Assets Planning and Delivery Group
Engineering

# Guideline for Selection of Chlorine Analysers

## Fixed Online Chlorine Analysers

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JULY 2022

# FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

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Overview of Western Australia’s Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

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**Head of Engineering**

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# Guideline for Selection of Chlorine Analysers

## Fixed Online Chlorine Analysers

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# 1 Purpose

The purpose of this Guideline is to ensure that fixed chlorine analysers that monitor water and wastewater quality are appropriately selected for each application.

## 1.2 Scope

Evaluate the differences between chlorine analysers currently on the market and the applications for which they are appropriate.

Appropriate analyser selection will allow for more accurate results, enabling assets to achieve the required water quality. When inappropriate analysers are installed, it contributes to time required to troubleshoot issues, poor quality water, potential to damage public trust, and the additional cost of replacing the analyser with one that is appropriate for the application. By standardising chlorine analyser selection, future considerations should be simpler and provide consistent results.

The information in this Guideline will also be used to identify chlorine analysers that are suitable for inclusion on the SCADA Approved Equipment List #16977329. Only chlorine analysers on the SCADA AEL are to be selected and used, units not on the list must be trialled and added to the list to be used. For any additions or removal from the SCADA AEL, a request is to be submitted via the Approved Equipment List (AEL) Change Request (Operation Technology) form in IT Self Service.

This guideline covers free chlorine, total chlorine and chloramination (monochloramine and ammonia) analysers which may be used in the following applications:

- Within a potable water treatment plant or advanced water recycling plant (eg. measurement of filter inlet free chlorine concentration)
- At the outlet of a potable water treatment plant or advanced water recycling plant
- Within a potable water distribution system
- Measurement of free or total chlorine in a recycled water scheme

## 1.3 Abbreviations

| | |
|---|---|
| DoH | Department of Health |
| GAR | Goldfields and Agricultural Region |
| HOCl | Hypochlorous Acid |
| LRR | Low Risk Reuse |
| OCl- | Hypochlorite Ion |
| ppm | Parts per million |
| SCADA | Supervisory Control and Data Acquisition |

## 1.4 References

Current Technology of Chlorine Analysis for Water and Wastewater
https://stpnq.com/wp-content/uploads/2014/08/Chlorine-Analysis-EN.pdf

Comparison of on-line chlorine analysis methods and instrumentation built on amperometric and colorimetric technologies
*https://www.hach.com/cms-portals/hach_com/cms/documents/pdf/Application-CaseHistory-Whitepaper/ComparisonofOn-lineChlorineAnalysis.pdf*

Guidelines for the Non-potable Uses of Recycled Water in Western Australia
https://ww2.health.wa.gov.au/-/media/Files/Corporate/general-documents/water/Recycling/Guidelines-for-the-Non-potable-Uses-of-Recycled-Water-in-WA.pdf

SCADA Approved Equipment List – Shows approved chlorine analysers. #16977329

**Chlorine Analyser related Generic Work Instructions (GWI)**
E00070 Analyser Chlorinator Maintenance and Calibration *Frequency dependent on WQ* #47411425
C00118 Chlorination/Chloramination System Residual Analyser Calibration 1Weekly #45832200
E00132 Analyser Ammonia Major Maintenance (Chemscan UV-2150S) 52Weekly #83172936
E00133 Analyser Ammonia Major Maintenance (Chemscan UV-2150S) 4Weekly #83174891
C00163 Analyser Ammonia Condition Monitoring (Chemscan UV-2150S) 52Weekly #82084146
E00135 Analyser Ammonia Minor Maintenance (HACH APA6000) 13Weekly #74814286

# 2 Chlorine in Water Treatment

When chlorine or chlorine compounds such as sodium hypochlorite are added to water the process is called water chlorination. Water chlorination is a common disinfection method used in drinking water to kill pathogens which pose a serious risk to public health. Pathogens include bacteria, viruses, protozoa, and other microbes in water. Chlorination is used to prevent the spread of waterborne diseases.

Pathogen reduction is one of the main focuses of water treatment processes. Pathogens are not easily monitored online. Online monitoring of parameters such as chlorine ensures adequate dosing has been implemented to achieve the required pathogen reduction.

Chlorine based disinfectants can take a number of forms; chlorine gas ($Cl_2$), sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine dioxide ($ClO_2$). All are very reactive in water and disinfect in a similar manner with the reactions often completed in less than 1 second, even at temperatures as low as 1°C.

Common reactions involve the dissociation of chlorine to produce hypochlorous acid (HOCl). Hypochlorous acid can then further dissociate (break-up) to hypochlorite ions ($OCl^-$) and hydrogen ions ($H^+$). Both hypochlorous acid and the hypochlorite ion are disinfectants, with HOCl being the stronger and more effective of the two – approximately 100 times more powerful. The effectiveness of HOCl is due to its similarity to water, allowing it to easily pass-through micro-organism cell walls and thus kill or inactivate the organism; $OCl^-$ is less effective as a disinfectant because it cannot pass through cell walls as readily. Dissociation of hypochlorous acid to hypochlorite ion is pH dependent with increasing proportion of hypochlorous acid (the more powerful disinfectant) at lower pH. At a pH of 7.5 the ratio of hypochlorous acid to hypochlorite ion is 50:50. Figure 2-1 below shows the percentage of HOCl and $OCl^-$ ions present given the pH conditions. When pH exceeds 8.5, the effectiveness of disinfection drops off substantially for the same chlorine concentration.

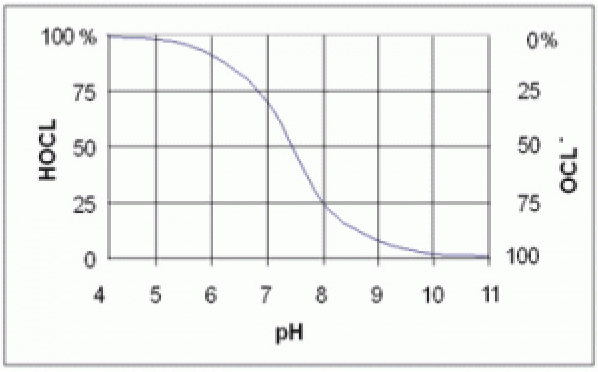


**Figure 2-1: Chlorine Dissociation curve on pH**

## 2.1 Breakpoint Chlorination

Breakpoint chlorination involves a number of different reactions that occur when chlorine is added to water.

The overall process involves 4 stages:

1. The initial chlorine is used up by reaction with dissolved minerals and metals such as manganese and iron.
2. Additional chlorine then reacts with dissolved organic materials and ammonia (from plants and animals – including micro-organisms) to form chloramines.
3. Adding more chlorine destroys most of the chloramines.
4. ‘Breakpoint’ is reached when any added chlorine becomes ‘free’ chlorine in water as ($HOCl$ and $OCl^-$).

Figure 2-2 below illustrates the stages.

