The Cooperative Research Centre for Water Quality and Treatment is an unincorporated joint venture between:
- ACTEW Corporation
- Australian Water Quality Centre
- Australian Water Services Pty Ltd
- Brisbane City Council
- Centre for Appropriate Technology Inc
- City West Water Ltd
- CSIRO
- Curtin University of Technology
- Department of Human Services Victoria
- Environmental Protection Agency Queensland
- Griffith University
- Melbourne Water Corporation
- Monash University
- Orica Australia Pty Ltd
- Power and Water Corporation
- Queensland Health Pathology & Scientific Services
- RMIT University
- South Australian Water Corporation
- South East Water Ltd
- Sydney Catchment Authority
- Sydney Water Corporation
- The University of Adelaide
- The University of New South Wales
- The University of Queensland
- United Water International Pty Ltd
- University of South Australia
- University of Technology, Sydney
- Water Corporation
- Water Services Association of Australia
- Yarra Valley Water Ltd

The Cooperative Research Centre for Water Quality and Treatment is Australia’s national drinking water research centre. An unincorporated joint venture between 30 different organisations from the Australian water industry, major universities, CSIRO and federal and state governments, the CRC combines expertise in water quality and public health.

The CRC for Water Quality and Treatment is established and supported under the Federal Government’s Cooperative Research Centres Program.
Fact sheet objective

The new Australian Drinking Water Framework outlines the methodology for providing safe drinking water by managing the water supply system from the catchment to the tap. Understanding the level of risk in our water supplies and treatment systems is fundamental to the Framework. This allows managers of catchments and water utilities to focus their efforts on policies, works and operational practices to not only lower risks to public health but also improve the environmental health of these waters.

These fact sheets present the findings of research carried out by the Cooperative Research Centre (CRC) for Water Quality and Treatment into understanding the character of natural organic matter (NOM) in Australian water supplies and assessing its impact on water quality such as increasing disinfectant demand and formation of byproducts which adversely affect health. NOM also impacts on water treatment processes by increasing required coagulant doses, reducing the effectiveness of adsorption processes and fouling membrane systems. A range of treatment options have been evaluated to remove NOM to reduce its impact on the described treatment processes and produce water which requires less disinfectant but also minimises biofilm growth in distribution systems.

Fact sheet contents

These fact sheets are derived from the following CRC for Water Quality and Treatment research projects:

- Microbial Degradation and Remineralisation of Dissolved Organic Carbon in the Warren Reservoir
- Impacts of Destratification of Reservoir Waters on the Character of NOM and on the removal of NOM by Water Treatment Processes
- Impact of NOM on the Movement of Phosphorus in Soils
- Characterisation of NOM
- Development of Treatment Systems for Removal of NOM
- Hybrid Membrane Processes in Water Treatment
- Optimisation of Adsorption Processes – Stages 1 and 2
- Modelling Coagulation to Maximise Removal of Organic Matter – a Pilot Plant and Laboratory Based Study
- Development of Combined Treatment Processes for the Removal of Recalcitrant Organic Matter
- Biological Removal of UV Pretreated NOM from Potable Water
- Factors affecting Biofilm Development under Controlled Conditions
- Development of Tools for Improved Disinfection Control within Distribution Systems

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In Australia, drinking water quality management is undertaken in the context of the Australian Drinking Water Guidelines Framework. In the table below the salient research findings are presented within the Framework to aid in their implementation by the Australian Water Industry.

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- FS 1
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Summary of key points

The CRC research has identified that NOM is impacted by the soil and vegetation surrounding catchments and reservoirs and is also affected by seasonal variations. However characterising the NOM using a range of techniques, in addition to the quantitative measure of dissolved organic carbon (DOC), allows understanding and prediction of a waters susceptibility to coagulation, disinfection and formation of disinfection by-products. For example, monitoring NOM character by measuring the very hydrophobic (VHA) fraction will allow operators to better control coagulant dose to optimise DOC removal.

The optimum selection of treatment processes to remove organics will depend on the character of the organics present and the final treated water quality required. Conditions for optimum removal of organics in conventional treatment have been identified and software developed to assist operators to implement this more effectively within treatment plants.

