# INTELLIGENT WATER TREATMENT PROCESS SELECTION

***A. Wong*, D. Pernitsky‡, R. Oakley****

****Stantec New Zealand, Dunedin***
***‡Stantec Consulting Ltd., Calgary, Canada***

**ABSTRACT**

Selecting the most appropriate treatment process or technology for a new or upgraded water treatment plant (WTP) can be challenging. For City and District Councils with limited budgets, selecting the wrong process or technology can have significant cost and operational implications.

These risks can be mitigated by taking a careful and intelligent approach to WTP process selection through the development of a multi-season database of key water quality parameters. Some common drinking water treatment processes, how they address treatment challenges as indicated by the water quality parameters, their limitations, and how they meet the requirements of the Drinking Water Standards for New Zealand (DWSNZ) are summarized. The importance of bench- and pilot-scale testing, and the impact the data can have on the WTP design is highlighted through past projects to illustrate the concepts presented.

**KEYWORDS**

**Water Treatment, Process Selection, Pilot Testing**

**PRESENTER PROFILE**

Andrew Wong is a Process Engineer with seven years of experience in the water industry in Canada and New Zealand. The focus of his experience is in water treatment plant process design, operation, troubleshooting, and optimization at both pilot- and full-scale water treatment plants.

## 1 INTRODUCTION

Selecting the most appropriate treatment process or technology for a new or upgraded water treatment plant (WTP) can be challenging. For City and District Councils with limited budgets, selecting the wrong process or technology can have significant cost and operational implications. The selection process has been further complicated by the desire to "future proof" water supply systems against changes to the raw water quality, drinking water demand, and the Drinking Water Standards for New Zealand (DWSNZ).

These risks can be mitigated by taking a careful and intelligent approach to WTP process selection. First and foremost, it is important to develop a multi-season database of water quality data as it provides the basis for the process selection. Key water quality parameters that should be analysed are outlined, with their importance, and how they impact the treatment process selection. These parameters include: turbidity, UV absorbance, Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), colour, hardness, iron, manganese, and algae.

Also discussed is the importance of Natural Organic Matter (NOM) in drinking water treatment, as measured by Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), colour, and/or UV absorbance. It is a common misconception that clarification processes such as sedimentation and Dissolved Air Flotation (DAF) are not needed for low turbidity sources. However, if there are high NOM concentrations in the source water, clarification may be needed to remove the coagulant floc particles associated with the high coagulant demands that are required to remove the NOM. Seasonal manganese concentration fluctuations in the source water are not always detected in cursory water analyses, and when missed, can lead to severe operational issues and coloured water problems. The presence of algae is also of critical importance in process selection, as even low concentrations of algae – of all types – can render a direct filtration, direct membrane filtration, or cartridge filtration plant inoperable.

A summary of some of the most common drinking water treatment processes, how they address treatment challenges as indicated by the water quality parameters, their limitations, and how they meet the requirements of the DWSNZ is provided.

Lastly, the importance of bench- and pilot-scale testing, and the impact the data can have on the WTP design is highlighted. Experiences from WTP projects in will be used to illustrate the concepts presented in the paper.

# 2 KEY RAW WATER QUALITY PARAMETERS

A robust raw water quality database spanning multiple seasons is paramount to determining the level of treatment that is required, and the most suitable treatment processes or technologies that should be considered. Prior to undertaking a new sampling programme, available historical water quality and operational data should be reviewed to identify any seasonal trends or possible parameters of importance. Additionally, data collected from past monitoring programmes from other sites should be checked to ensure that parameters that have been monitored in the past are not missed.

## 2.1 GENERAL TESTING

The general testing parameters that should be assessed include turbidity, colour, temperature, and pH. They are important in assessing the need for pre-treatment processes, coagulant demand, and water stability.

Turbidity is an aggregate measure of light scattering, and is a key parameter in the assessment of water quality and water treatment process design. Turbidity is not a direct measure of suspended particles, but rather a general measure of the scattering and absorbing effect that suspended particles have on light (Health Canada, 2012). It is typically expressed in Nephelometric Turbidity Units (NTU), and describes the cloudiness of the water caused by suspended particles, chemical precipitates, organic particles, and organisms (World Health Organization, 2017). It is often used at critical control points to determine whether process units are operating properly. Turbidities less than 1 NTU are recommended to support effective disinfection (World Health Organization, 2017). Higher turbidity water will often require treatment (e.g., coagulation, filtration) to remove the suspended solids.

Colour is a aggregate measure of suspended and dissolved matter in the water, and is expressed in True Colour Units (TCU). Colour in water can arise from organics, microorgansisms, metals (e.g., iron and manganese), or contamination from industrial or municipal waste. Apparent Colour is the colour measured in water containing suspended particles, while True Colour is the colour of the water with the suspended particles removed (Health Canada, 2005). In general, the colour of surface water is often due to organic substances, and soft waters typically have higher colour than hard water (Health Canada, 2005). The colour of groundwater is usually due to the mineral content from which the water is drawn from (Health Canada, 2005). Similar to turbidity, coloured water will often require chemical pre-treatment (e.g., coagulation, oxidation) to remove it.

