Introduction

Water treatment installations featuring spiral wound membrane elements require to be fed with water containing a low level of colloidal and particulate material. If this is not achieved, then the membranes will foul. The most common pre-treatment system used to achieve acceptable feed water quality for these applications is multi-media filtration (MMF). In order to improve the efficiency of the filtration, a coagulant may be added.

This paper reviews the selection, optimisation and ongoing monitoring of suitable coagulants for membrane systems and gives guidelines for application of Avista Technologies range of coagulants.

Background on Membrane Plant technology

Membrane water treatment plants are employed on a wide variety of sources to produce numerous product water qualities. These include seawater and brackish water reverse osmosis for drinking water production, seawater nanofiltration for reduced sulphate waterflood injection and brackish water reverse osmosis for industrial water production.

A diagram of a typical membrane unit pre-treatment is included in Figure 1 for information. The process sequence is typical of most membrane plants in that pre-treatment is required to clean up the feedwater to an SDI of less than 5 (silt density index). Failure to remove colloidal and particulate matter to this level results in membrane fouling which results in poor quality product, higher operating costs due to more frequent cleaning and even shortened membrane life.

Pre-treatment for spiral wound membrane units frequently includes chlorination, coagulation, multi-media filtration, fine 'guard' cartridge filtration, dechlorination and antiscalant dosing upstream of the membranes.

The source and TDS of the feedwater effects the treatment chain and the chemicals used to enhance the performance of the system. The following sections provide general guidelines on what approach is most suitable for a range of common applications.

In addition, environmental restrictions, which vary from site to site, limit the type and quantity of chemicals, which may be employed to assist the operation of membrane units.

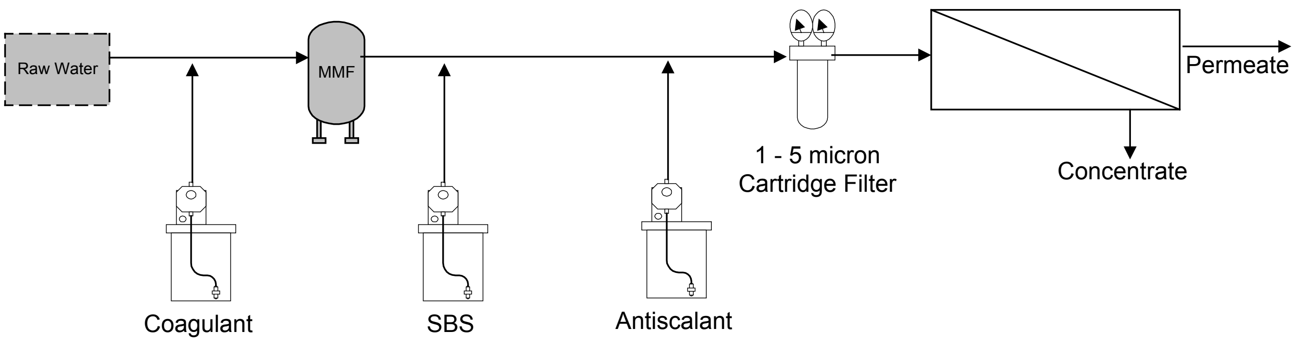


Figure 1: Typical Membrane System Pre-treatment Chain

How Coagulants Work

Coagulants are designed to aid the removal of small and colloidal particulate in multi-media filters and clarifiers. Multi-media filters can remove particles down to about 1 micron in diameter. Large particles are removed by sedimentation and interception with smaller ones being removed by diffusion mechanisms[(1)] . In most natural waters the particulate has a net negative charge which is also the case for most filter media. All of the filtration mechanisms for particle removal are significantly improved if this electrical repulsion is minimised and it is by overcoming these net negative charges that coagulants assist in filtration. Cationic coagulants overcome the net negative charges and destabilise colloids by the following mechanisms[(3)]:

Charge Neutralisation – Addition of ions of opposite charge (cations) which adsorb onto the colloidal particles and filter media and reduce the net negative charge of the system. Care must be taken not to overdose such colloids which would result in the system being charged in the opposite polarity.

Particle Bridging – Addition of large organic polymeric molecules with multiple cationic or anionic charges along their structure are used to attract colloidal particles and form larger less charged and more easily filtered particles.