However, there is a portion of the organic matter that cannot be removed by coagulation processes and will require additional treatment if more NOM removal is required. Processes to remove NOM that may be implemented together with conventional treatment that were investigated in this research included MIEX® and powdered activated carbon. Application of these processes will result in significant decrease in chlorine demand and trihalomethane formation potential (THMFP).

The residual NOM after treatment impacts on the disinfectant demand, formation of disinfection by-products and biofilm formation in the distribution system. Removal of biodegradable organics will reduce disinfectant decay and biofilm growth in distribution systems. Characterising the remaining NOM using UV$_{254}$ will allow operators to predict chlorine demand and THMFP and optimise chlorine residuals in distribution systems.

Increasing DOC concentrations in the source water impacts the effectiveness of powdered activated carbon for removal of problem contaminants and necessitates an increased carbon dose. Some measures to decrease the fouling of low pressure membranes by NOM were also identified.
FS 1 NOM Character - Tools to Assist Operators

The Issues
NOM impacts on the efficiency and effectiveness of water treatment processes and on the final water quality reaching the customer tap.

Available Tools for Operators
A range of analytical techniques offer more information on NOM character. The usefulness of each technique varies depending on the application.

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Research Findings
Dissolved organic carbon (DOC) is the most commonly used parameter to quantify NOM. The DOC concentrations of waters from around Australia were quite diverse – ranging from very low in eastern states (NSW and VIC) and NT to very high in SA and WA. The difference after treatment is demonstrated in the graph opposite - the SA/WA supplies with high DOC have optimised treatment to obtain significant removal whereas the NSW treatment plants with lower DOC values are not optimised to remove DOC to the same extent.

DOC levels in Australia - Snap shot from early 2003
The results of the survey of nine water samples including river, reservoir and ground water sources from around Australia over a 24-month period indicated that all water sources experienced seasonal variation in DOC concentration. In extreme situations where both the percentage variation and DOC concentration are high, this could have a significant impact on water treatment plant operation.

DOC is not a sufficient measure of NOM character to determine the impact on water treatment. Generally the higher the DOC, the higher the coagulant and disinfectant doses required to treat the water, however, there are exceptions (Chow et al, 2004a).

Simple Organic Characterisation

- UV absorbance at 254nm ($\text{UV}_{254}$) is a useful surrogate measure for DOC although it tends to include only the more complex NOM character. This technique only requires very simple instrumentation and can be performed by the operators in the treatment plant.

![Graph showing correlation between DOC and UV$_{254}$ for both raw and treated waters](image)

- Care must be taken when using $\text{UV}_{254}$ as a DOC surrogate. Good correlation can only be obtained with similar water quality. The above example indicates that this raw water has higher UV absorbance ($\text{UV}_{254}$) per DOC than the treated water.

- $\text{UV}_{254}$ correlates well with the chlorine demand and disinfection by-product (DBP) formation (refer FS 7).

- The ratio of $\text{UV}_{254}$ to DOC (specific UV absorbance – SUVA) or colour to DOC (specific colour) is also often used to characterise organics. To date, SUVA and specific colour have not provided useful measures to assist plant operation.

- Trihalomethane formation potential (THMFP) is a useful technique to compare the potential of waters to form DBPs. Extra information can be obtained by using THMFP per DOC. The THMFP/DOC value in treated water is generally lower than in raw water, indicating that the treatment process selectively removes THM precursors.

High Performance Size Exclusion Chromatography (HPSEC)

- HPSEC separates NOM constituents according to molecular weight (MW) (size) by a differential permeation process, using a high performance liquid chromatography system with UV detector. This technique is simple and informative.
• The HPSEC chromatogram can be used to distinguish water sources (e.g., river, ground water and reservoir water).

For example, the post-rainfall (August 2004) chromatogram below shows significant increases in NOM concentration and in particular an increase in higher MW fractions, characteristic of catchment source water. Furthermore, a high MW peak (likely to be colloidal organic matter) is observed.

• This HPSEC system is limited as it does not detect NOM which contains little or no UV activity (coagulated or chlorinated water). To overcome this problem, the CRC for Water Quality and Treatment is currently developing a new detector system for HPSEC based on direct measurement of DOC.

Rapid Fractionation (RF)
• Rapid Fractionation (RF) describes the NOM as a mixture of four organic fractions, very hydrophobic acids (VHA), slightly hydrophobic acids (SHA), hydrophilic charged (CHA) and hydrophilic neutral (NEU), by using adsorption on various resins (Chow et al, 2004d).

