Australian Water Recycling
Centre of Excellence

A national framework
for validating water-recycling technology

Validating chemical and photochemical oxidation treatments

Summary of Street map 3

Water is being recycled all over Australia for a variety of uses. To protect the health of people and the environment, treatment technologies used in water recycling schemes need to meet the performance targets specified in the Australian Guidelines for Water Recycling. Across Australia, there is currently no consistent approach to validating treatment technologies against these guidelines. The Australian Water Recycling Centre of Excellence has engaged Water Quality Research Australia to deliver a national framework for validating treatment technologies.

Most chemical and photochemical treatments have been developed for drinking water applications, which is reflected in the techniques used to validate them. Improvements to these techniques will allow them to be adapted to wastewater applications.

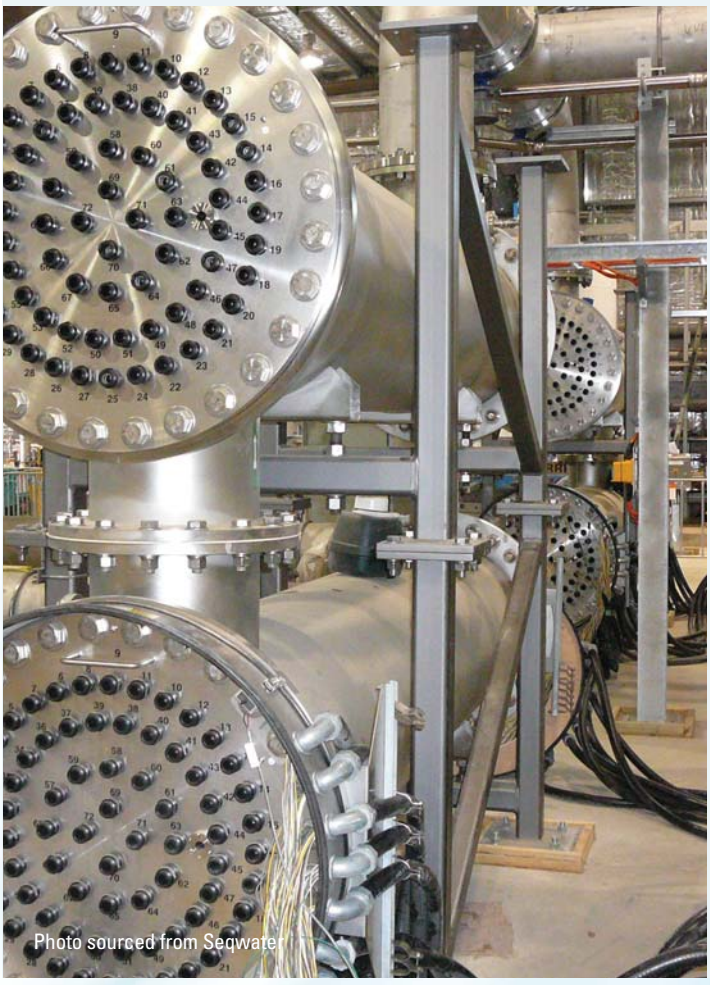

Photo sourced from Seqwater

What is validation?

The *Australian Guidelines for Water Recycling (2006)* require that a treatment technology or process be validated before the water recycling scheme is operational. Validation is the confirmation that the treatment technology meets the specified performance targets. The guidelines describe the concept of and need for validation but do not specify how the validation should be done.

What are chemical and photochemical oxidation treatments ?

Wastewater can be treated by using ultraviolet (UV) light alone, by adding oxidants or disinfectants to the water ('chemical treatments') or by combining them with UV light ('photochemical treatments').

The chemicals and UV light react with contaminants in water, inactivating pathogens (microorganisms that cause disease, such as bacteria, protozoa and viruses) and removing organic chemicals such as pesticides. In some cases they are used to remove tastes, colours and odours.