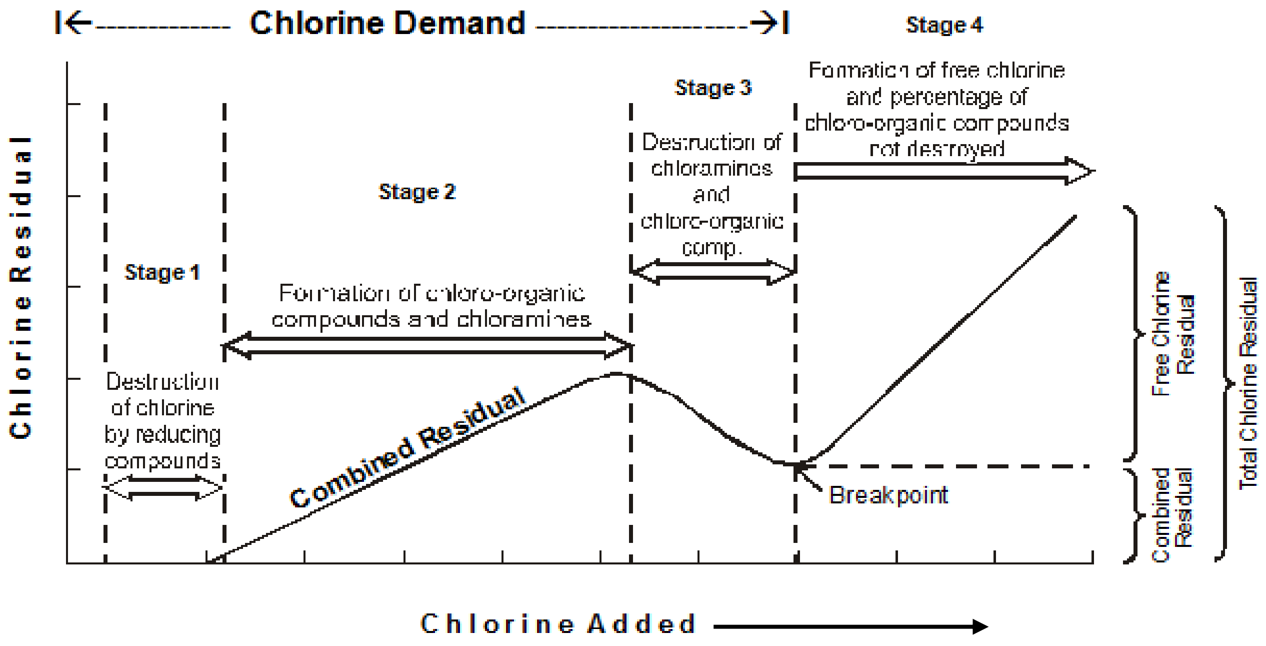


**Figure 2-2: Chlorine demand curve showing the breakpoint chlorination process**

Stages 1 - 3 consume chlorine and are called the chlorine demand. Stages 1 - 3 must be completed before breakpoint chlorination is achieved and a ‘free residual’ chlorine level is present. The breakpoint is where all of the chlorine consuming compounds are completely combined with chlorine and any additional chlorine produces free ‘residual’ chlorine, this occurs at the conclusion of Stage 3. The Water Corporation always aims to operate chlorination systems in either Stage 2 (monochloramine) or Stage 4 (free chlorine).

## 2.2 Chlorine Demand

There are several factors that influence chlorine demand, all of these will affect the dose rate required to satisfy the demand and provide ongoing disinfection.

These factors include:

- The amount of oxidisable material (e.g. ammonia, dissolved metal ions, bacteria, algae, tannins, organic acids, organic suspended solids) in the water. Each of the different forms of oxidisable material will react with any chlorine added however some forms will react rapidly and some slowly. For example, ammonia and Ferrous ($Fe^{2+}$) ions react within seconds while long chain organics may take days to react. This results in most waters having an initial chlorine demand within the first

minute which then gradually increases over hours and days until all of the oxidisable material has been oxidised or all of the dosed chlorine has reacted.
- Events (e.g. rainfall and contamination) that add increased amounts of oxidisable material to the water that has been disinfected and reverse the disinfection process, moving it backwards' along the chlorine demand curve so the breakpoint no longer exists.

All water sources have a chlorine 'demand' associated with it. Typical chlorine demand curves can be developed for different water sources and these are useful in working out how much dosing will be required.

## 2.3 Chlorine Residual

Sampling to measure chlorine residual determines whether or not breakpoint chlorination has been achieved. The different types of residual chlorine measurements post-breakpoint are shown in Figure 2-2.

Free chlorine is the amount of chlorine residual left over after the chlorine demand has been satisfied. Free chlorine residual provides the ongoing protection of the treated water against pathogens, disease, and contamination. Normal free chlorine concentrations in scheme drinking water supplies in Western Australia usually range from 0.5 – 1.5 mg/L.

Combined chlorine is the form of chlorine that is chemically bound to impurities in the water. It can contribute to disinfection but is much less effective than free chlorine. Total chlorine is the sum of free chlorine and combined chlorine after breakpoint is achieved.

## 2.4 Department of Health (DoH) Wastewater Requirements

Following the WA DoH's publication of the *Guidelines for the Non-potable Uses of Recycled Water in Western Australia* in 2011, the Corporation has completed audits of all recycling schemes supplied with treated wastewater by the Corporation. Chlorination is the main disinfectant of choice in wastewater treatment. The current DoH WA guideline recommends a disinfection residual of 0.2 - 2.0mg/L free chlorine. Previously the guideline recommended a disinfection residual of 0.2 - 2mg/L of total chlorine, however this was changed to free chlorine in late 2018. However, this criterion only applies to future wastewater plants, existing plants that have previously agreed to measure and target total chlorine will continue to do so.

The need for continuous online chlorine residual monitoring is determined on a risk basis for each scheme according to DoH risk categories. Low-risk reuse (LRR) schemes represent approximately 95% of water reuse systems in the region, many do not require online monitoring. Appendix 7.2 shows monitoring requirements for different reuse risk levels as defined by DoH.

Historically it has been difficult to get chlorine analysers to work well in LRR schemes and address the continuous online monitoring requirement. The reasons why these schemes are problematic for chlorine monitoring include:
- The high concentration of organic matter and nutrients in the water leads to rapid fouling of the chlorine analyser.
- The water is typically not filtered (unlike medium and high-risk reuse schemes); hence, they tend to have high suspended solids concentration and also lack pH control.

The ongoing issues with chlorine monitoring for LRR schemes has seen a memorandum of understanding between Water Corporation and DoH (#49593061). The memorandum acknowledges the issues with chlorine analyser capabilities and expected monitoring frequency just for LRR. The memorandum states that for LRR schemes it is acceptable to use weekly chlorine residual monitoring in place of daily or continuous chlorine residual monitoring, where the chlorine delivery system complies with the requirements under the guidelines (Refer to Appendix 7.1).

# 3 Chloramination

For the purpose of this Guideline, a brief summary on chloramination is given.

## 3.1 Chloramination Disinfection

Inorganic chloramines are used for chloramination disinfection. Inorganic chloramines are formed when ammonia or some of its compounds are added to water containing chlorine gas (or hypochlorite solution). There are three different types of chloramines which are produced dependent on the ratio of ammonia to chlorine, they are: monochloramine, dichloramine and trichloramine. During chloramination, the intention is to form monochloramine. Monochloramine is the desired product as it is an effective disinfectant, and it produces the least offensive taste of any of the chloramine species.

The main advantage of using chloramines over chlorine for water disinfection purposes is that it stays active in water for longer than chlorine (days vs hours). This is particularly useful in water distribution mains where water will spend an extended period of time between treatment points and customers. A secondary advantage is that higher dose rates can be applied (compared to free chlorine) due to the lower taste threshold and lower tendency to form disinfection by-products. This secondary advantage further aids disinfection in very large distribution systems. The Water Corporation uses chloramination along the Mundaring-Kalgoorlie trunk main (GAR) for this purpose.

## 3.2 Chloramine Formation

Figure 3-1 shows the reaction formation of chloramines. One molecule of monochloramine will form when one molecule of chlorine reacts with one molecule of free available ammonia. However, if too much chlorine is present, all the ammonia molecules are used up and the excess chlorine reacts with monochloramine molecules to form dichloramine. At really high chlorine concentrations dichloramine molecules can be converted to trichloramine (also commonly called nitrogen trichloride).

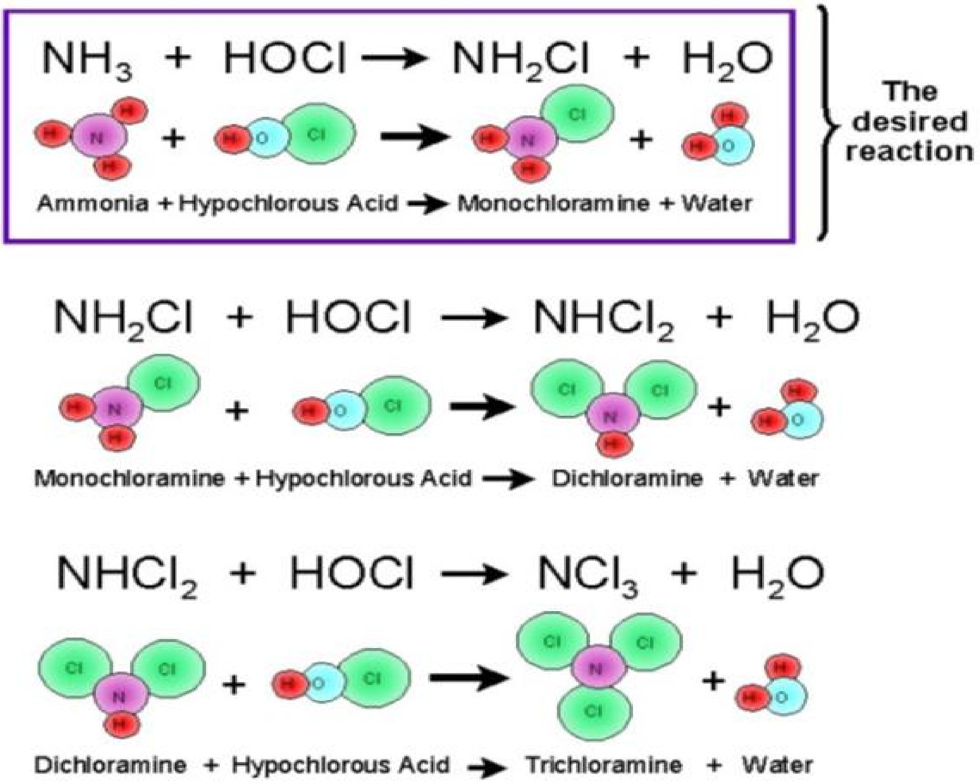


**Figure 3-1: Chloramine Chemical Reactions**

The volatile and unstable trichloramine is not usually formed under treatment conditions used in drinking water facilities but is typically associated with disinfected water used in swimming pools where chlorine reacts with free ammonia from bathing loads.