Entrapment in Precipitate – Addition of metal salts (ferric or aluminium based) at the correct pH will result in the precipitation of the hydroxide. The precipitation will be seeded on some of the colloidal particles in the water and others will be trapped in the 'floc' formed.

Double Layer Compression – Addition of an electrolyte to the feedwater can reduce the electrical double layer[(4)] that surrounds each colloidal particle and acts to reduce the overall electrical charge.

Most coagulants exhibit more than one of the above properties as can be seen in the table below.

Coagulant Type	Charge Neutralisation	Particle Bridging	Entrapment in Precipitate	Double Layer Compression
Inorganic salt (ferric or alum)	✓		✓	✓
High Molecular weight Polymers	✓	✓		
Low molecular weight polymers	✓			

Coagulation using inorganic salts is limited to ferric salts for membrane systems as aluminium* fouls membranes and is difficult to remove. Ferric salts generally produce good water quality but also provides a discharge of sludge which is costly to treat and dispose of. Ferric dose is often inversely proportional to the turbidity of the feedwater, rendering low turbidity waters expensive to treat by inorganic coagulant alone.

Care should be exercised when selecting cationic organic coagulants for membrane pre-treatment systems as the membrane surfaces are anionically charged and coagulant carryover can result in permanent damage of the membrane surfaces. In addition the coagulant should

* Aluminium salts can be used if the pH of the feed is kept within a strict range

be shown to be compatible with any antiscalant or disinfectant chemicals which are also dosed. Avista Technologies RoQuest 3000 is a blend of low and high molecular weight polymers which have been proven to be compatible with membranes and a selection of Avista antiscalants. Inorganic coagulants will generally produce a slightly better finished water quality than organic coagulants but organic coagulants normally allow the required SDI<5 limit to be achieved and the ability to discharge backwash waters without treatment reduces capital and operating costs significantly.

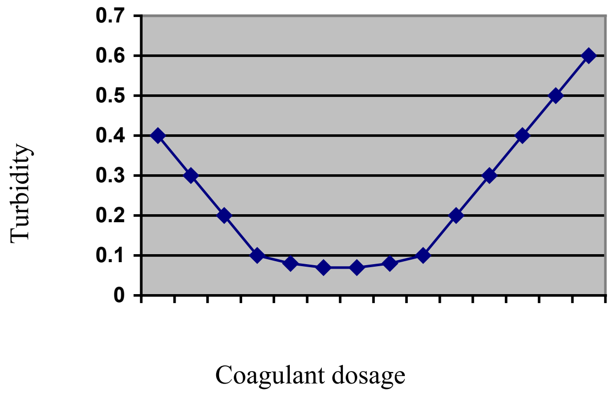
RoQuest 4000 – 6000 coagulants provide a blend of inorganic and organic coagulants which give good water quality in waters with turbidity and colour. Required dose rates vary widely but the combination of ferric and polymer often gives a reduced dose compared with either on their own.

Coagulant selection

When selecting a suitable coagulant for a membrane pre-treatment system, the following should be considered;

Efficacy – The coagulant should be proven to be effective at coagulating typical contaminants found in the feed water. Guidelines can be found at the end of this section for typical coagulant selections for different types of feedwater. Once the type of coagulant has been selected the performance can be evaluated by jar tests on feed water samples. (See Avista Technologies Jar Test Procedure for details.)

Jar testing should always be employed to evaluate optimum coagulant dose level as well as the best product for the application. The graph on the left shows the typical results from jar testing different dose rates of a particular coagulant. The optimum dose being that which results in the lowest turbidity product.



For low total dissolved solids feedwaters (<2000 ppm) a Zeta potential or Streaming current instrument can be used to determine the coagulant dose required to achieve charge neutralisation. This can be used to supplement the jar test procedures but should not be used as a substitute as no indication of relative filtered water quality can be obtained using these devices.

Membrane Compatibility – Although the coagulant should be removed from the water by the filtration process, there is the possibility of the coagulant reaching the membrane system. The cationic coagulants and (anionic) membrane surfaces result in a strong bond. This bond is difficult to break, and can result in irreversible fouling on a membrane. In all cases it is good practice to minimise the coagulant dose applied to minimise the chance of carryover to the membrane system.

Chemical/Environmental Compatibility – Where there is a possibility of the chemical mixing with other chemicals present in the system, it is important that there is no adverse reaction between the chemicals or any diminishment of chemical efficiency due to the presence of others. The chemicals must also be approved for discharge to the aquatic environment.