Chemical/photochemical oxidation treatments include:

- **UV:** UV light kills or inactivates living cells and is a good disinfectant, particularly for some pathogens that are resistant to other disinfectants. UV is particularly effective against protozoa and bacteria.
- **UV and hydrogen peroxide disinfection and advanced oxidation:** Used with UV light, hydrogen peroxide is a strong disinfectant, removing taste and colour from water.
- **Ozone:** Ozone is a strong disinfectant and oxidant, particularly effective against viruses and bacteria.
- **Peroxone:** Peroxone combines ozone and hydrogen peroxide, mostly used for removing organic chemicals.
- **Free chlorine:** Chlorine is a strong disinfectant that is particularly effective against viruses and bacteria.
- **Chloramine:** Chloramines form when chlorine and ammonia are added to water. They're more persistent than free chlorine, but require longer contact time. Chloramines are effective against viruses and bacteria.
- **Chlorine dioxide:** Similar to chlorine but more effective, this reactive gas is made on-site. It is sometimes used with monochloramine.

Validating chemical and photochemical oxidation treatments

Summary of Street map 3

Contaminants in water, such as dissolved organic material, may react during chemical/photochemical oxidation treatments to produce by-products, some of which may be hazardous.

The effectiveness of these treatments is influenced by:

- the type and quantity of pathogen being targeted
- how long water is in contact with the disinfectant (contact time)
- how well the water and chemical treatment are mixed
- whether the pathogens are shielded or protected by particles in the water
- the temperature and pH of water.

Current and emerging validation approaches

UV disinfection

Some UV systems are pre-validated by the manufacturer. The preferred approach for validation of a UV disinfection system is described in the US EPA *Ultra Violet Disinfection Guidance Manual*. Guidelines exist for low- and medium-pressure UV lamps.

Emerging approaches to validation include:

- Computer simulations of treatment systems ('computational fluid dynamics'). Critical uncertainties prevent widespread acceptance of this technique.
- UV light-sensitive chemicals that cause particles to change colour as they are 'treated' ('dyed microspheres') to measure treatment exposure down to individual particles. This technique is used for drinking water and appears useful for validating UV disinfection in periodic challenge testing the system.

Advanced oxidation, ozone and peroxone—for removing chemicals

These treatments use very high UV doses, generally assuring disinfection. Organic material levels and ozone consumed are usually measured when testing the effectiveness of ozonation and peroxone.

Emerging technologies include:

- dyed microspheres (as for UV disinfection above) in periodic challenge tests
- chemicals that help measure the energy of UV light imparted ('actinometers'), such as iodate
- measuring how transmissive the water is to UV radiation for use in dose control (on-line spectrophotometry).

Ozone and peroxone—for disinfection

Ozone and peroxone are most often used to remove organic chemicals, colour and taste. Use for disinfection is less well understood. Contact time between the water and the disinfectant is an important control that needs to be measured in real time (on-line).

Validation techniques exist for disinfecting drinking water but site-specific tests need to ensure that the same validation guidelines can be applied for disinfecting treated wastewater.

Chlorine-derived disinfectants

A validation study is not required for chlorine-derived disinfectants, as long as contact time for given turbidity levels, pH and temperatures are demonstrated. Currently, disinfectant residuals are checked to verify adequate disinfection.

Photo sourced from SA Water


Photo sourced from Melbourne Water

Validation limitations and difficulties

Most chemical/photochemical oxidation treatments have been developed and validated for drinking water application. Their effectiveness and validation for wastewater application is often slightly different.

UV disinfection

The conditions of manufacturers' pre-validation may limit how UV systems are used on-site.

Some validation manufacturer's pre-validation cannot be applied when physical factors of the system are different from those specified in the guidelines, so any time a change occurs validation must be repeated.

Advanced oxidation, ozonation and peroxone—for chemical removal

Designing an optimal removal process is difficult due to the number of chemical contaminants and possible reactions between them producing more/different contaminants. Current practice is to design for a desired removal for a target contaminant, applying safety factors to account for various uncertainties.

The concentration of hydrogen peroxide influences effectiveness, as it mops up reactive 'radicals' generated by UV light. Hydrogen peroxide consumption is easy to measure accurately in a laboratory but there is no reliable on-line test.

Surrogates (chemicals that indicate the effectiveness of treatment) could be measured but expert knowledge is needed to interpret data, optimise treatment and determine reliable operating conditions.

Ozone and peroxone—for disinfection

Current validation techniques don't consider factors such as increased ozone demand and particle levels in treated wastewater, and there are critical uncertainties around the appropriate contact times for this matrix.