The equations above show that free chlorine and free available ammonia cannot coexist to any significant degree because they will react with each other. It is also extremely unlikely that free chlorine and monochloramine will exist in the same sample for very long since the free chlorine also reacts with monochloramine.

## 3.3 Chlorine and Ammonia Ratios

As the different compounds of ammonia and chlorine can vary in concentration, a chlorine to ammonia (as nitrogen) ratio of 5:1 weight-to-weight is often quoted as being the peak before breakpoint reactions start to occur. For this reason, it is common for potable water chloramination to be operated near a 4:1 ratio, to avoid potential taste and odour problems associated with dichloramine formation. Figure 3-2 shows this graph shows the amounts of chlorinated and ammoniated species for different chlorine to ammonia ratios.

It should be noted that ammonia can be measured as nitrogen and also as ammonia. For clarity, Water Corporation measures ammonia as nitrogen for all applications.

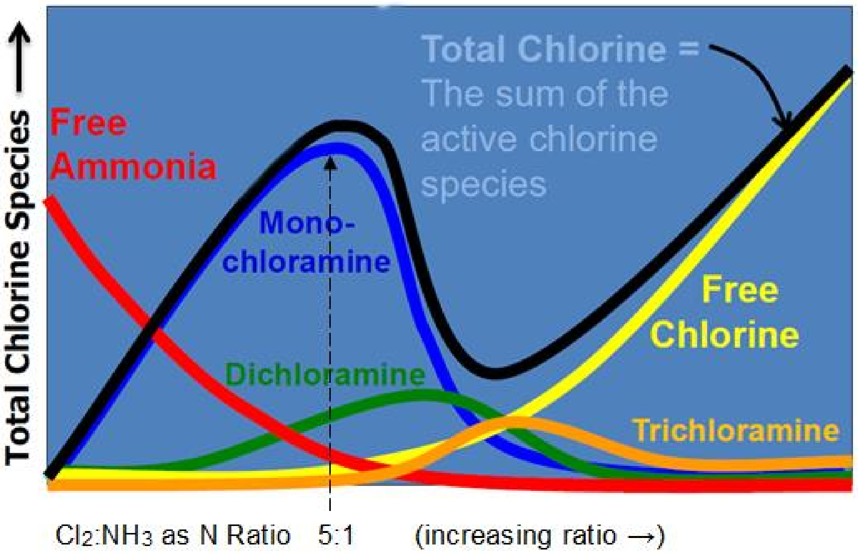


**Figure 3-2: Cl2:NH3-N ratios and chloramine formation**

## 3.4 Monitoring Chloramination

Chloramination analysers can determine where along the breakpoint curve they are operating by monitoring a minimum of 3 out of the 4 parameters. These parameters are:

- Free available chlorine (FAC)
- Total available chlorine (TAC)
- Monochloramine (mono)
- Free available ammonia (FAA).

The ideal operating point is just before the peak of the mono-chloramine curve. This can be monitored based on a 4:1 – 4.5:1 chlorine to ammonia-nitrogen ratio and the presence of a small concentration of free ammonia.

In wastewater systems, where a high level of monochloramine is required to achieve a specified pathogen reduction, the dosing and monitoring of ammonia commonly becomes an additional requirement to ensure the chloramines stay within the monochloramine range. This is regardless of the tendency of waste stabilisation pond system to commonly have sufficient ammonia present in the discharge to create monochloramine. The issue being that you cannot guarantee the discharge ammonia concentration and therefore it must be monitored or supplemented. For these applications, dosing in the free chlorine range may be considered a more cost-effective alternative for smaller systems. Note however that for wastewaters containing significant concentrations of ammonia, the chlorine dose required to achieve breakpoint and provide a free chlorine residual is very high i.e., high demand. In practice it takes 7-10 mg/L of chlorine to oxidise 1mg/L of free ammonia. The pH change that results from such high chlorine dose rates must be considered – a decrease in pH for chlorine gas and an increase in pH for sodium hypochlorite.

## 3.5 Other Chloramination Considerations

A number of conditions can influence chemical reaction rates and the stability of chloramines. These factors need to be considered in the design and operation of chloramination facilities. They include:

- Iron and manganese levels in raw water
- Types of organic matter in raw water
- Water flow rates
- Temperature
- pH

These factors can vary in potable water, making it difficult to accurately calculate doses needed to achieve a specific level of chloramine disinfection.

# 4 Methods of Measurement for Chlorine in Water

There are three types of chlorine measurements:

- Free chlorine (residual chlorine)
- Total chlorine (residual + combined chlorine)
- Chloramination (monochloramine, total Chlorine, total and free ammonia)

Below are the different methods that online analysers use to determine these measurements.

**Amperometric**
Amperometry is a voltametric method in which a constant potential is applied to the electrode and the resulting current measured. The sensor usually consists of a gold cathode (a.k.a. working electrode) and silver chloride electrode which forms the anode. The cathode and anode are located inside a reaction chamber that is filled with an electrolyte. A membrane separates the reaction chamber from the medium to be measured. The membrane is made of a super hydrophobic polyvinylidene fluoride (PVDF) which allows gaseous HOCl molecules to pass through the membrane to diffuse while it repels $OCl^-$ ions due to its negative charge. The membrane behaves similar to the cell membranes of bacteria.

When the sensor is immersed in the medium containing free chlorine, the HOCl molecules diffuse through the sensor membrane and are reduced to chloride ions ($Cl^-$) at the gold cathode in the reaction chamber. The anode silver reacts to form silver chloride, releasing electrons which result in a current that flows through the discharge system, connected to both anode and cathode. This current is proportional to the concentration of free chlorine. The current is processed in the transmitter then displayed as concentration in mg/L.

Amperometric probes can also come with an internal buffer which alters the sample pH in the area adjacent to the probe. By doing so this converts the $OCl^-$ ions to HOCl molecules, which allows the probe to measure both HOCl and converted chlorine (from $OCl^-$). A buffer can increase reliably of readings in a greater pH range.

**Polarographic**

Polarography is a voltametric method and a subset of the Amperometric type sensors. Polarography uses a rotating gold electrode as the indicator electrode and a silver/silver chloride electrode as the counter electrode. When a DC voltage is applied between the indicator and counter electrodes in a sample solution, reactions take place at each electrode surface which causes a current to flow. The chlorine causes a reduction reaction to occur at the indicator electrode which produces a current-voltage characteristic (called a polarogram or plateau characteristic). The chlorine concentration of the sample can be calculated by applying a large voltage in which no chlorine remains unreacted at the electrode surface. The rate of reaction is limited by the rate of supply of chlorine. This is called the diffusion-limited reaction and the remaining flowing current that flows is called the diffusion current.

**Colorimetric & Spectrophotometric (Reagent based)**
Colorimetry is a reagent method that uses light in the visible part of the spectrum. Colorimeters pass a coloured light beam through an optical filter. This optical filter transmits only one particular colour or band of wavelengths of light to the colorimeter's photodetector, where it is measured. A reagent (DPD N,N-diethyl-p-phenylenediamine) is mixed with a water sample whereby it reacts with the free chlorine, resulting in a red-ish colour. The more free chlorine that is available in the sample, the greater the colour intensity. This colour intensity is then measured based on the fact that the red-ish colour absorbs or attenuates light of this specific wavelength. The built in spectrophotometer measures the colour intensity based on the wavelength. For chlorine, the wavelength is fixed (510-530nm), for ammonia this is 640nm.