• RF of supplies from around Australia indicated that waters with higher DOC tended to have a higher proportion (percentage) of hydrophobic fractions (VHA/SHA) whereas supplies with lower DOC tended to have higher proportions of the hydrophilic neutral (NEU) fractions. Most waters surveyed in Australia tended to have very low concentration of CHA and NEU fractions with the greatest concentration of the DOC present as hydrophobic fractions (VHA/SHA).
- Coagulation with increasing alum dose results in increased removal of the VHA and SHA fractions and to a lesser extent the CHA fraction but little or no removal of the NEU fraction, which results in the character of the treated water differing significantly from that of the raw water.

- RF can quantify the proportion of DOC that will definitely not be removed by conventional treatment (most of NEU fraction).

- The amount of VHA present correlates very well with both coagulant and chlorine demands (refer FS 3 and 7).

### Biodegradable Organics

- Bacterial regrowth potential (BRP) is a technique developed to measure the ability of water to support microbiological growth. The growth of bacteria is measured after filtering the sample and re-inoculating with bacteria from the original sample. Growth is measured over 3-5 days by automatically measuring turbidity changes (12° forward scatter) (Withers and Drikas, 1998).

- Generally, after oxidation with either chlorine or ozone, BRP increases. This is a result of larger compounds being oxidised and/or broken down to more assimilable compounds. Waters with higher BRP have a higher potential for regrowth in distribution systems.

- In studies to date, an increase in BRP appears to occur when high molecular weight compounds are removed from water. This could be due to the release of more assimilable organics which were previously complexed and unavailable.

- Biodegradable Dissolved Organic Carbon (BDOC) is defined as the fraction of dissolved organic carbon (DOC) that can be mineralised by bacteria on a fixed support media.

- The reduction of BDOC in drinking water is an important part of the water treatment process as even low concentrations are sufficient to support bacterial growth in the distribution system.

- Conventional treatment consisting of coagulation/filtration reduces BDOC. The higher the applied alum dose the lower the BDOC in the treated water.

### Implementation

- Understanding the organic character of the water allows operators to predict the applicability of coagulation to remove the organics and to predict the required chlorine demand.

- Treatment plant operators can use BDOC and BRP to optimise water treatment processes for removal of biodegradable organic carbon to minimise disinfection requirements and reduce disinfection by-products.
More Information


Research Findings

- Surveys in Victoria and South Australia revealed there is large variation in aqueous extractable DOC in soils with different vegetation covers. The lowest DOC concentrations were from soils with grass or pasture cover.

- The application of gypsum as a soil ameliorant can retard the transport of DOC through the soil profile and limit transport of DOC in subsurface flows.
  - Gypsum application at 15 T/ha caused a reduction in anion adsorption capacity in the upper 10 cm of soils studied, with an increase in anion adsorption capacity below 10 cm.
  - The increase in anion adsorption capacity below 10 cm with gypsum treatment enhanced the overall anion adsorption capacity resulting in soil leachates having reduced concentrations in both NOM and Phosphorous concentrations.
  - A relatively high minimum dose of gypsum appears to be required (= 10 T/ha).
  - DOC leached from soil treated with gypsum was found to be harder to remove with conventional water treatment using alum, compared with DOC from soils not treated with gypsum.
  - In soils, exchangeable cations with ameliorant sourced calcium, such as manganese may reach high concentrations in leachates.

- In cooler autumn and winter months riverine inflow containing freshly leached NOM travels along the bottom of the reservoir and can rapidly reach reservoir offtakes. This could lead to poorer quality water reaching the water treatment plants.

Implementation

- Gypsum application may provide a means of minimising the transport of NOM and phosphorus in catchments although the potential for deleterious water quality effects such as increased manganese release needs further investigation.

- Offtake of reservoir water to a water treatment plant should be based upon knowledge of reservoir hydrodynamics and the consequential changes in water quality due to river inflows.

- When possible water should not be harvested from within a riverine intrusion as this water generally has poorer water quality including higher concentrations of DOC and higher turbidity.

- A simple model called INFLOW is available to predict the depth of a riverine intrusion, and how quickly it will travel from the inflow to the offtake. The model is available online at http://www2.cwr.uwa.edu.au/~ttfadmin/model/inflow/

More Information


Research Findings

- Optimisation of coagulation conditions can yield significant improvements in DOC removal and this is most effectively achieved by pH manipulation.

