the conversion factor for grams to kilograms (0.001kg/g) and grams/100mL to grams/L (1,000mL/L)

Worked example of Equation 5

10 L of a saturated sodium fluoride solution (4% or 4g/100mL) was added to the water supply over the course of one day.

$$m_{F^-}(kg) = 10L \times \frac{4g}{100mL} \times 0.452 \times 0.001kg/g \times 1{,}000\ mL/L = 0.18\ kg$$

Calculate the fluoride ion concentration in the treated water

It is a requirement to record, each day, the calculated fluoride concentration. For all systems, other than those that blend naturally occurring fluoride into the water supply, the fluoride concentration can be calculated from the volume of treated water, the amount of fluoride ion added, and the concentration of fluoride in the raw water (Equation 6).

Equation 6

$$C_{tw} = \frac{m_{F^-}}{V_t} + C_{rw}$$

Where:

C_{tw} is the fluoride ion concentration in the treated water (mg/L)
m_{F^-} is the amount of fluoride ion added in a day (kg) [from Equation 3 (dry feed and acid systems), Equation 4 (solution feed), or Equation 5 (saturator systems)]
V_t is the volume of treated water produced in a day (ML)
C_{rw} is the fluoride ion concentration in the raw water (mg/L)

Worked example of Equation 6

1.8 kg of fluoride ion was added to 3ML of treated water over the course of one day. The concentration of fluoride in the raw water is 0.1 mg/L.

$$C_{tw}(mg/L) = \frac{1.8kg}{3ML} + 0.1mg/L = 0.7\ mg/L$$

Section 2 - Additional calculations

Calculate the fluoride ion concentration in a solution in units of mg/L

The concentration of fluoride ion in solution, Cs, is expressed in milligrams per litre (mg/L) from the mass of the dosing chemical added for a given K and P, and the volume of the solution, and applying appropriate conversion factors (cf) (Equation 7).

Equation 7

$$C_s = \frac{(m \times K \times P)}{V} \times cf$$

Where:

C_s	is the concentration of the fluoride ion in solution (mg/L)
m	is the mass of dosing chemical added (kg)
K	is the purity of the chemical as indicated on the batch analysis certificate (powder) or concentration (liquid), expressed as a fraction
P	is the proportion of fluoride in the molecular formula of the compound
V	is the volume of water to which the dosing chemical is added (L)
cf	is the conversion factor for kilograms (kg) to milligrams (mg)

Worked example of Equation 7

Using the example from Equation 2, above: 5 kg of sodium fluoride (98% purity) is dissolved into a solution tank with 250 L of water. P for NaF is 0.452.

$$C_s\ (mg/L) = \frac{(5\ kg \times 0.98\ \times 0.452)}{250\ L} \times 10^6\ mg/kg = 8{,}900\ mg/L$$

The concentration can be calculated from solution strength (S) using Equation 8.

Equation 8	$C_s = S \times P \times cf$

Where:

C_s is the concentration of the fluoride ion in solution (mg/L)
S is the solution strength of the dosing chemical in a solution tank (from Equation 2)
P is the proportion of fluoride in the molecular formula of the compound
cf is the conversion factor for grams (g) to milligrams (mg) and millilitres (mL) to litres (L)

Worked example of Equation 8

From the worked example of Equation 2, 5 kg of sodium fluoride (98% purity) is dissolved in a holding tank of with a volume of 250 L.

$$C_s\ (mg/L) = \frac{1.96g}{100mL} \times 0.452 \times 1{,}000 mg/g \text{ x } 1{,}000\ mL/L = 8{,}900\ mg/L$$

Alternatively, the concentration of fluoride ion solution can be calculated using F^- from equation 9.