Spectrophotometers use either a tungsten or xenon flashlamp as the source of white light. The white light passes through an entrance slit and is focused on a ruled grating consisting of 1200 lines/mm. The grating causes the light to be dispersed into its various component wavelengths. The monochromator design allows the user to select which specific wavelength of interest will be passed through the exit slit and into the sample. The use of mirrors and additional filters prevents light of undesired wavelengths (diffraction of higher order, stray light) from reaching the sample. A photodetector measures the amount of light, which passes through the sample. Spectrophotometers may be able to test multiple wavelengths.

Chloraminated water can also be measured by spectrophotometry, with the use of reagents (reagent assisted spectrophotometry). Using light from the UV part of the light spectrum, a UV absorbance curve of the sample is generated across the range of 200 – 450nm. This is compared to baseline reference curves generated from spectral data during calibration and allows for measurement of ammonia, chlorine and monochloramine. This spectrographic technique uses real time advanced pattern recognition and enables the measurement of “true” monochloramine compared to colorimetric techniques.

**Wet Chemistry**
All offline sample tests are completed through wet chemistry, which includes both spectrophotometric and colorimetric methods. This method is not within the scope of this specification.

## 4.1 Units of Measurement

There are two ways to measure chlorine:

- mg/L – milligrams per Litre
- ppm – parts per Million

Chlorine analysers may show the chlorine measurement in either of the two units, both measurement units are directly interchangeable as 1ppm = 1mg/L. The Water Corporation standard units of measurement are mg/L for chlorine concentration in water, whereas chlorine concentration in air (such as using chlorine leak detectors) has units of ppmv.

## 4.2 Corporation Approved Online Chlorine Instruments

The online chlorine analysers currently approved for installation at Water Corporation sites are listed in the SCADA Approved Equipment List. In conjunction with this specification, designers shall also consider the following from the SCADA AEL:

1. The notes contained in the SCADA Approved Equipment List for each instrument.
2. The appropriateness of each instrument for the specific application based on information available from the instrument manufacturers.

Note that some online chlorine analysers listed in the SCADA Approved Equipment List may no longer be available from suppliers and are included in the list for legacy reasons only.

## 4.3 Offline /Hand-held Chlorine Analysers

The portable chlorine analysers currently approved for use at Water Corporation sites are listed in S337 – Field Instruments Approved for the Operational Monitoring of Drinking Water Quality – Nexus Doc #58557081

# 5 Analyser Selection Considerations

Prior to the selection of a fixed chlorine analyser, the application for its use should be evaluated to determine what measurement method would be most suitable. Multiple parameters influence the selection of an analyser. Contaminants which can interfere with analyser readings are discussed below.

## 5.1 Suspended Solids

All chlorine analyser methods suffer from interference due to the presence of some specific compounds. Reagent analysis is known to be sensitive to the presence of certain iron and manganese species in water. The amperometric method is free of this interference, however amperometric sensors are more prone to fouling with the presence of iron and manganese compounds in the sample (as well as in the presence of high turbidity). This will result in increased cleaning and calibration frequency, although the frequency would likely be impractical from an operational perspective. It is recommended to implement a flow cell that reduces high solids loading potential on the electrode or a self-cleaning unit for water quality with high solids loading.

## 5.2 Bubbles

Build-up of air bubbles on the membrane tip can be problematic for amperometric sensors by causing unstable or drifting readings. The following analysers were found to be least problematic for situations where bubbles are present in the sample water:
Free Chlorine

- Yokogawa FC800D
- Prominent CLE probes (with non-standard DG2 de-bubbler flow cell)

Total Chlorine

- HACH CL17sc
- Prominent CTE probes (with non-standard DG2 de-bubbler flow cell)

Alternatively, for amperometric sensors, increased flow rate set point and lowering of probe into the flow cell can prevent air bubbles from adhering or forming on the membrane surface.

## 5.3 pH

Amperometric analysis for both free and total chlorine is heavily affected by pH. The viable range for amperometric analysers is approximately pH 6.5 – 8.5. When approaching the limits of this pH range, a pH sensor installation is recommended to assist with factoring in the sample pH and producing a more accurate result, all amperometric analysers offer an optional pH sensor. There have been previous successful applications in Water Corporation where Prominent total chlorine amperometric analysers have been recalibrated to analyse free chlorine for potable drinking purposes. The free chlorine analysers were nearing the limit of the suitable pH range and measuring less accurately. The total chlorine analyser provided a larger pH measuring range compared to the equivalent free chlorine analysers allowing more leeway for pH to be accurately measured in a larger bound.

For water quality where pH frequently fluctuates, or is beyond or bordering the viable pH range, it is recommended that a reagent method (e.g. colorimetric) is used, as these methods are not affected by pH.

## 5.4 Temperature

The pH of water is directly dependent on temperature, as temperature increases. Like pH, amperometric analysers are affected by large changes in temperature. Many analysers include internal sample temperature compensation or optional sample temperature compensation to produce a more accurate reading. It is recommended for the amperometric method that a temperature sensor is used when there are concerns with temperature variance in the sample water. Temperature has no impact on reagent method analysis.

## 5.5 Reagent Based Measurement

For reagent-based measurement methods, the sample discharge from the analyser will have been contaminated by the reagents. This contamination must be considered when considering the disposal or recycling of the analyser sample discharge. Additional works are required for installation of a reagent analyser. There are additional operational costs for frequent replenishment of reagents (consumables and labour).

# 6 Analyser Selection Guide

The chlorine analyser selection guide has been simplified into a flow chart, **Figure 6** below. This flow chart looks at the main influences for appropriate selection of a chlorine analyser for a specific application.

Refer to Appendix 7.1 for an analyser specification comparison and Appendix 7.2 for manufacturer specification data.

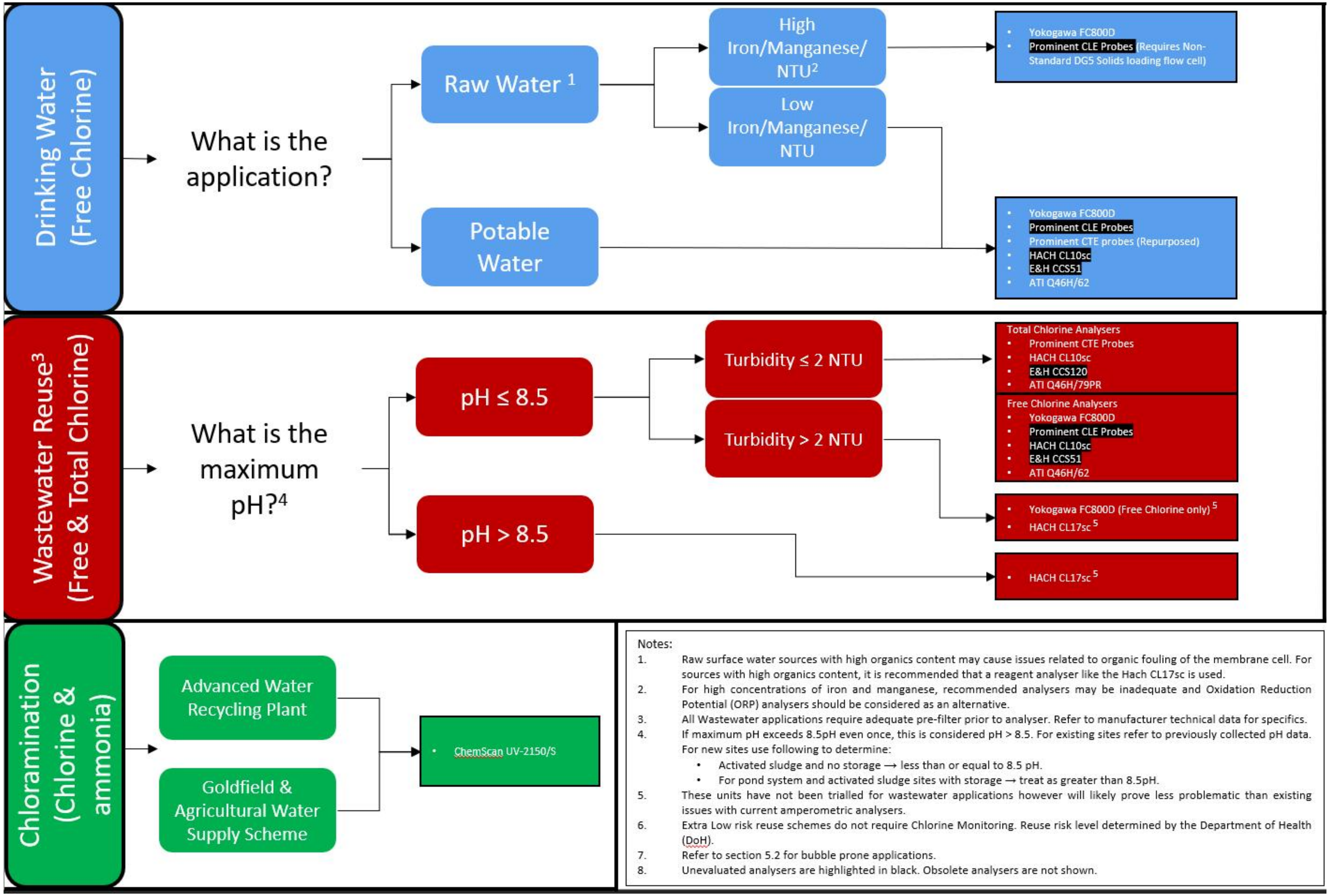
## 6.1 Summary Comparison: Voltametric and Reagent (DPD)

Table 6-1 below is a summary comparison of all different fixed chlorine analyser methods.

