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The Australian Water Association is an independent, not-for-profit association for water professionals, with an overarching mission to promote the sustainable management of water. AWA is Australia's peak water industry association, being the largest and most broadly based.

It represents and connects individuals and organisations working around the nation, integrating ideas and knowledge among people involved in regulation, consultancy, research, management and operations, drinking water, wastewater and stormwater disciplines.

AWA is represented in sectors including engineering, utilities, science and research, and manufacturing and has over 4,000 individual and 650 corporate members, nationally.

For latest updates, detailed program information and online registration visit: www.ozwater09.com.au

Chairman's Welcome

Welcome to Ozwater 2009, the AWA's 23rd national conference and exhibition since the inaugural convention held in 1964.

Ozwater and AWA are synonymous with quality water conferences and exhibitions. In these days of water's enormous profile in all sectors of government and the wider community, there are many forums for discussion. Ozwater is the pinnacle for balanced and informed presentations and debate, along with networking with more than 1000 national and international delegates.

Ozwater 2009's theme "From Challenges to Solutions" acknowledges the emerging and current solutions for the many challenges facing the water industry such as climate change, water shortages and skills shortages. These solutions are essential to ensure sustainability, not only for water but for the whole planet.

Australia is at the forefront in many aspects of water management; water resource management, water conservation, asset management and institutional arrangements are just a few examples. A further consideration is the interdependence of rural and urban user needs and the careful balance required between them. However, we are not alone in the challenges and it is important to ensure that the latest international trends and learnings are presented.

Consequently some 12 eminent speakers encompassing experiences, challenges and solutions from within Australia, Europe, Asia, the Indian sub-continent and the Americas are presenting under the themes of:

- Integrated Water Management
- Water and Wastewater Systems and Processes
- Policy and Strategy
- Emerging and Innovative Technologies and Research

The keynotes are supported by some 200 platform papers and a multitude of poster papers chosen from over 500 abstracts.

Choosing the papers was a challenge for the Program Committee and the band of paper reviewers; the outcome has been assurance of quality across the many subjects of importance to the water industry.

AWA's national partner, the Water Services Association of Australia, and international partner, the International Water Association, have their specialist themes integrated to ensure a balanced program.

Ozwater 2009 also presents the largest exhibition of water technologies, processes, equipment, materials and intellectual property ever assembled in Australia. The wide range of major multi-faceted companies, along with specialist suppliers of goods and services, ensures the opportunity to view and touch and to discuss particular needs with exhibitor's experts in one location.

Talking location, Melbourne's convention and exhibition complex is unique in providing an opportunity to get some fresh air while moving between the venues, something we should all take advantage of.

The famous Ozwater networking opportunities will be here – the welcome reception, the gala dinner, the exhibition drinks and the breaks throughout the day mean that you will be able to catch up with old acquaintances and make new ones.

Specialist workshops on Sunday and technical tours on Thursday provide opportunities for that little bit extra that the main conference and exhibition cannot cover. And accompanying persons have not been forgotten – a program has been organised to enable you to meet other accompanying persons and have the opportunity to experience some of the inimitable features of Melbourne and its surrounds.

Ozwater 2009 has all the ingredients to continue the internationally-acclaimed conference and exhibition established by previous Ozwaters. The only other ingredient is you – the delegates. I invite you to come along and contribute to the solutions required to the many challenges facing the Australian and international water industries.

Allen Gale
Chairman,
Ozwater 2009 Committee

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Invitation from AWA's Chief Executive

Water is not just 'Flavour of the Month' it seems; when it comes to topical issues, water is 'Flavour of the Decade'. This is a double edged sword for those in the water industry. It is wonderful to be recognised, to be busy and to have lots of interest in our endeavours. The flip side however is that we all find it very hard to make the time to attend conferences.

But it is exactly because of the criticality of water and the demands placed on us as water professionals that we need to make time. The depth and strategic significance of the challenges that confront us – in Australia and around the world – demand innovative thinking and new approaches and technologies. Whether we are water professionals or we just have an abiding interest in water matters, it is important to take time to reflect; to share our experiences and learn from others; and to celebrate the achievements of our peers. This is the essence of Ozwater.