Temperature monitoring of raw water sources is important to track seasonal changes in water quality. Temperature can be used as an indicative tool for Operators to anticipate changes in water quality, especially where temperature fluctuations can be large (e.g., ≥20°C). It is also an important parameter to consider in clarification and membrane design. Lower water temperatures and increased in water density will result in slower sedimentation rates and lower membrane flux rates.

pH is a measure of the acidic or basic property of the water. The aesthetic guideline range for pH is 7-8.5 (Ministry of Health, 2018). In addition to providing an indication of whether pH adjustment of the treated water will be required, it also indicates how effective coagulation pre-treatment and chlorination processes will be. Coagulation process are more effective at removing NOM at a lower pH (pH<7) (Pernitsky & Edzwald, 2006). pH is also important in assessing the stability and corrosivity of the water. Lower pH waters with low alkalinity and hardness will require addition of lime or caustic soda.

## 2.2 ORGANICS

The control of Natural Organic Matter (NOM) in the treated water is important to achieve water quality goals related to microbial protection, Disinfection By-Product (DBP) control, biological stability in the distribution system, and corrosion control (Brown & Cornwell, 2011). NOM exerts a much higher coagulant demand than inorganic materials (Pernitsky & Edzwald, 2006). Low turbidity waters can have relatively high NOM concentrations which would need to be removed.

Both TOC and DOC are important parameters to determine the need for chemical pre-treatment, provide an indication of the coagulant demand, and provide an indication of the formation potential of chlorinated DBPs. The presence of organic carbon will also impact chlorine demand, and in turn the design of the chlorination system. In general, treated water DOC concentrations less than 2 mg/L and 4 mg/L are recommended for source waters with high and low DBP yields, respectively (US EPA, 1998).

As an alternative to measuring TOC and DOC concentrations in a lab, UV Absorbance ($UVA_{254}$) can be used as an indicator of the NOM concentration in the water. $UVA_{254}$ and UV Transmittance (UVT) describe the same physical phenomenon, and are related by the following equation:

$$UVA_{254} = 2 - \log_{10} UVT \quad (1)$$

Further, $UVA_{254}$ can be used to calculate the Specific UV Absorbance (SUVA), which can be used as an indication of the DBP formation potential of the water. SUVA is calculated as follows:

$$SUVA = UVA_{254}\ (cm^{-1}) / DOC\ (mg/L) \times 100$$

A summary of SUVA values is presented in

Table 1.

*Table 1: Summary of SUVA values and corresponding descriptions (US EPA, 1998)*

| SUVA Value (L/mg.min) | Description |
|---|---|
| < 2 | Low chlorine demand and low chlorine DBP formation potential |
| 2-4 | Higher chlorine demand and higher chlorine DBP formation potential |
| >4 | Higher chlorine demand and high chlorine DBP formation potential |

## 2.3 ANIONS AND CATIONS

A full anion and cation profile is recommended, as it provides important information about the stability of the water, and the potential risk of fouling of a UV reactor, downstream equipment, or the distribution system. Parameters to include as part of this analysis are: pH, alkalinity, hardness, conductivity, bicarbonate, chloride, nitrite, nitrate, sulphate, calcium, magnesium, sodium, and potassium. The anion/cation profile permits an ion balance to be performed for a quality check and confirm the water is electrically neutral. If the ion balance results suggest that the water is not electrically neutral, this suggests that there is a species that needs to be added to the parameter suite. Monitoring ammonia and phosphorus concentrations are important as they will exert a chlorine, oxidant, and coagulant demand.

## 2.4 METALS

A full-suite of total and dissolved metals analysis is recommended to identify any metal determinands that are: close to or above the 50% Maximum Acceptable Value (MAV), exert a chlorine demand, or lead to fouling of downstream equipment. However, the most common problematic determinands are iron and manganese.

Canada and New Zealand have both set aesthetic treatment objectives for iron of 0.3 mg/L and 0.2 mg/L, respectively; neither jurisdiction has set a MAV for iron. It is noted that the staining of laundry and plumbing fixtures, as well as objectionable colour and taste can occur at iron concentrations above 0.3 mg/L (Health Canada, 1978).

In New Zealand, there is an aesthetic objective for manganese of 0.04 mg/L to prevent the staining of laundry and objectional colour and taste. In contrast, Health Canada it has proposed to set an MAV and aesthetic objective of 0.10 mg/L and 0.02 mg/L, respectively (Health Canada, 2016). This proposed change has been driven by improvements in treatment technology, as well as the results of studies suggesting an association between manganese in drinking water and neurological effects in children (Health Canada, 2016).

Both iron and manganese are predominantly found in groundwater, and can be removed through pre-oxidation and adsorption. Higher pH, warm water, and low organic content are preferred for the oxidation of manganese (Knocke, et al., 1991).