**Table 6-1: Chlorine Analyser Methods Comparison**

| | **Reagent-based** | | **Voltametric** |
|---|---|---|---|
| **Measurement Methods** | Colorimetric, spectrophotometric | Spectrophotometric, UV (chloramination unit) | Amperometric, polarographic |
| **Interferences** | Iron and manganese interfere at all concentrations. | Turbidity and organic matter | Dependent on consistent pH, sample temperature, flow and pressure. |
| **Maintenance** | • Replacement of the reagents is generally monthly.<br>• Replacement of tubing generally every 6 months.<br>• Cleaning requirements are dependent on application. | • Replacement of reagents is generally monthly.<br>• Fill zeroing and cleaning solution weekly | • Replacement of membrane and electrolyte required every 3 – 6 months.<br>• Periodic electrode polishing required for polarographic sensors.<br>• Electrode replacement every 6 – 12 months |
| **Calibration** | No calibration required; factory calibrated. | Monthly calibration verification and adjustment | Possibly required up to once per week due to electrode drift. Calibration frequency dependent on application. |
| **Causes of Fouling** | • Air in sample line.<br>• Biological growth in measurement cell.<br>• Sample turbidity >100 NTU. | • Biological growth in measurement cell. | Iron, manganese and high turbidity can increase calibration and maintenance requirements. |
| **Advantages** | • Easier to install and use.<br>• User calibration not required.<br>• Minimal sample conditioning.<br>• Not as affected by changes in pH, chlorine concentration, temperature, pressure or flow.<br>• Predictable maintenance schedule. | • Measures chlorine, chloramines and ammonia<br>• Measures true monochloramine compared to colorimetric<br>• Autozeroing and autocleaning<br>• Not as affected by changes in pH, temperature, pressure or flow.<br>• Predictable maintenance schedule. | • No reagents (some exceptions in certain applications).<br>• Fast (instantaneous) reaction time.<br>• Provides continuous monitoring. |
| **Disadvantages** | • Uses reagents and creates waste.<br>• Higher maintenance costs.<br>• Interferences with iron and manganese species. | • Initial site-specific calibration required to "teach" the system<br>• Uses reagents and creates waste. | • Potential interferences by changes in 5+ variables.<br>• Frequent user calibrations required.<br>• Sensors are prone to fouling. |

| | | | |
|---|---|---|---|
| | • Waste stream discharge considered harmful to the environment or drinking water.<br>• Analysis takes several minutes as a batch operation rather than continuous monitoring. | • Higher maintenance costs.<br>• Waste stream discharge considered harmful to the environment or drinking water.<br>• Not continuous - analysis takes several minutes as a batch operation | • Unpredictable maintenance, high cost of ownership in consumables.<br>• Inaccurate at measuring chlorine near bounds of pH range even with pH and temperature sensor installed. |



Notes:

1. Raw surface water sources with high organics content may cause issues related to organic fouling of the membrane cell. For sources with high organics content, it is recommended that a reagent analyser like the Hach CL17sc is used.
2. For high concentrations of iron and manganese, recommended analysers may be inadequate and Oxidation Reduction Potential (ORP) analysers should be considered as an alternative.
3. All Wastewater applications require adequate pre-filter prior to analyser. Refer to manufacturer technical data for specifics.
4. If maximum pH exceeds 8.5pH even once, this is considered pH > 8.5. For existing sites refer to previously collected pH data. For new sites use following to determine:
    - Activated sludge and no storage ⟶ less than or equal to 8.5 pH.
    - For pond system and activated sludge sites with storage ⟶ treat as greater than 8.5pH.
5. These units have not been trialled for wastewater applications however will likely prove less problematic than existing issues with current amperometric analysers.
6. Extra Low risk reuse schemes do not require Chlorine Monitoring. Reuse risk level determined by the Department of Health (DoH).
7. Refer to section 5.2 for bubble prone applications.
8. Unevaluated analysers are highlighted in black. Obsolete analysers are not shown.

Figure 6-1: Chlorine Analyser Selection Flow Chart

# 7 Appendices

## 7.1 Analyser Specification Comparison

Obsolete and unevaluated equipment is in red text. Note: Unevaluated probes are ones that are not on the SCADA AEL.