Chlorine-derived disinfectants

Operators are likely to encounter different turbidity levels and temperatures than specified in current contact time guidelines. Standard contact times for differing turbidity, pH and temperatures would assist this.

Wastewater can contain ammonia, resulting in chloramine being formed when chlorine is dosed. Monochloramine is often used to prevent biological fouling of membranes, however it is not effective in killing all viruses and is not generally used in water treatment to achieve $\log_{10}$ removal credits for viruses. In water treatment plants free chlorine is used to kill viruses with ammonia added subsequently to maintain disinfection in pipe networks. If chloramination in water recycling is to be validated for microbiological $\log_{10}$ credits new techniques may be needed.

Validating chemical and photochemical oxidation treatments Summary of Street map 3

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Research gaps

Validation of chemical/photochemical oxidation treatments could be improved by research examining:

- the effect of treated wastewater matrix on oxidant demand
- the effects of treatment on by-products
- cheaper chemical surrogates
- differences between laboratory-cultured and naturally occurring viruses.

For **UV disinfection**, on-site validation methods should be developed, particularly ones that assess the range of treatment doses a water sample receives because of fluid mechanics. The effect of particles on disinfection needs to be quantified. More information is required about how viruses are inactivated, and how this is accurately measured.

For ozone disinfection, our understanding needs to be improved of the effect of shorter contact times and how they can be validated, verified and controlled in a real process. Guidelines are needed for disinfection of viruses and protozoa.

For **chlorine-derived disinfection,** guidelines are needed for virus disinfection when temperature or turbidity is outside the testing guidelines. Information is needed about how contact time might change for the most chlorine-resistant viruses, and for viruses susceptible to chlorine but not monochloramine.

Recommendations

Evaluate the research gaps for feasibility, cost and impact on existing validation practices.

For example:

- UV disinfection would benefit from cost-effective validation systems to work out dose distribution on-site – this would allow existing equipment to be validated under local conditions.
- Understanding more about chlorine-derived disinfectants could reduce the need for overdosing and reduce by-products.
- Validation of ozone disinfection at low contact times is expected to be efficient for virus and bacteria inactivation, but the efficiency cannot be validated with current guidelines.

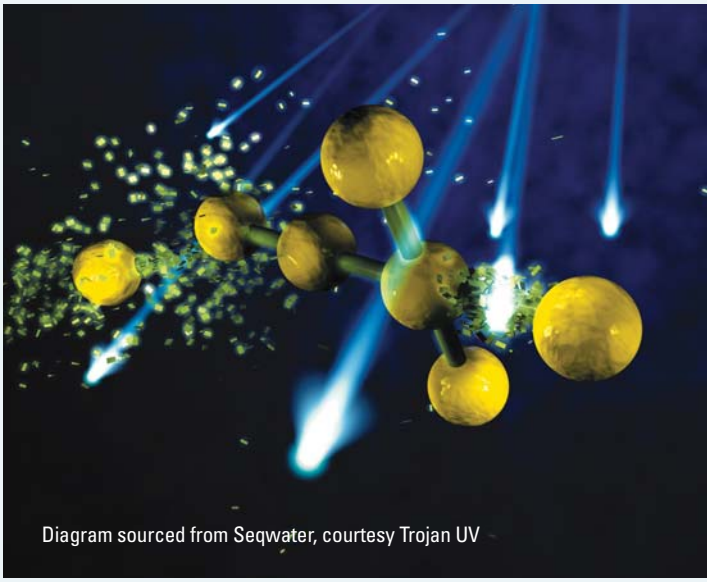

Diagram sourced from Seqwater, courtesy Trojan UV

National Validation Framework factsheet suite

This brochure is based on a 'road map' report funded by the Australian Water Recycling Centre of Excellence. The 'road map' describes a national approach for validating treatment technologies, and was based on extensive consultation with stakeholders.

This brochure is one of a series that describes the outcomes of the first stage of this national validation project.

Other brochures in the series cover:

> An overview of the draft National Validation Framework
> Perspectives of water recyclers, technology suppliers and regulators
> Validation of various treatment systems
> Building capacity in the industry

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For further information visit www.australianwaterrecycling.com.au

Australian Water Recycling Centre of Excellence

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