For over forty years now the Australian Water Association has brought together the best and brightest to explore and challenge. Ozwater is without doubt the biggest and best event on Australia's national water calendar. It offers:

- Leading national and international keynotes and invited speakers
- A comprehensive and substantive program of papers, peer reviewed to deliver outstanding quality and relevance
- An extensive exhibition
- Further support through parallel meetings, events and workshops

What makes Ozwater unique is its value proposition; it is run by and for the benefit of water professionals. Behind the scenes there has been a mountain of work done by Allen Gale (the Conference Chairman) and the Committee. Every one of these people is a volunteer who has committed their time and talent to delivering this event. It has been time well spent, as can be seen by the quality of the program and associated activities.

Occasionally one hears the complaint that Ozwater has too much on offer; that delegates cannot attend all the presentations that they would wish to. AWA makes no apology for the extensive coverage of topics and the breadth of the program on offer. What it means is that, whoever is the delegate, their investment in Ozwater will be amply rewarded.

I look forward to welcoming you to Melbourne for what will be an outstanding event.

Tom Mollenkopf
Chief Executive
Australian Water Association

From Challenges to Solutions

Ozwater is an event like no other, organised by the industry for the industry where the issues that drive the industry are discussed and future directions decided. Ozwater '09 will take place at the Melbourne Convention and Exhibition Centre, 16-18 March 2009 and will address the wide ranging issues that face the water industry today. These include major national water reforms, climate change and its impacts, technological advances and the challenges of human resources to name a few.

The theme for Ozwater '09 is 'From Challenges to Solutions' where the conference will address some of the important issues that impact on our industry. The Ozwater '09 Conference will feature inspirational international and national keynote speakers, numerous invited speakers, scientific and technical papers, case studies, workshops and poster sessions. This will be a water industry opportunity like no other to network and engage with industry leaders and experts from all over Australia.

As well as an international-standard three day conference, a major component of the event will be an extensive Ozwater '09 Trade Exhibition that will showcase the best of what the industry has to offer. Leading organisations from around the world will participate, exhibiting their products, services and innovations. In addition to the Ozwater '09 delegates, it is anticipated that thousands of trade visitors will attend the free exhibition. An exciting new floor plan layout will ensure maximum interaction between exhibitors, delegates and trade visitors.

There will be extensive multi-level networking and social activities that will offer the opportunity to engage leaders and industry experts on an individual basis and discuss and share issues important to you. No other water industry event in Australia receives the support or promotion as does Ozwater.

MICROBIAL DECAY FACTOR METHOD: A SIMPLE PRE-WARNING TOOL OF ONSET OF SEVERE NITRIFICATION IN CHLORAMINATED DISTRIBUTION SYSTEM

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ABSTRACT

Maintaining adequate disinfectant residual in systems with long retention times is a challenge due to microbial acceleration of chloramine decay. Various findings showed that nitrification, major cause of microbiological acceleration, can be controlled by controlling free ammonia and chloramine residual. Chloramine control to the required level will be difficult, if microorganisms in the water accelerate chloramine decay. In the past such acceleration is not quantified and hence is not utilised as a control parameter. Recently, a sensitive method - "microbial decay factor" (F_m) – was developed to measure this acceleration. It was shown that measurement of F_m can provide early warning as opposed to traditional indicators. This paper shows how F_m could be utilised as a pre-warning tool in a real distribution system using a hypothetical distribution system reservoir.

INTRODUCTION

Since the mid-1970s, the use of (mono)chloramine to disinfect drinking water has greatly increased. This maintains a longer-lasting disinfectant residual and reduces chlorinated disinfection by-product (CDBP) formation. When the chloramination process is well controlled, chloramine reacts with the dissolved organic matter remaining in drinking water after treatment, at a relatively slow stable rate. This, together with the auto-decomposition of chloramine, constitutes the basic "chemical decay rate". It is generally slow enough to maintain an adequate residual for several hundreds hours.

Another important factor adding to the instability of monochloramine in the distribution system is the existence of nitrifying bacteria – thus resulting in microbial decay. The main source of nutrients for these nitrifiers is free ammonia compounds released when combined forms of chloramine is decayed. Nitrite (NO_2^-) is produced by the oxidation of ammonia; then nitrate (NO_3^-) is produced by the oxidation of nitrite. This process is known as nitrification. Nitrification is very well known to cause accelerated chloramine decay in the distribution systems and severe losses of chloramine have been reported. Once severe nitrification is triggered it is usually hard to revert back to the original non-nitrifying situation without serious interference. Therefore it is very important to understand when possibly nitrification is induced.