| Brand/ Supplier | **ATI (Trility)** | | **Endress & Hauser** | | **HACH*** | | **Prominent**** | | **Yokogawa** | **ChemScan** |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit / Meter | Q46H Series (Analyser & Transmitter) | | CCS140N(Obsolete Probe)<br>CCM253(Analyser & transmitter)<br>CCA151 & CCA250 (Flow Assemblies) | | Compatible Universal Controllers (Transmitters)<br>SC200 – Universal Controller<br>SC1000 – Controller Display Module + Module Probe<br>SC1500 – Controller<br>SC4200c – Controller | | Compatible Universal Controllers (Transmitters)<br>Dulcometer – DMTa<br>Dulcometer – Compact Controller<br>Dulcometer – D1Cb/D1Cc Controller | | Compatible Transmitter FLXA402T – Analyser for Turbidity and Chlorine | UV-2150/S – Chloramination Analyser |
| Probe Model(s) | Q46H/62 – Residual (Potable Water) | Q46H/79 PR – Total (Wastewater Application) | CCS51 – Analog Free Chlorine Probe (Unevaluated) | CCS120 – Analog Total Chlorine Probe (Unevaluated) | CL17sc– Colorimetric Chlorine Analyser | CL10sc– Amperometric (Unevaluated) | CTE 1 Probe – Total Chlorine | CLE 3 Probe – Free Chlorine (Unevaluated) | FC800D – Non-reagent Type Free available Chlorine Sensor Unit | As above |
| Measurement method | Polarographic | Polarographic | Amperometric | Amperometric | Colorimetric | Amperometric | Amperometric | Amperometric | Polarographic | Spectrometric |
| Sensor | Membrane-covered Amperometric (Polarographic) | Membrane-covered Amperometric (Polarographic) | Membrane-covered Amperometric | Membrane-covered Amperometric | LED, measurement at 510 nm, 1 cm light pathlength | electrochemical, three electrode Amperometric system | Diaphragm-covered sensor (encapsulated) | Diaphragm-covered sensor (encapsulated) | Rotating electrode with electrode polishing beads | High Resolution, Ultraviolet Absorbance via Optical Spectrometer |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chlorine Measurement Type | Free Chlorine | Total Chlorine | Free Chlorine | Total Chlorine | Free Chlorine or Total Chlorine (based on reagent used) | Free Chlorine or Total Chlorine by sensor selection | Total Chlorine | Free Chlorine | Free Chlorine | Free Ammonia, Total Ammonia, True Monochloramine, Total Chlorine |
| Measurement Frequency | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | 150 second measurement interval (fixed) | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | Continuous, Online, Automatic monitoring | Batch, On-Line, Automatic Monitoring of one or two Sample Lines 10-minute loop time (adjustable from 3 – 9999 minutes) |
| Reagent Consumption | N/A | N/A | N/A | N/A | 0.5 L of buffer solution and 0.5 L of indicator solution in 31 days | N/A | N/A | N/A | N/A | Yes (multiple) – consumption depends on preset sample interval, measurement range and water quality |
| **Sensor & Flowcell** | | | | | | | | | | |
| Optional pH Sensor | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✗ |
| Digital Communication Options | Profibus DP, Modbus RTU, Modbus TCP/IP, | Profibus DP, Modbus RTU, Modbus TCP/IP, | HART, Profibus PA, Profibus DP | HART, Profibus PA, Profibus DP | Modbus RS232/RS485, Profibus DPV1, or HART 7.2 optional | Modbus RS232/RS485, Profibus DPV1, or HART 7.2 optional | PROFIBUS® DP and CANopen bus | PROFIBUS® DP and CANopen bus | (Modbus RTU or Modbus TCP/IP) | 4-20mA (4 outputs per sample line max.), Modbus RTU, RS-232, others optional |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ethernet IP | ethernet IP | | | | | | | | |
| Materials | PVC & 316SS | PVC & 316SS | PVC, PVDF, Polycarbonate, ABS PC Fr, Polyester, UV-resistant | PVC, PVDF, Polycarbonate, ABS PC Fr, Polyester, UV-resistant | Polycarbonate, Aluminium (powder coated), Stainless Steel | ABS (display module) and metal (probe module) enclosure with corrosion resistant finish | Membrane cap: PPE | Membrane cap: Clear PVC<br>Electrode shaft: Black PP and natural coloured PMMA | Smart unit: PC (poly carbonate) resin<br>Electrode unit: m-PPE resin, SUS316<br>Wetted parts: Pipe: Polyethylene resin, Rigid polyvinyl chloride | Polyurethane Enamel over Polyester Urethane on Steel (Standard) or Type 316 Stainless Steel (Optional) |
| Response time | 90% in 60 seconds | 90% in 60 seconds | 90% in 25 seconds (after polarisation) | 90% in 60 seconds (as concentration rises and falls) | 150 second loop time | Free Chlorine: 140 seconds or less for 90% change (T90) at a stable temperature and pH<br>Total Chlorine: 100 seconds or less for 90% change (T90) at a stable | T90 approx. 60 s (as concentration rises and falls) | T90 approx. 60 s (as concentration rises and falls) | Approx. 2 minutes (90% response) | 10 minutes for the entire four parameter suite |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | temperature and pH | | | | |
| **Sample Temperature Limits** | -5 to 55°C | 0 to 50°C | 0 to 55°C | 5 to 45°C | 5 – 40 °C | 5 – 45 °C | 5 – 45 °C | 5 – 45 °C | 0 to 50°C | 1 – 60°C |
| **Storage Temperature Limits** | - | - | With Electrolyte: 0 to 35°C<br>Without Electrolyte: -20 to 60°C | With Electrolyte: 5 to 50°C<br>Without Electrolyte: -20 to 60°C | 5 – 40 °C<br>0 – 90% relative humidity, non-condensing | Sensor: 0 to 50°C<br>dry, without electrolyte<br>Electrolyte: 15 to 25°C | +5 to +50 °C<br>max. 90 % rel. humidity, below dewpoint | 5 – 50 °C<br>max. 90 % rel. humidity, noncondensing | -30 to 70ºC Humidity; 10 to 90 % RH at 40ºC (No condensation) | Ambient Temperature 5 – 45°C<br>Relative Humidity 0 – 100% (Non-Condensing)<br>For installation in an indoor or sheltered location |
| **Pressure Limit** | 0-50 PSIG (0 – 344 kPa) | 0-50 PSIG (0 – 344 kPa) | Dependant on specific fitting and installation (Refer to Technical Data) | Dependant on specific fitting and installation (Refer to Technical Data) | 0.3 – 5.2 bar (4.5 – 75 psig) supplied to Y-strainer – 0.3 bar (1.5 – 5 psig) supplied to analyzer | 0.5 bar, no pressure impulses and/or vibrations | Max 3.0 bar | Max 1.0 bar | 1 to 150 kPa | Pressurized Sample Lines Std. Regulated to 34-69 Kpa (5-10 psi), |
| **Sensor cable** | 7.5m Standard | 7.5m Standard | Max 3m | Max 15m | 2m | 1 m (between gateways and sc-controller) | Varies from 2m – 10m (Refer to Technical Data) | Varies from 2m – 10m (Refer to Technical Data) | 1m standard | N/A |
| **Sensor flow cell** | Clear Acrylic Constant-head | Clear Acrylic Constant-head | Acrylic glass assembly, houses 1x | Acrylic glass assembly, houses 3x | Plastic Container | Acrylic glass | Acrylic glass | Acrylic glass | Acrylic resin | Polymer Body with Quartz Windows |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | overflow standard sealed acrylic flow cell optional | overflow standard sealed acrylic flow cell optional | emplacement | emplacements | | | | | | |
| Sample Flowrate | 0.5 – 1 l/min | 0.5 – 1 l/min | 0.9 – 4.8 l/min | 0.9 – 3 l/min | 0.06 – 0.2 l/min through the instrument | 0.5 – 0.83 l/min through the instrument | 0.5 – 1.0 l/min | 0.5 – 1.0 l/min | 0.1 to 2.5 L/min | 0.5 to 5.0 l/min. 1.5 L flush per sample |
| **Electronic Monitoring** | | | | | | | | | | |
| Display Range | 0 – 2.000, 0 – 20.00, or 0 – 200.0 PPM | 0 – 2.000, 0 – 20.00, or 0 – 200.0 PPM | 0 – 5, 0 – 20 mg/l | 0.1 – 10 mg/L | 0.03 -10 mg/L $Cl_2$ | 0 -20 ppm | 0.00-0.500/2.00/5.00/10.0/20.0/50.0/100.0 ppm | 0.00-0.500/2.00/5.00/10.0/20.0/50.0/100.0 ppm | Unit: mg/L, ppm, you can input any letters by alphanumeric. Display resolution: 0.000 to 9999 | Free Ammonia 0.02 – 1.00 mg/l as N<br>Total Ammonia 0.02 – 2.00 mg/l as N<br>Monochloramine 0.05 – 5.0 mg/l as Cl2<br>Total Chlorine 0.05 – 5.0 mg/l as Cl2 |
| Accuracy | 0.5% of selected range or 0.02 PPM | ± 0.05 PPM | ±2 % or ±5 µg/l (ppb) of value measured (depending on which value is higher) | ±2 % or ±5 µg/l (ppb) of value measured (depending on which value is higher) | ± 5% or ± 0.04 mg/L (whichever is greater) from 0 – 5 mg/L $Cl_2$ | Refer to Specification Data | 0.5% of the upper measuring range value | 0.5% of the upper measuring range value | - | +/- 0.02 or 2% (whichever is greater) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Power | 90-260 VAC, 50/60 Hz, 10 VA max. ; 12-24 VDC, 500 mA max. | 100-240 VAC ±10%, 50/60 Hz., 10 VA max. 12-24 VDC, 500 mA max. optional | Voltage 10 – 50 V, Max 10mA | Voltage 10 – 50 V, Max 10mA | 100 – 240 V AC, 24 V DC Power, 50/60 Hz | 100 – 240 V AC, 24 V DC Power, 50/60 Hz | 3.3 V DC (5 P) – Probe<br>90…253 V, 50/60 Hz (wide voltage power unit) | Via CAN interface (11 – 30 V) – Probe<br>90…253 V, 50/60 Hz (wide voltage power unit) | AC Power Supply Ratings: 100 to 240 V AC<br>Acceptable range; 90 to 264 V AC<br>Ratings: 50/60 Hz<br>Acceptable range: 50 Hz ± 5 %, 60 Hz ± 5 %<br>Power consumption: 15VA | AC Supply Rating: 240V, 50-60 Hz, 4 Amps maximum |
| Analog Outputs | Two isolated 4-20 mA, 500 Ω load max. (3rd output optional) | Two isolated 4-20 mA, 500 Ω load max | Switching current with ohmic load (cos □ = 1): max. 2 A, Switching current with inductive load (cos = 0.4):max. 2 A, Switching voltage: max. 250 V AC, 30 V DC, Switching power with ohmic load | Switching current with ohmic load (cos φ = 1): max. 2 A Switching current with inductive load (cos φ = 0.4):max. 2 A Switching voltage: max. 250 V AC, 30 V DC Switching power with ohmic load | Two (Five with optional expansion module) isolated current outputs, max 550 Ω. Optional 4 addition 4/20 insolated current outputs, max 550 Ω | Two (Five with optional expansion module) isolated current outputs, max 550 Ω. Optional 4 addition 4/20 insolated current outputs, max 550 Ω | 1 x 0/4-20 mA galvanically isolated<br>max. load 450 Ω<br>Adjustable range and allocation (measured variable, correction variable, controlled variable) | 1 x 0/4-20 mA galvanically isolated<br>max. load 450 Ω<br>Adjustable range and allocation (measured variable, correction variable, controlled variable) | Isolated outputs: 4-20 mA DC<br>Accuracy: ± 0.02 mA<br>Repeatability: ± 0.02 mA<br>Linearity: ± 0.02 mA<br>Maximum load: 600 Ω<br>Number of outputs: select by suffix code<br>2 isolated outputs: -N2<br>4 isolated outputs: -N4 | 4-20mA (4 outputs per sample line max.), |