- The results of NOM characterisation techniques such as HPSEC indicate that coagulation preferentially removes higher molecular weight UV absorbing compounds, leaving lower molecular weight, less UV adsorbing material in the treated water.

- Sequential coagulation treatment, using repetitive doses of alum, has identified that there is a portion of the organic material which cannot be removed by coagulation processes, regardless of dose and conditions. This portion of organic matter is known as recalcitrant NOM.

- The CHA, VHA and SHA fractions are the most amenable to removal by coagulation. The higher the proportion of these fractions present in the water, the greater the amount of DOC that will be removed by coagulation. Most of the NEU fraction of DOC will not be removed by conventional treatment.

- Generally alum is the best performing inorganic coagulant for NOM, colour and turbidity removal under conventional pH conditions (6-7) as these conditions are closer to the optimum operating range of alum of pH 5-6.

- Generally ferric salts are the best performing inorganic coagulants for enhanced coagulation (higher doses, depressed pH) as these more acidic pH conditions are closer to the optimum operating range of ferric salts of pH 4-5.

Comparison of %DOC removal for alum and ferric chloride treatment of Myponga Reservoir water.

- A model called mEnCo, has been established that enables the following two functions, relevant to conventional water treatment,
  - rapid determination of coagulant dose (alum and ferric chloride) and pH control reagents for enhanced coagulation
  - prediction of residual DOC in treated water over wide ranges of coagulant doses and coagulation pH conditions from limited jar test data.

- Poly-aluminium chloride (PACl), also known as aluminium chlorohydrate (ACH), is an effective coagulant for low alkalinity waters in situations where pH control can not be used and acidic coagulants such as alum and ferric salts depress the pH below the effective coagulation range. The advantage of pre-formed coagulation products is also apparent in low temperature situations where coagulation with other inorganic coagulants can be too slow for the hydraulic flow of the treatment plant.
Advanced coagulants (such as poly-ferric sulphate (PFS)) can remove more DOC over a wider range of operating conditions as they are less pH and dose dependant. However, they do not necessarily target significantly more organic components of concern such as recalcitrant neutral hydrophilics. The increased DOC removal was found to result in only marginal changes in secondary water quality parameters (chlorine demand, THMFP) and failed to show benefits to bacterial regrowth in the treated water.

Implementation

- DOC removal can be optimised in conventional treatment by increasing applied coagulant dose, changing coagulant and manipulating pH.
- Monitoring NOM character by measuring the VHA fraction will allow operators to better control coagulant dose to optimise DOC removal.
- Software for implementation of mEnCo to predict coagulant doses, pH control reagents and residual DOC in treated water is available through the CRC for Water Quality and Treatment. This software is currently being applied by several Australian water utilities.

More Information


Other Processes to Remove NOM

Research Findings

- There is a portion of the organic matter, known as recalcitrant NOM, which cannot be removed by coagulation processes. Coagulants alone were incapable of producing required reductions in chlorine reactivity, DBP formation and bacterial regrowth.

- For the treatment of water for potable use, there are a number of advanced treatment techniques that have been developed worldwide. These generally fall into three categories: oxidative processes, adsorbents and membrane filtration.

- UV treatment of NOM leads to progressive reduction in its molecular weight, DOC and eventual mineralisation. The reduction in molecular weight is correlated with increased biodegradability, and the UV dosage for maximum biodegradability can be optimised to maximise NOM removal in a sequential UV/biologically activated carbon (BAC) process. VUV (vacuum ultraviolet) pre-treatment was shown to be five to six times faster and lead to greater NOM biodegradability than UV$_{254}$ pre-treatment.

- The product water from the VUV/BAC process was shown to present low potential health risks in terms of THMFP, haloacetic acid formation potential, nitrite, hydrogen peroxide, bromate, cytotoxicity and mutagenicity.

- RF was used to demonstrate which fractions of the NOM were degraded by the UV and biological processes and was shown to be useful in predicting the applicability of the developed process for different NOM sources.

- The MIEX® process was designed specifically for the removal of DOC from drinking water. It is a polymer adsorption resin incorporating iron to enhance aggregation and settling (via magnetic interaction) (Morran et al, 1996).