Equation 9	$C_s = \frac{m \times F^-}{V} \times cf$

Where:

C_s is the concentration of the fluoride ion in solution (mg/L)
m is the mass of the dosing chemical added to the solution tank (kg)
F^- is the fluoride ion content in chemical (from Equation 1)
V is the volume of water to which the dosing chemical is added (L)
cf is the conversion factor for kilograms (kg) to milligrams (mg) and dividing by 100%

Worked example of Equation 9

6 kg of sodium fluorosilicate (of 99% purity) (K=0.99) is added to 1000 L of water. The fraction of fluoride ion in sodium fluorosilicate (P) is 0.606.

$$F^- = P \times K \text{ x } 100 = 0.606 \times 0.99 \times 100 = 60\%$$

$$C_s\ (mg/L) = \frac{6\ kg \times 60\%}{1{,}000\ L} \times 10^6\ mg/kg \times \frac{1}{100\%} = 3{,}600\ mg/L$$

The concentration of fluoride ions in an aqueous solution of fluorosilicic acid can be determined using the specific gravity (s.g.) of the fluorosilicic acid (Equation 10).

Equation 10 $$C_s\ (mg/L) = s.g. \times K \times P \times cf$$

Where:

C_s	is the concentration of the fluoride ion in solution (mg/L)
s.g.	Is the specific gravity of the solution (kg/L)
K	is the purity of the chemical as indicated on the batch analysis certificate(powder) or concentration (liquid), expressed as a fraction
P	is the proportion of fluoride in the molecular formula of the compound
cf	is the conversion factor for kilograms (kg) to milligrams (mg)

Worked example for Equation 10

A 20% W/W solution, the specific gravity (*s.g.*) is 1.1748 at 17.5˚C. The concentration of H_2SiF_6 in a 20% W/W solution is 20 g/100 g (0.2 g/g or 0.2 kg/kg).

$$C_s\ (mg/L) = 1.1748\ \text{kg/L} \times 0.2\ \text{kg/kg} \times 0.791 \times 10^6\text{mg/kg} = 190{,}000\ \text{mg/L (as F}^-\text{)}$$

Calculate the mass of fluoridation chemical needed to make a specific fluoride solution strength

Equation 2 above can be used to calculate the mass of fluoridation chemical needed to be added to make a specific concentration of the pure chemical in solution. Rearranging the equation, the mass of fluoridation chemical (m) in kilograms (kg) can be calculated as follows using Equation 11.

Equation 11 $$m = \frac{S \times V}{K} \times cf$$

Where:

m	is the mass of the dosing chemical to be added to the solution tank (kg)
S	is the solution strength of the dosing chemical in a solution tank (from Equation 2)
V	is the volume of water in the solution tank (L)
K	is the purity of the chemical as indicated on the batch analysis certificate (powder) or concentration (liquid) expressed as a fraction
cf	is the conversion factor for litres (L) to millilitres (mL) and kilograms (kg) to grams (g)

Worked example of Equation 11

A 4% solution (therefore *S* = 4 g/100 mL) of sodium fluoride (NaF) is required in a tank containing 200 L of water (*V* = 200). According to the certificate of analysis, the purity of the NaF is 97% (*K* = 0.97).

$$m(kg) = \frac{4\ \text{g}}{100\ \text{mL}} \times \frac{200\ \text{L}}{0.97} \times 1{,}000\ \ \text{mL/L x } 0.001\ \text{kg/g} = 8.2\ \text{kg}$$

That is, 8.2 kg of the fluoridating chemical NaF needs to be added to the holding tank containing 200 L of water to make a pure 4% solution of NaF.