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | (cos □ = 1): max. 500 VA AC, 60 W DC, Switching power with inductive load (cos = 0.4): max. 500 VA AC, 60 W DC | (cos φ = 1): max. 500 VA AC, 60 W DC Switching power with inductive load (cos φ = 0.4): max. 500 VA AC, 60 W DC |  |  | **Control outputs**<br>2 pulse frequency outputs for metering pump actuation | **Control outputs**<br>2 pulse frequency outputs for metering pump actuation | (Not isolated between analog outputs 1 and 2) |  |
| Relays | Three SPDT, 6A @250 VAC, 5A @24 VDC (3 additional SPST non-isolated, 1A @30 VDC optional) | Three SPDT, 6A @ 250 VAC standard Three additional SPST low voltage relays optional | Four Current-free contact position Relays | Four Current-free contact position Relays | Four electromechanical SPDT (Form C) contacts, 1200 W, 5 A | Four electromechanical SPDT (Form C) contacts, 1200 W, 5 A | 2 relays (limit value or pulse length) | 2 relays (limit value or pulse length) | Contact input; Type; Non-voltage contact output Number; 2 contacts (-N4), 1 contact (-N2) Function; Select among Remote 2range switching, Remote 3range switching, Remote wash start, Remote calibration start, Disable | - |
| Display | 4 digit, 0.75” numeric LCD with 12 character | 4 digit, 0.75” numeric LCD plus 12 digit | LC Display | LC Display | Graphic dot matrix LCD with LED backlighting | Graphic dot matrix LCD with LED backlighting | LC Display | LC Display | QVGA color LCD with a touch screen | 2 x 20 LCD and 4 x 4 Keypad |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | second line, LED back light. | second line | | | | | | | | |
| Enclosure | NEMA 4X (IP-66) Polycarbonate, V-0 flammability | NEMA 4X (IP-66) Polycarbonate | IP-66 – Probe<br>Panel mounted instrument: IP 54 (front), IP 30 (housing)<br>Field instrument: IP 65 / tightness acc. To NEMA 4X | IP-66 – Probe<br>Panel mounted instrument: IP 54 (front), IP 30 (housing)<br>Field instrument: IP 65 / tightness acc. To NEMA 4X | IP-66 – Probe<br>NEMA 4X/IP66 – SC200 | IP-66 – Probe<br>NEMA 4X/IP66 – SC200 | Wall mounting: IP 65<br><br>Control panel version: IP 54 | Wall mounting: IP 65<br><br>Control panel version: IP 54 | Smart unit IP65 NEMA Type4X (USA), CSA Type 4X (Canada) | Upper Enclosure: NEMA 4 (NEMA 4X Optional, 316 SS) Lower Enclosure NEMA 3R(Optional, 316 SS) (shielded spill drain) |
| Weight | 6 lbs (2.7 kg) with sensor, 28lowcell & accessories 15 lbs (6.8 kg) assembled into panel | 6 lbs. (2.7 kg) with sensor, 28lowcell & accessories 15 lbs (6.8 kg) assembled into panel | Panel-mounted instrument: max. 0.7 kg (1.5 lb)<br>Field instrument: max. 2.3 kg (5.1 lb) | Panel-mounted instrument: max. 0.7 kg (1.5 lb)<br>Field instrument: max. 2.3 kg (5.1 lb) | 4.1kg – CL17sc<br>1.7kg – SC200 | Approximately 5.5 kg (panel and empty panel-mounted components only)<br>1.7kg – SC200 | 0.8 kg – D1Cb/D1Cc | 0.8 kg – D1Cb/D1Cc | Approx. 3.0 kg | 59 kg |
| Operating Conditions | 0 to 50°C | 0 to 50°C | -10 to 55 °C,<br>10 to 95%, non-condensing | -10 to 55 °C,<br>10 to 95%, non-condensing | -20 to 60 °C , 0 to 95% RH non-condensing | -20 to 60 °C , 0 to 95% RH non-condensing | -5 – 50 °C | -5 – 50 °C | -20 to 55°C Humidity; 10 to 90 % RH at 40°C (No condensation) | Ambient Temperature 5 – 45°C Relative Humidity 0 – |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 100% (Non-Condensing) |

** For simplicity, SC200 will be used below for as standard specifications. For further detail on other Hach Controllers, refer to Hach's website.*
***For simplicity, Dulcometer – D1Cb/D1Cc system will be used below for as standard specifications. For further detail on other Prominent Controllers, refer to Prominent's website.*

## 7.2 Manufacturer Specification Data

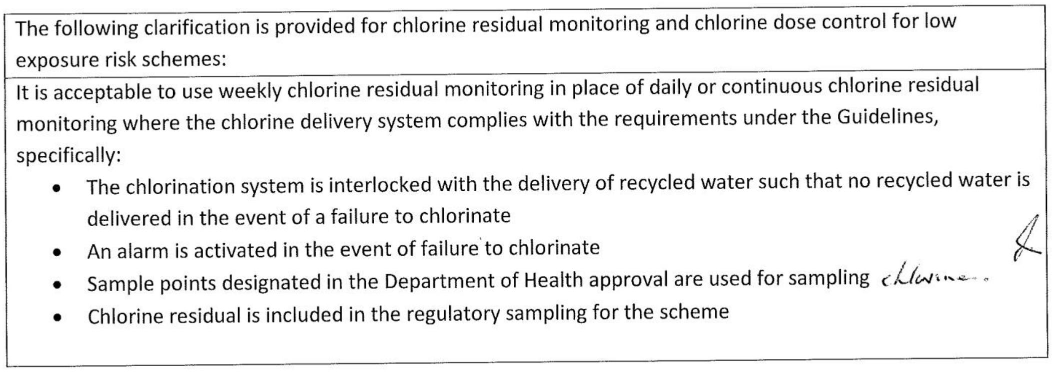
| Brand/ Supplier | ATI (Trility) | | Endress & Hauser | | HACH* | | Prominent** | | Yokogawa | ChemScan |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit / Meter | Q46H Series (Analyser & Transmitter) | | CCS140N(Obsolete Probe)<br>CCM253(Analyser & transmitter)<br><br>CCA151 & CCA250 (Flow Assemblies) | | Compatible Universal Controllers (Transmitters)<br>SC200 – Universal Controller<br>SC1000 – Controller Display Module + Module Probe<br>SC1500 – Controller<br>SC4200c – Controller | | Compatible Universal Controllers (Transmitters)<br>Dulcometer - DMTa<br>Dulcometer – Compact Controller<br>Dulcometer - D1Cb/D1Cc Controller | | Compatible Transmitter FLXA402T – Analyser for Turbidity and Chlorine | UV-2150/S – Chloramination Analyser |
| Probe Model(s) | Q46H/62 – Residual (Potable Water) | Q46H/79PR – Total (Wastewater Application) | CCS51 – Analog Free Chlorine Probe (Unevaluated) | CCS120 – Analog Total Chlorine Probe (Unevaluated) | CL17sc– Colorimetric Chlorine Analyser | CL10sc– Amperometric (Unevaluated) | CTE 1 Probe – Total Chlorine | CLE 3 Probe – Free Chlorine (Unevaluated) | FC800D – Non-reagent Type Free available Chlorine Sensor Unit | As above |
| Probe | Q46H-62-63-Resi<br>al-Chlorine-M | ATI Q46H-79PR<br>Total Chlorine M | E&H CCS51 - Free<br>Chlorine Probe.pd | E&H CCS120 - Total<br>Chlorine Probe.pdf | Hach - CL17sc<br>Colorimetric Chlor | Hach - CL10sc<br>Amperometric Chlor | Prominent - CTE<br>Probe.pdf | Prominent - CLE<br>Probe.pdf | Yokogawa -<br>FC800D&FLXA402T | Chemscan -<br>UV-2150s Ammonia, |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Transmitter/ Analyser | | | **E&H CCM253 - Transmitter & A** | **E&H CCM253 - Transmitter & Analy** | **Hach - SC200 Controller .pdf** | **Hach - SC200 Controller .pd** | **Prominent - Dulcometer Con** | **Prominent - Dulcometer Controll** | | |