- MIEX® significantly decreases required chemical dosing for effective treatment including reduced coagulant dosing and ultimately disinfectant dosing through improved DOC removal.

- Adding MIEX® to the treatment process either alone or combined with alum improved DOC removal when compared with alum alone resulting in decreased chlorine decay and lower THM formation.

- A three-stage MIEX®/powdered activated carbon (PAC) coagulant treatment was found to improve the amount of DOC removed by between 82-96%, decrease chlorine demand, and significantly decrease THMFP. Bacterial regrowth was increased, however, highlighting the critical difference between using treatment to reduce NOM concentration, and changing NOM character.

Effect on (a) DOC removal and (b) THMFP of PAC and alum treatment of Myponga Reservoir MIEX® treated water.
• PAC had a greater effect on DOC and THMFP removal than alum on the organics remaining after MIEX® treatment.

Implementation
• The selection of treatment process to remove organics will be dependant on the character of the organics and the extent of removal required.
• The need to remove NOM to improve water quality beyond that achievable by coagulation alone will require additional treatment.
• There is potential for the application of UV at higher irradiation doses for removal of NOM either alone or to increase biodegradability prior to a granular activated carbon (GAC) filter, similar to the current application of ozone/GAC.
• MIEX® has been applied to increase NOM removal and provide improved water quality in three Australian operating treatment plants.
• Data obtained from MIEX® and alum evaluations have been used to aid optimisation of treatment conditions at selected Australian water treatment plants including Mt. Pleasant WTP, South Australia.

More Information


Research Findings

- When activated carbon is applied for the removal of problem microcontaminants, such as taste and odour compounds, algal toxins or pesticides, NOM has a significant impact on its effectiveness.

- While these problem compounds in drinking water are typically found in concentrations of nanograms or micrograms per litre, NOM is virtually always three to six orders of magnitude higher in concentration, and always offers significant competition for adsorption sites.

- Strong competition for adsorption sites results in higher dose requirements for powdered activated carbon (PAC) and shorter lifetimes for granular activated carbon (GAC) filters.

For example, the figure shows the PAC dose required to reduce the taste and odour compound, methyl iso-borneol (MIB), by 50% in waters of different DOC concentration (contact time 60 mins).

- NOM character also plays a role in the competitive effect, with the NOM in the molecular weight range similar to the target compound causing the greatest competition, and therefore the greatest effect on adsorption.

- Pre-adsorption, or preloading of GAC by NOM is the most important factor controlling the lifetime of filters for the removal of microcontaminants. NOM is constantly present in the water, utilising adsorption sites that are no longer available for the microcontaminant. Once again, the most detrimental NOM to the lifetime of GAC is the molecular weight range similar to the microcontaminant.

Implementation

- An increase in DOC concentration in the inlet to the plant, such as might occur during an algal bloom, will result in an increased requirement for PAC, or a reduced life expectancy for GAC.

- For optimum application of either form of activated carbon the aim should be maximum prior removal of NOM.

- As prior removal of NOM is not always possible with the application of PAC, the effect can be at least partially offset by an increase in the PAC contact time, and avoiding dosing PAC with other chemicals such as chlorine or metal coagulant.
More information


Understanding Fouling

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<th>NOM Removal (%)</th>
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<tr>
<td>Nanofiltration</td>
<td>&lt;500</td>
<td>&gt;99</td>
<td>&gt;90</td>
<td>15-30</td>
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Microfiltration (MF)/Ultrafiltration (UF) membranes remove little NOM as the NOM is smaller than the pore size of MF or UF. However, NOM fouls low pressure membranes and chemical cleaning is required to restore the flux. Fouling rate does not correspond to the traditional water quality parameters of colour and DOC.

Research Findings

- Composition of NOM has a strong impact on the rate of fouling, with the high molecular weight, hydrophilic neutral compounds appearing to have a large influence over the fouling rate in studies using surface waters.

- Interactions between NOM fractions and inorganic components can also influence the fouling characteristics.

- The membrane type as well as the NOM composition and concentration influence the rate of membrane fouling, with hydrophilic membranes having lower fouling rates than more hydrophobic membranes.

- Filtration does not remove all membrane foulants from the water, so the organic components will be available to foul subsequent membrane processes eg. when using microfiltration as pre-treatment for reverse osmosis.