Calculate the fluoride concentration from the chemical usage for dry feed systems

If the quantity of fluoridation chemical being used (i.e. kilograms of chemical used over a defined period) is known and the volume V_t of water treated is known, the theoretical fluoride concentration (in mg/L) in the final treated water can be calculated using Equation 12 provided the concentration of fluoride in the raw water C_{rw} (in mg/L) is also known:

Equation 12

$$C_{tw} = C_{rw} + \left(\frac{m_t \times K \times P}{V_t} \times cf\right)$$

Where:

C_{tw} is the concentration of the fluoride ion in treated water (mg/L)

C_{rw} is the concentration of naturally occurring fluoride ions in the untreated (raw) water (mg/L)

m_t is the mass of the dosing chemical added to treated water (in (kg))

K is the purity of the chemical as indicated on the batch analysis certificate(powder) or concentration (liquid) expressed as a fraction

P is the proportion of fluoride in the molecular formula of the compound

V_t is the volume of treated water (in L)

cf is the conversion factor for kilograms (kg) to milligrams (mg)

Worked example of Equation 12

A dry feeder uses 2 kg of NaF (m = 2 kg) in one day to fluoridate 1 ML (Vt = 1,000,000 L) of water. The purity of the NaF is 98% (K = 0.98) and the P value for NaF is 0.452. The natural fluoride concentration C_{rw} in the raw water was found to be 0.1 mg/L.

$$C_{tw}\ (mg/L) = 0.1\ \text{mg/L} + \left(\frac{2\ \text{kg} \times 0.98 \times 0.452}{1{,}000{,}000\ L} \times 10^6\ \text{mg/kg}\right) = 0.99\ \text{mg/L (as F}^-)$$

Calculate the fluoride concentration from the chemical usage for solution feed systems

In a solution feed system where powdered NaF or Na_2SiF_6 or bulk fluorosilicic acid has been dissolved in a holding tank, the fluoridation chemical is added to the unfluoridated water stream from the dosing tank at a steady rate. The fluoride concentration of the treated water can be calculated from the volume of solution that was used from the dosing tank (V_b) and the volume of water that was dosed i.e. treated water produced in that period (V_t) (Equation 13).

Equation 13

$$C_{tw} = C_{rw} + \left(\frac{S \times P \times V_b}{V_t} \times cf\right)$$

Where:

- C_{tw} is the concentration of the fluoride ion in treated water (mg/L)
- C_{rw} is the concentration of naturally occurring fluoride ions in the untreated (raw) water (mg/L)
- S is the solution strength of the dosing chemical in a solution tank (from Equation 2)
- P is the proportion of fluoride in the molecular formula of the compound
- V_b is the volume of solution used from the dosing tank (L)
- V_t is the volume of treated water (L)
- cf is the conversion factor for millilitres (mL) to litres (L) and grams (g) to milligrams (mg)

Worked example of Equation 13

250 L of a 2% NaF solution was prepared (therefore S = 2 g/100 mL and P = 0.452). During a particular day, 1.5 ML of water was dosed (i.e. V_t = 1,500,000 L) and at the start of the day, the NaF holding tank was at a capacity of 250 L; at the end of the run, the volume of NaF solution remaining in the tank was measured to be 115 L. Therefore, V_b = 250 – 115 = 135 L. The natural fluoride content in the water (C_{rw}) was found to be 0.08 mg/L.

$$C_{tw}\ (mg/L) = 0.08\ \text{mg/L} + \left(\frac{2\ \text{g}}{100\ \text{mL}} \times \frac{0.452 \times 135\ \text{L}}{1{,}500{,}000\ \text{L}} \times 1{,}000\ \text{mL/L} \times 1{,}000\ \text{mg/g}\right) = 0.90\ \text{mg/L (as F}^-\text{)}$$

Calculate the fluoride concentration in treated water using flow rates for dry feed systems

In a dry feed system, powdered fluoridation chemical (NaF or Na_2SiF_6) is steadily added at a known rate in kilograms per hour (kg/h) to the water supply which is flowing at a known flow rate in litres per second (L/s). The concentration of fluoride ions in the treated water (C_{tw}) can be calculated from the delivery rate of the dry feed (R_g) and the flow rate of the water being dosed (R_p) (Equation 14).