## 2.5 ALGAE AND CYANOBACTERIA

Globally, the frequency of algal blooms has increased and has been attributed to variety of factors including climate change, human activities, and increased nutrient loading on receiving bodies. The presence of algae can challenge water treatment operations by negatively impacting clarification processes by impeding settling. Algae can also clog granular filters and membranes. Algal-based taste and odour episodes can become more frequent and more severe. In certain instances, algal toxins can be released impacting both public health and animals.

Under the right environmental conditions cyanobacteria can produce toxins such as microcystins which are stored in the cells and released when the cells are stressed, rupture, or die. Most scientific studies on cyanobacterial toxins focus on microcystins, which are generally regarded as the most important of the freshwater cyanotoxins. Health Canada has proposed an MAV of 0.0015 mg/L for total microcystins in drinking water (Health Canada, 2016).

# 3 TREATMENT PROCESSES

## 3.1 CARTRIDGE FILTRATION

Cartridge filtration has been used in a variety of applications, including: industrial processes, water treatment, and in-home use. They are typically housed in pressure vessels and can be designed to operate in an array plumbed in parallel. In water treatment applications, they are used to remove particles and protozoa, or as a pre-filter in membrane applications.

Cartridge filters that have been certified for 3-log protozoa removal receives a 2-log protozoa credit, but it is reduced to 1-log credit when followed by a UV reactor that provides a 3-log credit (Ministry of Health, 2018).

*Figure 1: Examples of cartridge filters (Industrial Process Technologies, 2016)*

The source water quality must be of high for the use of cartridge filters to be cost effective. Typically, the source water should have a turbidity less than 1 NTU, as well as low levels of suspended solids and algae. Low turbidity source waters can still have low levels of fine colloids or clays that can make cartridge filtration unsuitable (Pennsylvania Department of Environmental Protection, 2019). On their own, cartridge filters will not remove dissolved species like metals or NOM.

While cartridge filter systems are modular and can theoretically be increased to accommodate high flow rates, this technology favours smaller systems that are less than 380 $m^3$/day (Pennsylvania Department of Environmental Protection, 2019). A pre-filter with a larger pore size could be used to help extend the life of a cartridge filter, but may have a limited effect on removing colloids or fine clays. For water sources that have elevated turbidity following rain events or snow melt, a shutdown of the cartridge filters would be required until the water quality improves (selective abstraction). If treated water storage is limited, operation of the cartridge filters is still possible but at a reduced filter run time. Piloting of cartridge filters prior to implementation is strongly recommended to assess its change-out frequency.

## 3.2 CHEMICAL COAGULATION PROCESSES

For more challenging source waters with higher levels of turbidity, colour, and organic matter, a more advanced treatment system is needed. Figure 2 provides a general guideline for coagulation process selection based on NOM concentration, turbidity, and colour. Examples of chemical coagulation treatment processes include direct filtration, conventional treatment (coagulation, sedimentation, filtration), Dissolved Air Floatation (DAF) with filtration, and ballasted clarification with filtration.

These processes do require a higher level of Operator time and expertise to operate, optimize, and maintain. They are typically better suited for medium to large supplies. The key constituents that can be removed through coagulation processes, include: suspended solids and precipitated material, colloids, microorganisms, pathogens, and NOM.

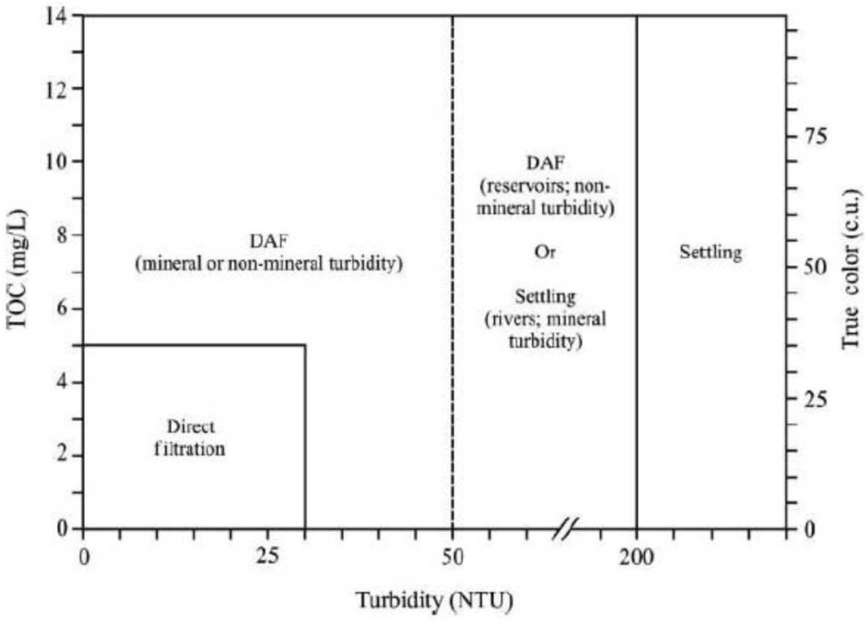


*Figure 2: Conventional process selection diagram based on raw water quality (Valade, et al., 2009)*