- Coagulants almost always lower the rate of membrane fouling. Aluminium chlorohydrate is the recommended coagulant for use with membranes.

- Addition of particles, such as magnetite, with a coagulant may improve membrane performance by increasing the porosity of the filter cake.

- Adsorbents (PAC, MIEX® etc) generally require extended contact times or high concentrations to be effective. Recycling of the adsorbent may make the use of high concentrations economic. Adsorbents are unlikely to be used effectively by in-line dosing and direct filtration onto the membranes because of the subsequent slow kinetics.

- To date there have been conflicting reports and results on the performance of MIEX® and membranes. Some reports indicate improved performance and others indicate increased fouling rates.

- New advancements being tested for NOM control or removal are:
  - Ultra fine PAC that increases the kinetics of adsorption (dose in line and direct filtration)
  - Novel coagulant, poly silicate iron, for reduced membrane fouling – particularly with hydrophilic membranes
  - UV degradation of NOM prior to membranes to lower the fouling rate of membranes.
  - Tailored membrane materials and coagulants/adsorbents for low fouling operation (ie. MIEX® and positively charged polyacrylonitrile membranes).
Implementation

- Prediction of fouling rates still requires pilot plant trials for accurate results.
- Coagulant addition should be planned, even if its use is not anticipated.

More Information


Research Findings

Surrogate Parameter to Predict Disinfectant Demand

- There is a strong relationship between chlorine demand and NOM. Parameters such as $\text{UV}_{254}$, DOC, colour or VHA fraction can be used to predict chlorine demand.

- A 24-month laboratory study with samples every 3 months from water sources, including rivers, reservoirs and ground waters, confirmed that a generic equation using $\text{UV}_{254}$ can predict chlorine demand. This also confirmed that the relationship between $\text{UV}_{254}$ and chlorine demand is not affected by water sources and seasonal variation.

- The use of the VHA fraction to predict chlorine demand is slightly more time consuming. However, it may be superior for certain waters to produce a more accurate demand prediction.

- Only a weak correlation between NOM and chloramine demand was observed. No surrogate parameter was identified which correlated well enough to be used to predict chloramine demand. At this stage it appears that whilst NOM impacts on chloramination, it may not be the major component contributing to chloramine demand.

Impact of Disinfection

- HPSEC can be used to compare the change in organics after disinfection. After chlorination, there is a general reduction of the UV absorbing components over the molecular weight range (100 to 10,000 Da) with higher reduction in the high molecular weight portion. This implies that it is very likely that the precursors are higher molecular weight compounds. However, chlorination did not reduce the colloidal organics peak (100,000 Da), indicating that the organic matter which appears after heavy rain may not contribute to the formation of DBPs.

- Chloramine is a weaker oxidant compared with chlorine and it has less impact on the organic character.

- DOC and $\text{UV}_{254}$ correlate well with THMFP and can be used as surrogate parameters to predict THM formation.
**Biofilm and NOM**
- Biodegradable organic carbon is the primary driver of biofilm regrowth in chlorinated systems.
- Removal of biodegradable organic carbon causes a decrease both in biofilm biomass and the impact of biofilms on disinfectant decay.
- An increase in biodegradable organic carbon causes an increase in biofilm development, biofilm mediated disinfectant decay and release of cells to the aqueous phase.
- Disinfection decay by biofilms is dependant on the presence of biodegradable organic carbon.
- Biofilms convert non-reactive biodegradable organic carbon into fractions that readily react with disinfectants.
- HPSEC is a potential tool to study biofilm activity. Biofilms in distribution systems can be considered as a bioreactor; the change in organic character due to biofilm activity can be used as an indirect tool to assess biofilms. Preliminary results indicate that this technique can be used to characterise organics in different sections of the distribution system.

**Implementation**
- Monitoring UV$_{254}$ will allow operators to predict chlorine demand and THMFP and optimise chlorine residuals in distribution systems.
- A trial using on-line UV spectrophotometry at the Myponga WTP demonstrated the feasibility of monitoring UV absorbance to predict chlorine demand. This can be further implemented to optimise chlorine residuals in distribution systems.
- Removal of biodegradable organics will reduce disinfectant decay and biofilm growth in distribution systems.