Equation 14 $$C_{tw} = C_{rw} + \left(\frac{R_g \times P \times K}{R_p} \times cf\right)$$

Where:

C_{tw} is the concentration of the fluoride ion in treated water (mg/L)
C_{rw} is the concentration of naturally occurring fluoride ions in the untreated (raw) water (mg/L)
R_g is the delivery rate of the dry feed fluoride system (in kg/h)
P is the proportion of fluoride in the molecular formula of the compound
K is the purity of the chemical as indicated on the batch analysis certificate (powder) or concentration (liquid) expressed as a fraction
R_p is the flow rate of the water being dosed in the plant (in L/s)
cf is the conversion factor for kilograms (kg) to milligrams (mg) and for seconds (s) to hours (h)

Worked example of Equation 14

A fluoride dosing facility is using sodium fluorosilicate (Na_2SiF_6) dry powder (i.e. P = 0.606) to fluoridate the water supply. The analysis certificate indicated that the product was 99% pure (i.e. K = 0.99). The powder is added to the plant water stream at a delivery rate of 0.05 kg/h (R_g = 0.05) and the treated water is flowing at a rate of 15 L/s (R_p = 15 L/s). The natural fluoride content in the water (C_{rw}) was found to be 0.15 mg/L

$$C_{tw}\ (mg/L) = 0.15\ \text{mg/L} + \left(\frac{0.05\ \text{kg/h} \times 0.606 \times 0.99}{15\ \text{L/s}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times 10^6\ \text{mg/kg}\right) = 0.71\ \text{mg/L (as F}^-\text{)}$$

Calculate the fluoride concentration in treated water using flow rates for solution feed systems

The concentration of fluoride ion in the final treated water where a solution feed system is being used to dose the water supply can be calculated using the flow rate of the fluoride dosing pump, R_d in mL/min (millilitres per minute), the flow rate of the water supply being dosed, R_p in L/s (litres per second), the concentration of fluoride ion in the holding tank C_s (Equation 7) and the concentration of fluoride ion in the unfluoridated water being treated (C_{rw}) (Equation 15).

Equation 15 $$C_{tw} = C_{rw} + \left(\frac{R_d \times C_s}{R_p} \times cf\right)$$

Where:

C_{tw} is the concentration of the fluoride ion in treated water (mg/L)
C_{rw} is the concentration of naturally occurring fluoride ions in the untreated (raw) water (mg/L)
C_s is the concentration of fluoride ion in the holding tank (mg/L)
R_d is the flow rate of the dosing pump (mL/min)
R_p is the flow rate of the water being dosed in the plant (L/s)
cf is the conversion factor for litres (L) to millilitres (mL) and for seconds (s) to minutes (min)

Worked example of Equation 15

A solution of sodium fluoride is pumped from a dosing tank at a rate of 50 mL/min (R_d = 50). The strength of the NaF solution is 2% (2 g/100 mL) so that the concentration of fluoride ion in the holding tank (C_s) is 9060 mg/L (Equation 7). The water to be fluoridated in the plant is flowing at a rate of 10 L/sec (R_p = 10 L/s). The concentration of fluoride in the untreated water was 0.1 mg/L (C_{rw} = 0.1)

$$C_{tw}\ (mg/L) = 0.1\ \text{mg/L} + \left(\frac{50\ \text{mL/min} \times 9060\ \text{mg/L}}{10\ \text{L/s}} \times \frac{1\ \text{min}}{60\ \text{s}} \times \frac{1\ \text{L}}{1{,}000\ \text{mL}}\right) = 0.86\ \text{mg/L}\ (\text{F}^-)$$

Calculate the fluoride concentration from blending with waters containing elevated levels of fluoride

Fluoridation of a water supply may also be carried out by blending a water source containing elevated levels of naturally occurring fluoride with a water supply that contains much less fluoride (the raw water) (Equation 16). It is important to know in advance the concentration of fluoride in both the water source with the elevated level of fluoride (C_n) and the raw water (C_{rw}), and how these concentrations vary. In the blending process, the water supplier will often have the flow rate of the raw water supply fixed at a constant value (R_p) and will adjust the flow rate of the water source containing the elevated level of fluoride (R_n) to achieve the target fluoride concentration in the treated water (C_p).