Traditional indicators such as nitrite, nitrate, ammonia, and drop in chloramine residuals are often used to assess the disinfection status of a chloraminated water supply. Traditional indicators have got three major drawbacks (Sathasivan et al., 2005): These do not measure how much micro-organisms or chemical reactions contribute to chloramine decay, thus it was difficult to know why chloramine is dropping when temperature increases in summer; Slow activity of nitrifiers in winter could be interpreted as not existing; and When traditional indicators reach levels of concern it is usually too late to implement any changes. Hence, the use of these indicators leads to reactive approach rather than preventive approach.

NEW DEVELOPMENT IN NITRIFICATION MONITORING AND CONTROL

Recently, a simple measurement method termed the microbial decay factor (F_m) was proposed to measure the microbiologically assisted chloramine decay, relative to chemical chloramine decay in a water sample (Sathasivan et al., 2005). In this method, the microbiological and chemical components of chloramine decay are determined by comparing the chloramine decay in an unprocessed sub-sample with the decay in a sub-sample with the microbiological contribution removed by inhibition or filtration. The authors showed that the method is capable of providing early warning of the potential escalation of microbiologically assisted chloramine decay (including that due to nitrification) in summer by measuring winter decay characteristics.

$$F_m = \frac{k_m}{k_C}$$ **Equation 1**

Where F_m is the microbiological decay factor, k_m is the microbiological decay rate coefficient and k_C is the chemical decay rate coefficient. All (first order) coefficients are estimated from daily chloramine readings of duplicate treated and untreated samples incubated at 20°C for about a week. The first order decay coefficient of untreated samples are termed total decay rate (k_T) and that of treated, inhibited by silver nitrate, samples are termed chemical decay rate coefficient. The k_m value can be estimated by the following relationship:

$$k_T = k_C + k_m$$ **Equation 2**

Biostable residual curve or nitrification potential curve provides a guidance residual level at which severe nitrification is seen (Fleming et al., 2005 and Sathasivan et al., 2008a and 2008b). Fleming et al., 2005 separated the nitrifying and non-nitrifying points in distribution system with nitrification potential curve. However, others (Sathasivan et al., 2008a) showed that this need not be the case. They showed critical threshold residual (CTR), the residual at which severe nitrification is triggered, need not always be at the biostable residual curve and there is a possibility that even when the residual drops below the biostable residual curve, signs of severe nitrification need not always be seen (Sathasivan, 2008b). The biostability curve is defined as follows:

$$\frac{\mu_m.N}{(K_s + N)} = k_d.TCl$$ **Equation 3**

Where N is the free ammonia nitrogen and TCl is the total chlorine concentration. K_s and μ_m/k_d were estimated as 0.08 and 2 mg/L respectively by Sathasivan et al., 2008b. This is defined by balancing growth (left hand side of Equation 3) and disinfection (right hand side of the Equation 3). The points at which severe nitrification could onset in real distribution system could be pictorially represented in Figure 1 as blue line. Profile of both total chlorine and free ammonia is presented in the same figure to demonstrate how onset of severe nitrification occurs.

Biostability curve is defined by very small Ks value, 0.08 mg-N/L. In other words, even a very small free ammonia concentration can trigger severe nitrification, if the residual is sufficiently low. For example, when 0.08 mg free ammonia–N/L was present 1 mg/L is not sufficient enough to prevent severe nitrification from happening.

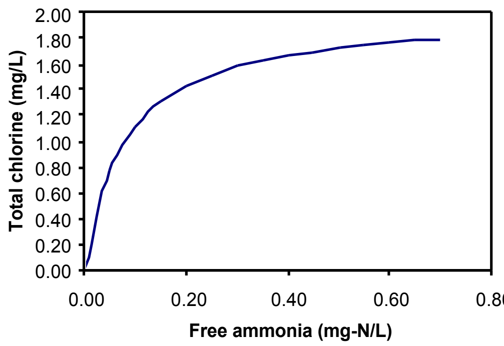

Figure 1: Biostability curve or nitrification potential curve as defined by Sathasivan et al., 2008b. The μ_m/k_d and K_s are 2 and 0.08 mg/L respectively.