**More Information**


Acknowledgements

Microbial Degradation and Remineralisation of Dissolved Organic Carbon in the Warren Reservoir

Project Participants
John van Leeuwen, Tanja Jankovic-Karasoulos, David Chittleborough, Steve Rogers, Ron Smernik, Friedrich Recknagel.

Impacts of Destratification of Reservoir Waters on the Character of NOM and on the removal of NOM by Water Treatment Processes

Project Participants
John van Leeuwen, Justin Brookes, Mike Burch, Kliti Grice, Nira Jayasuriya, Alan Wade, Leon Linden, Jonathon Yeow, Chong Soh, Felicity Roddick.

Impact of NOM on the Movement of Phosphorus in Soils

Project Participants
Friedrich Recknagel, Jon Varcoe, John van Leeuwen, David Chittleborough, Jim Cox.

Characterisation of NOM

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Development of Treatment Systems for Removal of NOM

Project Participants
Mary Drikas, Chris Chow, Rolando Fabris, Uwe Kaeding, Jim Morran, Kaye Spark, Brian Bolto, David Dixon, Rob Eldridge, Simon King, Felicity Roddick, Malcolm Hobday, Adele Parkinson, James Thomson, Dennis Mulcahy, David Davey, Shaun Thomas.

Hybrid Membrane Processes in Water Treatment

Project Participants
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Optimisation of Adsorption Processes – Stage 1 and 2

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Modelling Coagulation to Maximise Removal of Organic Matter – a Pilot Plant and Laboratory Based Study

Project Participants
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Development of Combined Treatment Processes for the Removal of Recalcitrant Organic Matter

Project Participants
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Biological Removal of UV Pretreated NOM from Potable Water

Project Participants
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Factors affecting Biofilm Development under Controlled Conditions

Project Participants
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Development of Tools for Improved Disinfection Control within Distribution Systems

Project Participants

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Fact sheet objective

The new Australian Drinking Water Framework outlines the methodology for providing safe drinking water by managing the water supply system from the catchment to the tap. Understanding the level of risk in our water supplies and treatment systems is fundamental to the Framework. This allows managers of catchments and water utilities to focus their efforts on policies, works and operational practices to not only lower risks to public health but also improve the environmental health of these waters.

These fact sheets present the findings of research carried out by the Cooperative Research Centre (CRC) for Water Quality and Treatment into understanding the character of natural organic matter (NOM) in Australian water supplies and assessing its impact on water quality such as increasing disinfectant demand and formation of byproducts which adversely affect health. NOM also impacts on water treatment processes by increasing required coagulant doses, reducing the effectiveness of adsorption processes and fouling membrane systems. A range of treatment options have been evaluated to remove NOM to reduce its impact on the described treatment processes and produce water which requires less disinfectant but also minimises biofilm growth in distribution systems.

Fact sheet contents

These fact sheets are derived from the following CRC for Water Quality and Treatment research projects:

- Microbial Degradation and Remineralisation of Dissolved Organic Carbon in the Warren Reservoir
- Impacts of Destratification of Reservoir Waters on the Character of NOM and on the removal of NOM by Water Treatment Processes
- Impact of NOM on the Movement of Phosphorus in Soils
- Characterisation of NOM
- Development of Treatment Systems for Removal of NOM
- Hybrid Membrane Processes in Water Treatment
- Optimisation of Adsorption Processes – Stages 1 and 2
- Modelling Coagulation to Maximise Removal of Organic Matter – a Pilot Plant and Laboratory Based Study
- Development of Combined Treatment Processes for the Removal of Recalcitrant Organic Matter
- Biological Removal of UV Pretreated NOM from Potable Water
- Factors affecting Biofilm Development under Controlled Conditions
- Development of Tools for Improved Disinfection Control within Distribution Systems

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- FS 1 NOM Character - Tools to Assist Operators
- FS 2 Managing NOM in the Catchment/Reservoirs
- FS 3 Optimising NOM Removal in Conventional Treatment Plants
- FS 4 Other Processes to Remove NOM
- FS 5 The Effect of NOM on the Application of Activated Carbon
- FS 6 Fouling of Low Pressure Membranes
- FS 7 Effect of NOM on Managing Distribution Systems
- FS 8 Acknowledgements
- ADWG Framework Elements

In Australia, drinking water quality management is undertaken in the context of the Australian Drinking Water Guidelines Framework. In the table below the salient research findings are presented within the Framework to aid in their implementation by the Australian Water Industry.