In direct filtration applications, chemical coagulation is immediately followed by filtration, without a clarification step in between. The chemical floc that is produced through coagulation is deposited directly onto the filter media. This process is well suited for the treatment of low turbidity water (1-5 NTU). It can handle higher turbidity water (<30 NTU) for short periods of time, but at the cost of shorter filter run times and more frequent backwashes. Due to the lack of a clarification step, direct filtration will often become challenged when faced with an algal bloom. When the filter effluent water quality requirements are met, direct filtration receives a 2.5-log protozoa credit (Ministry of Health, 2018).

Contact clarification followed by filtration is a variation of direct filtration. The coagulated water passes through a plastic media bed in an up-flow direction. Some of the coagulated material is removed through contact with the plastic media, before overflowing onto a granular media filter.

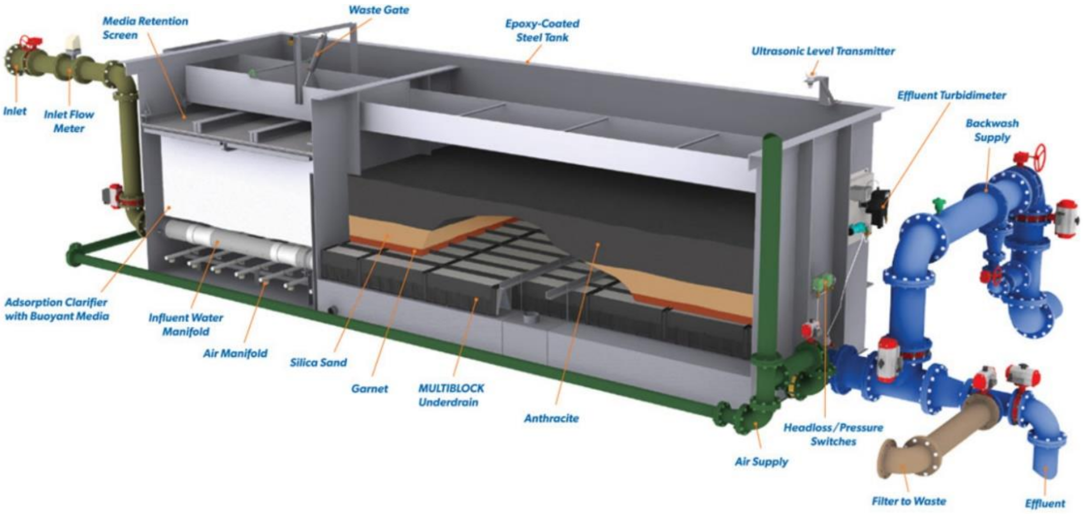


*Figure 3: Contact clarification and filtration (WesTech, 2019)*

Conventional coagulation treatment processes include coagulation, flocculation, sedimentation/clarification, and filtration. These systems can handle much higher levels of turbidity, colour, and NOM, but typically require a larger footprint. Open concrete sedimentation tanks can be retrofitted with parallel plate or tube settlers, to increase their capacity and transition to rapid rate sedimentation. When the filter effluent water quality requirements are met, conventional coagulation, flocculation, sedimentation and filtration receives a 3-log protozoa credit (Ministry of Health, 2018).

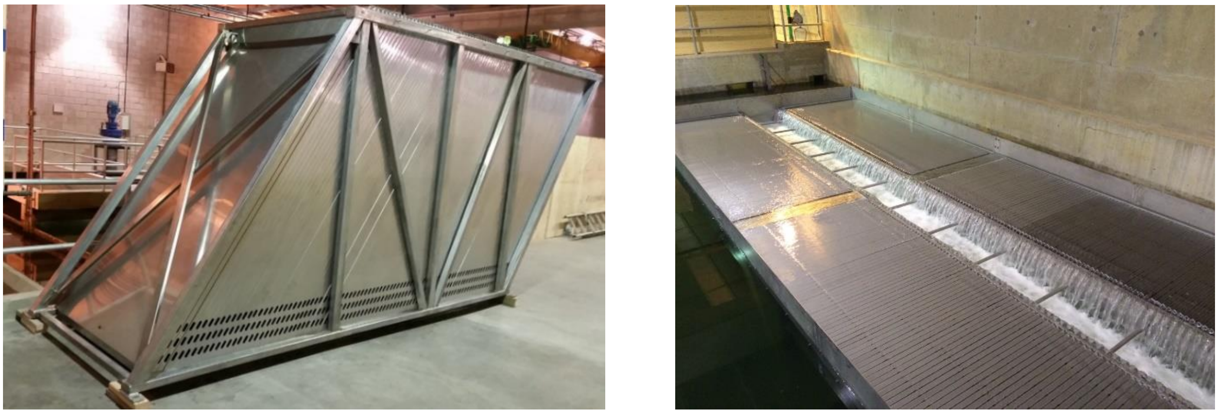

*Figure 4: Parallel plate settler pack retrofit*

DAF is a clarification process that separates solids by flotation of the floc, as opposed to gravity settling in conventional clarification. It is well suited to treat source water with a high level of turbidity and colour from high organic loading, or algae impacted waters. The light floc and algal cells that have poor settling characteristics can be floated easily and separated from the process water. However, it is not well suited to treat high levels of inorganic turbidity or settleable suspended solids.