Equation 16

$$R_n = R_p \times \frac{(C_p - C_{rw})}{(C_n - C_p)}$$

Where:

R_n is the flow rate of the water containing elevated levels of naturally occurring fluoride (L/s)

R_p is the flow rate of the raw water supply with low levels of fluoride (L/s)

C_p is the prescribed fluoride concentration in the treated (blended) water (mg/L)

C_{rw} is the concentration of fluoride in the raw water low in fluoride (mg/L)

C_n is the concentration of fluoride in the water containing elevated levels of naturally occurring fluoride (mg/L)

Worked example of Equation 16

A fluoridation plant will be blending bore water with elevated levels of fluoride with a local dam supply which is low in fluoride. The concentration of fluoride in the bore water (C_n) is 3.7 mg/L and the concentration in the dam water (C_{rw}) is 0.1 mg/L. The flow rate of the dam water (R_p) is usually set at 100 L/s and the desired target fluoride concentration (C_p) in the blended water is 0.7 mg/L.

$$R_n(L/s) = 100\ \text{L/s} \times \frac{(0.7 - 0.1)\ \text{mg/L}}{(3.7 - 0.7)\ \text{mg/L}} = 20\ \text{L/s}$$

The flow rate of the bore water (R_n) should be set at 20 L/s to achieve the desired 0.7 mg/L target fluoride concentration in the blended water.

Where the flow rate of the raw water supply varies, the same principle applies, but the value of Rn needs to be calculated for each value of R_p.

Equation 16 can be expressed alternatively as mass balance equation 16a:

Equation 16a $$(C_{rw} \times R_p) + (C_n \times R_n) = C_p \times (R_p + R_n)$$

Worked example of Equation 16a

Using the figures for the worked example of Equation 16 gives:

$$(0.1mg/L \times 100L/s) + (3.7 \times R_n) = 0.7mg/L \times (100L/s + R_n)$$

This gives:	$10 + 3.7R_n = 70 + 0.7R_n$
Subtracting 10 from both sides of the equation gives:	$3.7R_n = 60 + 0.7R_n$
Subtracting $0.7R_n$ from both sides of the equation gives:	$3.0R_n = 60$
Dividing both sides of the equation by 3 gives:	$R_n = 20\text{L/s}$

Calculate the mass of fluoride used in one day (kg)

The mass of naturally occurring fluoride sourced from water with the elevated level of fluoride in one 24-hour period, m_n (Equation 17).

Equation 17 : $$m_n = \frac{C_n \times R_n \times 86{,}400\ \text{s}}{10^6\ \text{mg/kg}} = (0.0864 \times C_n \times R_n)\ \text{kg}$$

Where:

R_n is the flow rate of the water containing elevated levels of naturally occurring fluoride (L/s)
C_n is the concentration of fluoride in the water containing elevated levels of naturally occurring fluoride (mg/L)
m_n is the mass of fluoride added per day from the water containing elevated levels of naturally occurring fluoride (kg)

Equation 18 can be used to calculate the mass of fluoride in the raw water containing low levels of fluoride, m_{rw}.

Equation 18: $$m_{rw} = \frac{C_{rw} \times R_p \times 86{,}400\ \text{s}}{10^6\ \text{mg/kg}} = (0.0864 \times C_{rw} \times R_{rw})\ \text{kg}$$

Where:

R_p is the flow rate of the raw water supply with low fluoride concentration (L/s)
C_{rw} is the concentration of fluoride in the raw water with low concentration (mg/L)
m_{rw} is the mass of fluoride added per day from the raw water source (kg)

Equation 19 can be used to calculate the total mass of fluoride in the blended water m_T is the sum of m_n and m_{rw}.