As the disinfectant drops, the most important energy source for nitrifying bacteria, free ammonia, increases creating a favourable condition for nitrifying bacteria. To demonstrate the usefulness of F_m method, a hypothetical example is developed. The example used the typical chemical decay rate measured in Sydney Water samples, variable F_m values and at variable temperatures. Usually, it is thought that maintaining retention time in the range of 3 days in reservoirs can prevent onset of nitrification. To show that required retention time could vary depending on F_m values, initial chloramine residual dosing and temperature, calculations are done in the following sections. Therefore, it is shown that F_m measurement or estimation of additional decay happening in reservoirs is important.

CHANGES OCCURRING DURING CHLORAMINE DECAY IN BULKWATER SAMPLES

Behaviour observed for one of the samples of a reservoir is shown in Figure 2. The behaviour was similar to what was observed by Sathasivan et al., 2008a, except for the value of CTR. In all the samples collected from Sydney Water, where total ammonia dosed was 0.35 mg-N/L, Sathasivan et al., 2008a reported the CTR value to be between 0.2 and 0.65 mg/L. In this sample, initial total ammonia was 0.75 mg/L. The CTR value in the sample was 1.22 mg/L. In other samples, the CTR varied between 0 and 1.22 mg/L, indicating a difficulty in accurate prediction of CTR. This is a clear indication that CTR is not simply controlled by the residual itself; it is also a function of other factors such as free ammonia and initial ammonia oxidising bacterial concentration.

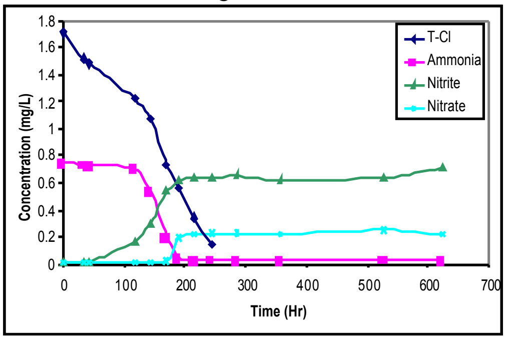

Figure 2: Behaviour of a bulk water sample when exposed to prolonged incubation. Critical threshold residual (CTR) is estimated to be 1.22 mg/L.

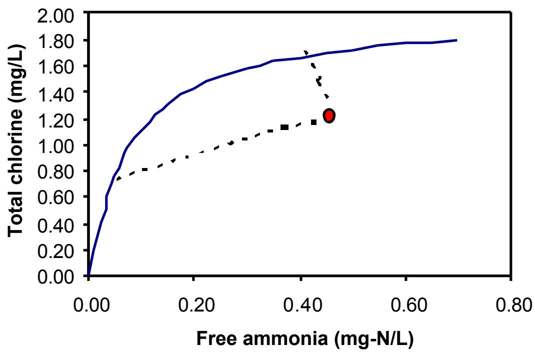

Figure 3: Profile of total chlorine and free ammonia of Sample A is plotted on biostability curve. Biostable curve is defined by free ammonia and total chlorine residual. CTR point is shown as red point.

CALCULATION OF SAFER RESIDUAL

The biostability point for this sample lies on the curve. CTR is shown as red dot in Figure 3. In Sample A, the CTR and biostable point are different, as previously observed by Sathasivan et al., 2008a. However, the upper limit for all CTR is biostable residual. Therefore, the point at which dotted curve and biostable curve meets is the residual that should be controlled in a reservoir. The residual is 1.75 mg/L for a water that contains total ammoniacal nitrogen of 0.75 mg/L. This would be the safest residual that the utility should maintain to avoid the onset of severe nitrification.