DAF is the best available technology to address the adverse effects that algal blooms have on conventional treatment systems. It is often added upstream of direct filtration or membrane systems to gently remove algal cells without rupturing them, which could result in the release of polymeric substances, toxins, or taste and odour compounds.

Following the addition of the coagulant and/or polymer, the floc is floated to the surface from the introduction of air bubbles at the bottom of the floatation basin. Solids are then skimmed from the top of the reactor, and the clarified water is removed at a location beneath the water surface. The floated sludge is mechanically scraped into a collection trough and typically is 2 to 4% solids. The relatively high solids content requires less thickening prior to undergoing further dewatering.

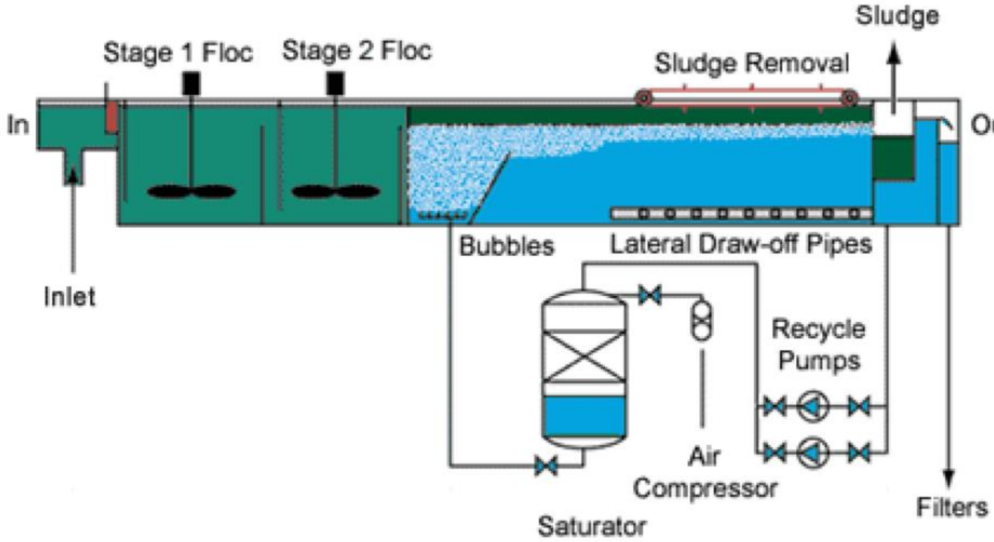


*Figure 5: Schematic of a DAF system*

Ballasted clarification systems, such as Actiflo® and CoMag®, have become popular replacements for conventional coagulation systems and traditional clarifiers due to its smaller footprint. Ballasted clarification is the generic name for settling processes that involves the addition of a high-density particulate material to the relatively low-density coagulant floc to improve its settling characteristics. Actiflo® employs a silica sand ballast that is recovered using a hydrocyclone. CoMag® uses magnetite ballast that is recovered using a modified magnetic drum. For both systems, coagulant and polymer are added to first mixing tank. In the second tank the ballast is added and flows into the sedimentation basin. The slurry of sludge and ballast material is drawn from the bottom of the tank. The ballast material is recovered and returned to the process. Similar to conventional and DAF systems, ballasted flocculation followed by filtration receives a 3-log protozoa credit (Ministry of Health, 2018).