The following tables may be of assistance in selecting the type of coagulant to screen for your feedwater type.

Feedwater Source/Type	General Characteristics and Limitations	Comments	Coagulants types to Screen
Brackish Surface water	Low TDS Turbidity <2NTU Colour <10	May require high dose of inorganic salts May need filter 'weighter' to assist if very low turbidity.	Organic (Such as RoQuest 3000)
Brackish Surface water	Low TDS Turbidity >2 NTU Colour >10	May require backwash treatment plant to treat sludge.	Inorganic salt or Organic/inorganic blend (Such as RoQuest 4000 – 6000)
Shallow seawater	High TDS Variable algal particulate, sand and silt particles	May require backwash treatment plant to treat sludge.	Inorganic salt or Organic/inorganic blend (Such as RoQuest 4000 – 6000)
Deep ocean seawater	High TDS Variable algal particulate Inorganic coagulant not permitted due to discharge constraints	Low charge on algae difficult to agglomerate without inorganic salt addition. Quality may not be optimised due to constraints.	Organic (Such as RoQuest 3000)

Dosing Coagulant Upstream of MMFs

The dosing regime required for optimum performance of coagulants is dependent on the mechanisms used to effect the colloid destabilisation.

For RoQuest 3000 – 6000 where direct filtration (no upstream clarifier) is employed coagulant is added just prior to the MMF. Residence time is not critical as the polymer / ferric is not designed to generate a precipitating or agglomerating floc and hence effective mixing is all that is required.

Coagulant Optimisation

It is worth reminding ourselves the reason for using coagulant and optimising the dose rate for membrane plants. The pre-treatment of any membrane plant must achieve an SDI of 5 or less to remain within the membrane manufacturers warranty on membrane life and performance over time. The SDI (Silt Density Index) is a measure of the waters ability to block a 0.45 micron filter paper in a direct filtration method.

Having selected the optimum coagulant for site from initial jar tests when commissioning starts it is good practice to repeat the jar test exercise at full scale. The filters should be operated for a few days at the jar test optimum dose rate and the first backwash procedure

carried out. After the first backwash the dose rate should be varied and the turbidity and SDI recorded. It should be noted that the jar test optimum dose rate is often higher than the actual optimum dose rate.

The initial impact of dosing the coagulant will take little longer than the hold up time in the system (typically 2-3 minutes) as the coagulant will immediately create larger, filterable particles which are removed by the media. Changes made to the dosing regime may take several hours to fully impact on the filtered water quality, due to the slow build up of coagulant on the filter media. Therefore although some changes will be noticeable very soon after modifying the dose rate, it is very important to allow several hours to see the full effect of the change.

It is therefore suggested that the dose rate should be varied every 24 – 48 hours until sufficient data is collected to produce graphs of turbidity (or SDI) v's dose rate. (Alternative methods of determining the product water quality such as particle counting are available. This can be used in place of turbidity if it is available.)

In some cases Zeta potential or Streaming Current instruments may be available. If they are available the normal procedure for determining optimum coagulant dose should be carried out in parallel to the above tests and the reading corresponding to the best product quality can be programmed in as an alarm for ongoing monitoring.

This procedure should ensure you obtain the best quality water from your pre-treatment system and have minimum particulate/colloidal fouling on your membrane system.

Coagulant Ongoing Monitoring

During the year the quality of water to the filters may vary for one or more of the following reasons:

- Storms and high rains bringing higher silt and solids loading from surface waters
- Bloom periods dramatically increasing the algal particulate in seawater
- Varying levels of organics in the feed due to rotting vegetation

SDI will be monitored on a daily basis in any membrane plant and increases in SDI over a week should be monitored and jar tests carried out to determine if varying the coagulant dose would reduce the SDI again.

It is suggested that jar testing is carried out once per month during the first year of plant operation to determine any seasonal variations and this pattern can be used to determine whether the first dose change is up or down when the next seasonal changes are encountered.

Conclusion

Coagulants can significantly improve membrane feedwater quality and hence improve plant operation. Selecting the best coagulant for the site should be carried out by a combination of theoretical evaluation and site testing.

Ongoing monitoring of coagulant dose rate is recommended to ensure best product water quality is maintained and to avoid overdosing.

References

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4. Avista Technical Datasheet. 'Electrical Charges on Colloidal Particles'

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