** For simplicity, SC200 will be used below for as standard specifications. For further detail on other Hach Controllers, refer to Hach's website.*

***For simplicity, Dulcometer – D1Cb/D1Cc system will be used below for as standard specifications. For further detail on other Prominent Controllers, refer to Prominent's website.*

## 7.1 MoU DoH: Schedule 1 – Chlorination control for low exposure risk schemes

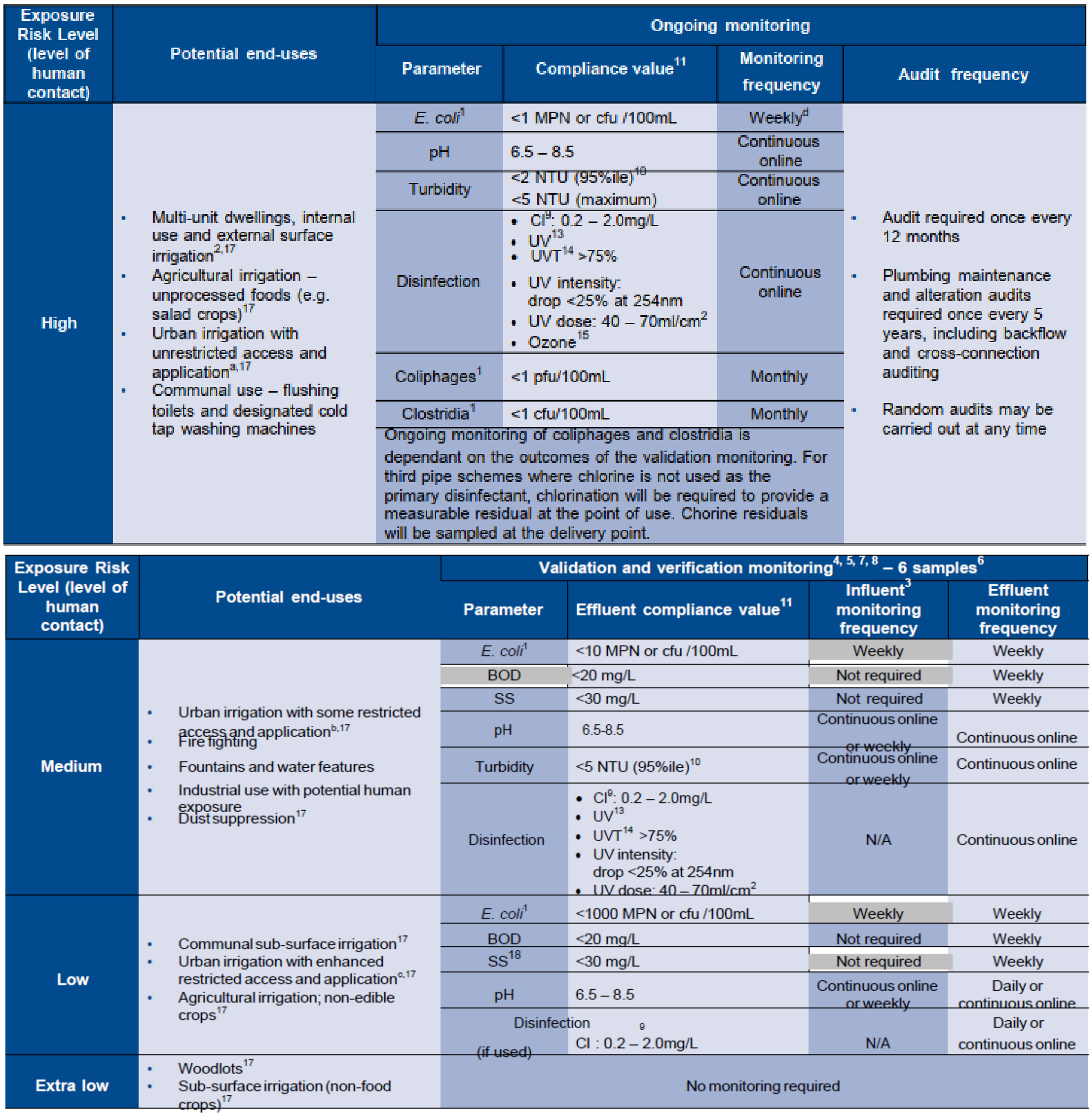


The following clarification is provided for chlorine residual monitoring and chlorine dose control for low exposure risk schemes:

It is acceptable to use weekly chlorine residual monitoring in place of daily or continuous chlorine residual monitoring where the chlorine delivery system complies with the requirements under the Guidelines, specifically:

- The chlorination system is interlocked with the delivery of recycled water such that no recycled water is delivered in the event of a failure to chlorinate &
- An alarm is activated in the event of failure to chlorinate
- Sample points designated in the Department of Health approval are used for sampling chlorine.
- Chlorine residual is included in the regulatory sampling for the scheme

## 7.2 Wastewater Reuse Scheme Risk Levels



| Exposure Risk Level (level of human contact) | Potential end-uses | Ongoing monitoring | | | |
|---|---|---|---|---|---|
| | | Parameter | Compliance value[11] | Monitoring frequency | Audit frequency |
| **High** | • Multi-unit dwellings, internal use and external surface irrigation[2,17]<br>• Agricultural irrigation – unprocessed foods (e.g. salad crops)[17]<br>• Urban irrigation with unrestricted access and application[a,17]<br>• Communal use – flushing toilets and designated cold tap washing machines | *E. coli*[1] | <1 MPN or cfu /100mL | Weekly[d] | • Audit required once every 12 months<br>• Plumbing maintenance and alteration audits required once every 5 years, including backflow and cross-connection auditing<br>• Random audits may be carried out at any time |
| | | pH | 6.5 – 8.5 | Continuous online | |
| | | Turbidity | <2 NTU (95%ile)[10]<br><5 NTU (maximum) | Continuous online | |
| | | Disinfection | • Cl[9]: 0.2 – 2.0mg/L<br>• UV[13]<br>• UVT[14] >75%<br>• UV intensity: drop <25% at 254nm<br>• UV dose: 40 – 70ml/$\text{cm}^2$<br>• Ozone[15] | Continuous online | |
| | | Coliphages[1] | <1 pfu/100mL | Monthly | |
| | | Clostridia[1] | <1 cfu/100mL | Monthly | |
| | | Ongoing monitoring of coliphages and clostridia is dependant on the outcomes of the validation monitoring. For third pipe schemes where chlorine is not used as the primary disinfectant, chlorination will be required to provide a measurable residual at the point of use. Chorine residuals will be sampled at the delivery point. | | | |

| Exposure Risk Level (level of human contact) | Potential end-uses | Validation and verification monitoring[4, 5, 7, 8] – 6 samples[6] | | | |
|---|---|---|---|---|---|
| | | Parameter | Effluent compliance value[11] | Influent[3] monitoring frequency | Effluent monitoring frequency |
| **Medium** | • Urban irrigation with some restricted access and application[b,17]<br>• Fire fighting<br>• Fountains and water features<br>• Industrial use with potential human exposure<br>• Dust suppression[17] | *E. coli*[1] | <10 MPN or cfu /100mL | Weekly | Weekly |
| | | BOD | <20 mg/L | Not required | Weekly |
| | | SS | <30 mg/L | Not required | Weekly |
| | | pH | 6.5-8.5 | Continuous online or weekly | Continuous online |
| | | Turbidity | <5 NTU (95%ile)[10] | Continuous online or weekly | Continuous online |
| | | Disinfection | • Cl[9]: 0.2 – 2.0mg/L<br>• UV[13]<br>• UVT[14] >75%<br>• UV intensity: drop <25% at 254nm<br>• UV dose: 40 – 70ml/$\text{cm}^2$ | N/A | Continuous online |
| **Low** | • Communal sub-surface irrigation[17]<br>• Urban irrigation with enhanced restricted access and application[c,17]<br>• Agricultural irrigation; non-edible crops[17] | *E. coli*[1] | <1000 MPN or cfu /100mL | Weekly | Weekly |
| | | BOD | <20 mg/L | Not required | Weekly |
| | | SS[18] | <30 mg/L | Not required | Weekly |
| | | pH | 6.5 – 8.5 | Continuous online or weekly | Daily or continuous online |
| | | Disinfection (if used) | Cl[9] : 0.2 – 2.0mg/L | N/A | Daily or continuous online |
| **Extra low** | • Woodlots[17]<br>• Sub-surface irrigation (non-food crops)[17] | No monitoring required | | | |

# END OF DOCUMENT