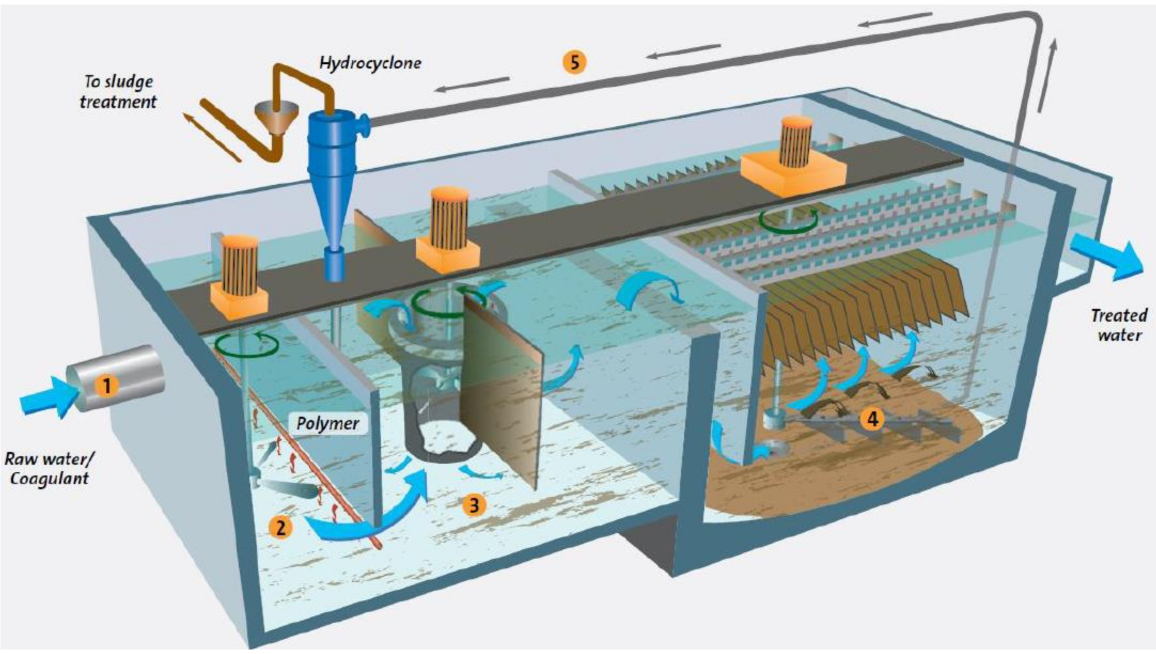


*Figure 6: Actiflo® schematic*

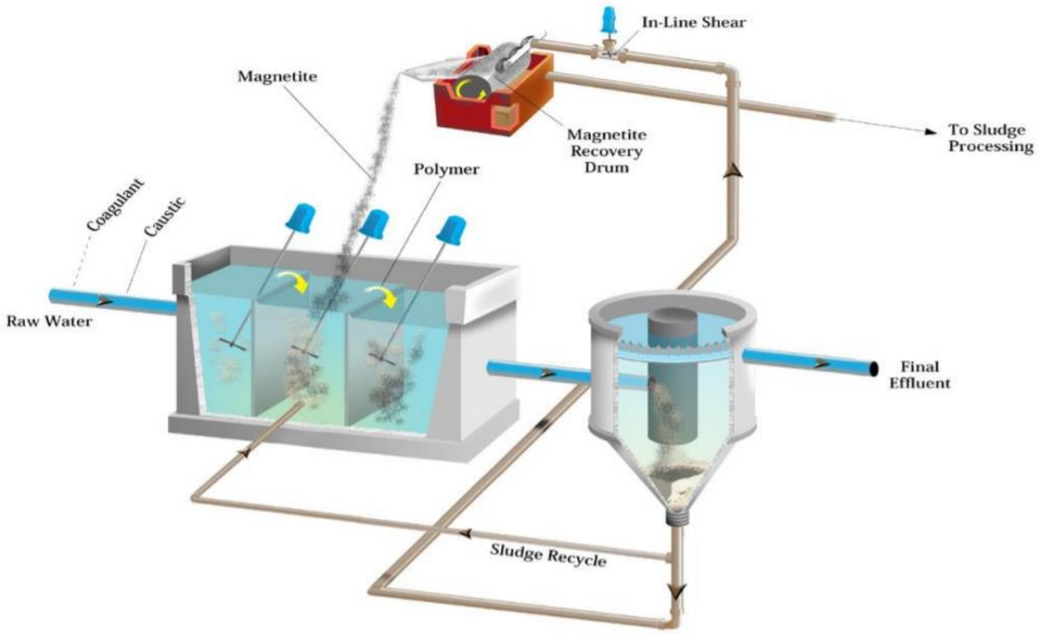


*Figure 7: CoMag® schematic*

## 3.3 MEMBRANE FILTRATION

Low pressure membrane systems, micro- (MF) and ultrafiltration (UF), have proved to be effective at removing suspended solids and pathogens. The number of MF and UF water treatment systems has increased as their resistance to fouling and harsh cleaning chemicals has improved, as well as becoming more economically viable in recent years. Recent cost evaluations have found that low pressure membranes are generally cost competitive with granular media filters for small and medium capacity WTPs. However, they are typically more expensive for large capacity facilities (>100 MLD).

Low pressure membranes provides a 4-log protozoa credit without requiring any pre-treatment (Ministry of Health, 2018). They are able to consistently produce low turbidity water, and are not subject to turbidity break-though due to sub-optimal coagulation chemistry. Membrane filtration has a much higher mechanical complexity, but this can be managed through automation. Low pressure membranes do not remove dissolved species like metals or NOM. For the removal of these constituents, pre-oxidation and/or coagulation would be required. If a non-chemical option is preferred, the more expensive high-pressure membranes (nanofiltration or reverse osmosis) could be considered.