<table>
<thead>
<tr>
<th>ADWG Framework Elements</th>
<th>Key research findings and reference to Fact sheet No.</th>
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</thead>
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<tr>
<td>Water Supply System Analysis</td>
<td>FS 2 Soil and vegetation impact on release of natural organic matter (NOM). The lowest dissolved organic carbon (DOC) concentrations were from soils with grass or pasture cover.</td>
</tr>
<tr>
<td>Assessment of the Drinking Water Supply System</td>
<td>FS 1 Understanding the organic character of the water allows prediction of treatability, disinfection demand and by-product formation.</td>
</tr>
<tr>
<td>Assessment of Water Quality Data</td>
<td>FS 1 DOC is not a sufficient measure of NOM character to determine the impact on water treatment.</td>
</tr>
<tr>
<td>Hazard Identification and Risk Assessment</td>
<td>FS 1 There are a range of simple analytical techniques that provide more information on NOM character. The usefulness of each technique depends on the application.</td>
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<tr>
<td>Preventive Measures for Drinking Water Quality Management</td>
<td>FS 2 Water from recent rainfall events with high DOC may short circuit through reservoirs during the cooler seasons.</td>
</tr>
<tr>
<td>Preventive Measures and Preventive Multiples Barriers</td>
<td>FS 2 Gypsum application may provide a means of minimising the transport of NOM in catchments.</td>
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<tr>
<td>Operational Procedures and Process Control</td>
<td>FS 4 The selection of treatment process to remove organics will be dependant on the character of the organics and the extent of removal required.</td>
</tr>
<tr>
<td>Operational Procedures</td>
<td>FS 1 There are a range of simple analytical techniques that provide more information on NOM character. The usefulness of each technique depends on the application.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 3 DOC removal can be optimised in conventional treatment by increasing applied coagulant dose, changing coagulant and manipulating pH. Software is available to assist with this.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 3 Coagulation preferentially removes higher molecular weight UV absorbing compounds.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 8 Addition of MIEX® to the treatment process either alone or combined with low alum doses will improve DOC removal when compared with alum alone, resulting in decreased chlorine decay and lower trihalomethane formation potential (THMFP).</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 5 An increase in DOC concentration in the inlet to the plant, such as might occur during an algal bloom, will result in an increased requirement for powdered activated carbon (PAC), or a reduced life expectancy for granular activated carbon (GAC).</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 6 The membrane type as well as the NOM composition and concentration influence the rate of fouling of low pressure membranes, with hydrophilic membranes having lower fouling rates than more hydrophobic membranes.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 6 Coagulants almost always lower the rate of membrane fouling. Aluminium chlorohydrate is the recommended coagulant for use with membranes.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 7 Monitoring NOM character by measuring the very hydrophobic (VHVA) fraction will allow operators to better control coagulant dose to optimise DOC removal.</td>
</tr>
<tr>
<td>Operational Monitoring</td>
<td>FS 8 Monitoring UV₇₅ will allow operators to predict chlorine demand and THMFP and optimise chlorine residuals in distribution systems.</td>
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<tr>
<td>Verification of Drinking Water Quality</td>
<td>FS 7 On-line UV spectrophotometry may be used to optimise chlorine residuals.</td>
</tr>
<tr>
<td>Drinking Water Quality Monitoring</td>
<td>FS 4 There is potential for the application of UV at higher irradiation doses for removal of NOM either alone or to increase biodegradability prior to a granular activated carbon filter.</td>
</tr>
<tr>
<td>Research and Development</td>
<td>FS 4 A 3-stage MIEX®/Powdered activated carbon/Coagulant treatment was found to improve the amount of DOC removed, decrease chlorine demand and significantly decrease THMFP. However bacterial regrowth was increased.</td>
</tr>
<tr>
<td>Investigative Studies and Research Monitoring</td>
<td>FS 8 A range of processes are being trialed to remove NOM prior to membrane filtration.</td>
</tr>
</tbody>
</table>
The Cooperative Research Centre (CRC) for Water Quality and Treatment is Australia’s national drinking water research centre. An unincorporated joint venture between 30 different organisations from the Australian water industry, major universities, CSIRO, and local and state governments, the CRC combines expertise in water quality and public health.

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