Equation 19: $$m_T = m_n + m_{rw}$$

$m_T = (0.0864 \times C_n \times R_n) + (0.0864 \times C_{rw} \times R_{rw})$
$m_T = 0.0864[(C_n \times R_n) + (C_{rw} \times R_{rw})]$

Where:

m_T is the total calculated mass of fluoride derived from both the water containing elevated levels of naturally occurring fluoride and the raw water low in fluoride levels (kg)
m_n is the mass of fluoride derived per day from the water containing elevated levels of naturally occurring fluoride (kg)
m_{rw} is the mass of fluoride derived per day from the raw water source (kg)

Worked example for Equation 19

Using the worked example given for Equation 16:

$$m_T(kg) = 0.0864[(3.7 \times 20) + (0.1 \times 100)] = 7.26\ kg$$

Calculate the fluoride concentration in the final water (C_{tw})

Equation 20: $$C_{tw} = \frac{(C_n \times R_n) + (C_{rw} \times R_p)}{(R_n + R_p)}$$

Where:

C_{tw} is the prescribed concentration of fluoride in blended water (mg/L)
C_n is the concentration of fluoride in the water containing elevated levels of naturally occurring fluoride (mg/L)
R_n is the flow rate of the water containing elevated levels of naturally occurring fluoride (L/s)
C_{rw} is the concentration of fluoride in the raw water with low concentration (mg/L)
R_p is the flow rate of the raw water supply with low fluoride concentration (L/s)

Worked example for Equation 20

In the worked example for Equation 18, C_p calculates to 0.70 mg/L, providing a check of the calculations.

$$C_{tw}(mg/L) = \frac{(3.7\ \text{mg/L} \times 20\ \text{L/s}) + (0.1\ \text{mg/L} \times 100\ \text{L/s})}{(20\ \text{L/s} + 100\ \text{L/s})} = 0.7\ \text{mg/L (as } F^-)$$

Index of symbols used in equations

Symbol	Description	Units
C_F	Conversion factor	
C_n	Concentration of fluoride in water containing elevated levels of naturally occurring fluoride (for blending)	mg/L
C_p	Prescribed fluoride concentration in the treated (blended) water	mg/L
C_{rw}	Concentration of fluoride in raw water with low concentration (for blending)	mg/L
C_s	Concentration of fluoride ion (F^-) in a prepared solution	mg/L
C_{tw}	Prescribed concentration of fluoride in blended or treated water	mg/L

Symbol	Description	Units
F^-	Fluoride ion concentration in dosing chemical	% or fraction
ĵ	Purity of fluoride chemical as supplied	% or fraction
ʛ	Mass of fluoride chemical	g or kg
$ʛ_{F^-}$	Mass of fluoride ion added in a day	g or kg
ʛ_ɱ	Mass of fluoride derived over time from water containing elevated concentration of naturally occurring fluoride (for blending)	kg
ʛ_ᶆ	Mass of fluoride derived per day from raw water source (for blending)	% or fraction
ʛ_ş	Mass of the dosing chemical added to treated water	mL/min
Ɔ	Proportion of fluoride in a fluoridation chemical	kg/h
P_C	Flow rate of a fluoride dosing pump	L/s
Pḟ	Delivery rate of a dry feed fluoride system	L/s
P_ɱ	Flow rate of a water supply containing elevated concentration of fluoride (for blending)	% or g/100 mL
P_õ	Flow rate of a raw water supply with low concentration of fluoride (for blending)	kg/L or g/mL
Ř	Solution Strength	L
ɿḟ#	Specific Gravity	L
Ữ	Volume	ML
Ữ_æ	Volume of solution used from the dosing tank	ML
Ữ_ɱ	Volume of water containing elevated levels of fluoride blended into the water supply	L
Ữ_ᶆ	Volume of raw water with low concentration of fluoride	L or ML
Ữ_ɩ	Volume of fluoride solution added in a day	g or kg
Ữ_ş	Volume of treated water	g or kg