## 3.4 GREENSAND FILTRATION

Iron and manganese are typically removed through pre-oxidation using sodium hypochlorite or potassium permanganate, followed by greensand filtration; this process is very effective. The oxidation of iron typically proceeds very easily and yields large flocs. In contrast the oxidation of manganese can be more challenging and yields very small particles (<0.2 µm). To mitigate these treatment challenges, greensand filters can be provided with a layer of anthracite media to remove the iron floc, while both particulate and soluble manganese is removed by the greensand filter media. This process does not provide any protozoa removal credits.

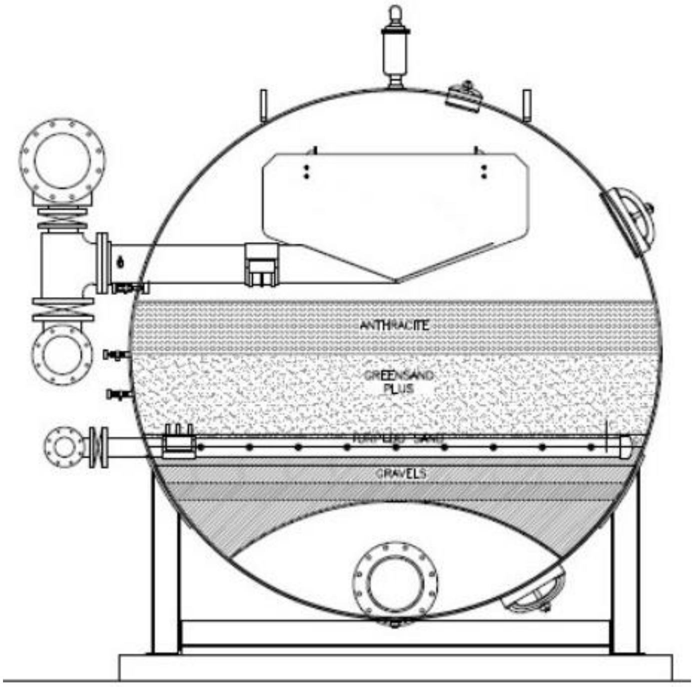


*Figure 8: Greensand filter schematic*

# 4 BENCH- AND PILOT-SCALE STUDIES

**Cartridge Filtration – Pilot Study**

A conceptual design completed by a competitor proposed the use of cartridge filtration followed by UV disinfection, to achieve the required 4-log protozoa removal credits, for a forecasted peak demand of 18 MLD. The available raw water quality data suggested that the source water may be a good candidate for cartridge filtration with turbidity <0.5 NTU, iron concentrations between 0.02 mg/L and 0.30 mg/L, manganese concentrations between 0.003 mg/L and 0.034 mg/L, and low hardness. Upon review of the conceptual design, Stantec recommended that a cartridge filter pilot study be undertaken to confirm the loading rates, number of cartridge filters required, and change-out frequency.

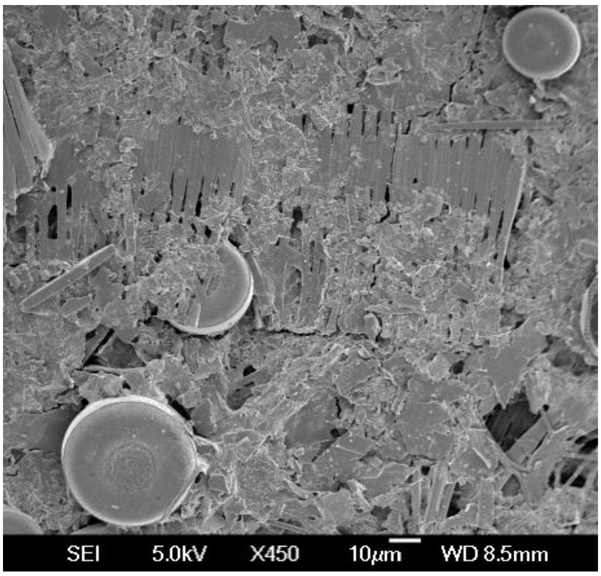


*Figure 9: Blinded cartridge filter SEM analysis*

It was found that the 25 cm cartridge filters, operated at a flow rate of 2 L/s, would blind from between 12 hours to 5 days of operation. It was concluded that cartridge filtration would not be the most appropriate treatment technology due to the change-out frequency required. Scanning Electron Microscope (SEM) analyses have revealed that the primary foulant is "rock flour", but it has also identified the presence of diatoms. Additional pilot testing is planned to select a more appropriate treatment technology.

**Conventional Treatment – Bench Study**

A client operating a conventional surface water treatment plant, with a design capacity of 72 MLD, observed reduced filter runtimes during their transitional temperature period and warm water conditions. In addition, a significant amount of sludge was accumulating on their parallel plate clarifiers. They were using a polyaluminum chloride coagulant (SternPAC) and a high molecular weight polymer flocculant (LT22S).

Stantec led a bench-scale study to assist with the optimization of the coagulation process by measuring the zeta potential of the coagulated particles at both cold and warm water conditions. Alternate coagulants and polymers were evaluated through jar testing. It was confirmed that at cold water conditions, the coagulant and polymer dosages were close to optimal. However, at warm water conditions the coagulation process could be improved by increasing the coagulant dose and decreasing the polymer dose to achieve an optimal particle charge which would help improve both the sedimentation and filtration processes. A lower molecular weight polymer with a higher charge density was recommended as an alternative to the LT22S; it would achieve the same coagulation performance but yield a less sticky sludge. This alternate polymer would increase the monthly chemical cost, but has the potential to reduce the Operator labour that is required for maintenance activities and reduce the filter backwash frequency.

*Figure 10: Malvern Zetasizer and jar testing equipment*

**Iron and Manganese Treatment– Pilot Study**

The conceptual design that was completed by a competitor for the removal of iron and manganese, included pre-oxidation using sodium hypochlorite followed by greensand filtration. The design was based on historic raw water quality data and a filter hydraulic loading rate of 21 $m^3/m^2/h$ (m/h), This design required five of vertical pressure filters each with a diameter of 4.3 m and height of 3.2 m. Upon review of the conceptual design, Stantec recommended that the filters be designed to a hydraulic loading rate of 12 m/h, which is in line with industry best practices, and that a pilot trial be completed.

The objectives of the pilot trial were to:

- Confirm the design details (e.g., oxidant dose, raw water quality, filter loading rates, filter size, number of filters, building size);
- Confirm that the proposed aesthetic objective for manganese (<0.02 mg/L) could be met consistently in the treated water; and,
- Determine the requirements for the residuals management system.

The results of pilot study confirmed that the raw water quality had changed from the available historical data, and the conservative loading rate of 12 m/h would allow for future operational flexibility. This loading rate also offered long filter run times (>70 hours). The backwash wastewater was found to meet the sanitary sewer bylaws and could be discharged for treatment at the wastewater treatment plant. Lowering the filter loading rate did increase the building size by a factor of 2.5, but provided a more robust treatment system.

*Figure 11: Containerized greensand filtration pilot system*

# 5 CONCLUSIONS

A summary of conclusions is prsented below:

- Key raw water quality monitoring parameters include: turbidity, colour, temperature, pH, TOC, DOC, $UVA_{254}$, anion/cation suite, ammonia, phosphorus, iron, manganese, algae, and cyanobacteria.
- Cartridge filtration should be limited to small supplies with very high-quality water with low concentrations NOM and dissolved species.
- Chemical coagulation processes are used to target: suspended solids and precipitated material, colloids, microorganisms, pathogens, and NOM. They are typically better suited for medium and large supplies.
- Membrane filtration systems have become more economically viable for small to medium supplies. They should be preceded by chemical coagulation or oxidation to remove organics, algae, or dissolved species.
- Pre-oxidation and greensand filtration is effective at removing nuisance metals like iron and manganese.

**REFERENCES**

Brown, R. & Cornwell, D., 2011. Impact of anion exchange pre-treatment on downstream processes, Denver: Water Research Foundation.

Health Canada, 1978. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Iron, Ottawa: Health Canada.

Health Canada, 2005. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Colour, Ottawa, Ontario: Health Canada.

Health Canada, 2012. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Turbidity, Ottawa, Ontario: Health Canada.

Health Canada, 2016. Cyanobaterial Toxins in Drinking Water, Ottawa: Health Canada.

Health Canada, 2016. Manganese in Drinking Water, Ottawa: Health Canada.

Industrial Process Technologies, 2016. Cartridge Filters. [Online] Available at: https://iptva.com/products/category/filtration/cartridge-filters/ [Accessed 11 July 2019].

Knocke, W. et al., 1991. Kinetics of Manganese and Iron Oxidation by Potassium Permanganate and Chlorine Dioxide. Journal - AWWA, 83(6), pp. 80-87.

Ministry of Health, 2018. Drinking-water Standards for New Zealand 2005 (revised 2018), Wellington, NZ: Ministry of Health.

Pennsylvania Department of Environmental Protection, 2019. Module 18: Bag Filtration and Cartridge Filtration, Harrisburg, PA: Commonwealth of Pennsylvania.

Pernitsky, D. & Edzwald, J., 2006. Selection of alum and polyaluminum coagulants: principles and applications. Journal of Water Supply: Research and Technology - AQUA, 55(2), pp. 121-141.

US EPA, 1998. National primary drinking water regulations: Disinfection and disinfection byproducts, Washington, D.C.: US Government Publishing Office.

Valade, M., Becker, W. & Edzwald, J., 2009. Treatment selection guidelines for particle and NOM removal. Journal of Water Supply: Research and Technology - AQUA, 58(6), pp. 424-432.

WesTech, 2019. Trident Package Water Treatment Plant. [Online] Available at: http://www.westech-inc.com/en-usa/products/package-water-treatment-plant-trident
[Accessed 11 July 2019].

World Health Organization, 2017. Guidelines for drinking-water quality: fourth edition incorporating the first addendum, Geneva: Licence CC BY-NC-SA 3.0 IGO.