F_m RELATED PARAMETERS AND THEIR IMPLICATIONS FOR RESIDUAL MANAGEMENT

The decay rate coefficients measured in the sample, for which the decay characteristics are shown in Figure 2, is shown in Table 1. The result shows microbiological decay rate is about 0.9 times that of chemical decay rate (F_m =0.9). Chemical decay rate in many mildly nitrifying bulk water samples collected from Sydney Water did not change very much. Smaller increases of nitrite are not expected to increase the chloramine decay substantially. This had been shown in Sathasivan et al., 2008a. However, microorganisms impacting chloramine decay can grow, thereby microbes can accelerate the chloramine decay. Therefore, only parameter that could change substantially is microbiologically assisted chloramine decay rate k_m. The change of microbiological decay rate can increase the total decay rate and hence reduce the time available, before severe nitrification is onset.

Table 1: F_m method related parameters

Measured parameters	Measured values[1]
Total decay coefficient, k_T	0.0028
Chemical decay coefficient, k_c	0.0015
Microbiological decay coefficient, k_m	0.0013
Microbiological decay factor, F_m	0.9

[1]: All decay coefficients are in hr^{-1}.

CALCULATION OF SAFER RETENTION TIME BEFORE POTENTIAL ONSET OF SEVERE NITRIFICATION.

In a typical water distribution system, water spends majority of travel time in reservoirs. Therefore, the reservoirs would be critical in distribution system. If severe nitrification would onset at 1.75 mg/L, then the retention time needed to reach such residual with different F_m values could be calculated, assuming completely mixed constant volume reactor and 20°C temperature. Resulting residual for different F_m values and retention time is plotted in Figure 3. For 2.5 mg/L inlet residual, safer retention time is calculated from Figure 3. As shown below for three cases:

Case 1: If F_m is zero, i.e. there was no microbiological acceleration, then the residual can last for about 290 hrs. This scenario is unrealistic, since there is rarely a case when only pure chemical decay is present in the distribution system water.

Case 2: In the original sample, safe retention time is calculated to be 150 hrs. The safer retention time is half that of the previous best case scenario.

Case 3: If F_m is 4, then safer retention time will be further reduced to about 57 hrs.

It is usually possible to have both second and third cases. In some cases, F_m value of even 20 was obtained in laboratory as well as real distribution system samples.

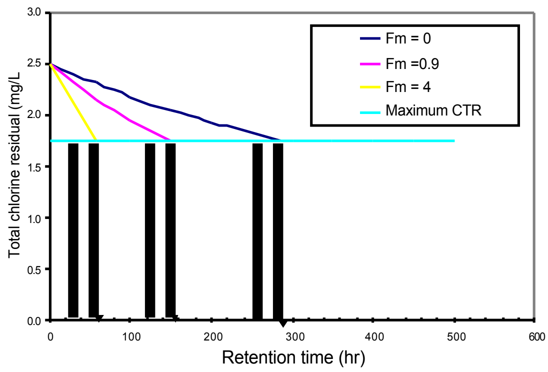

Figure 3: Demonstration of safer retention time before onset of severe nitrification in a reservoir.

Similarly increase in temperature would increase both chemical decay and microbiological decay (Sathasivan *et al.,* 2008c). This will also decrease the retention time that can be safely maintained. Therefore, F_m measurement and understanding when onset of severe nitrification would happen will pre-warn water utilities.

CONCLUSIONS

If there is no microbiological component, k_T is equal to k_c, chemical decay rate. When chloramine residual drops, free ammonia is eventually released into the water, leading to increased energy source for ammonia oxidising bacteria. When right advantage is present, nitrifying bacteria can proliferate. The point at which these signs are starting to show is referred to as critical threshold residual. Depending on the presence of number of microorganisms responsible for accelerating chloramine decay and temperature, the decay rate will change. At higher temperatures, bacterial growth as well as increase in impact on both microbiological and chemical chloramine decay will result. This will further shorten the time takes for onset of severe nitrification.

Knowing when severe nitrification would onset and what decay rates or F_m is present, would help in determining the allowable retention time. Such calculations are not possible when traditional indicators such as nitrite, ammonia, or chloramine are used. Because microorganisms growth is dependent on initial concentration of bacteria, reduction in initial concentration can greatly prevent the onset of severe nitrification. Such presence of microorganisms is usually manifested in microbiological decay rate coefficients. Therefore measurement and control of microbiological decay rates can help in suppressing chloramine decaying organisms. Overall microbiological decay factor method can help in pre-warning water utilities about possible onset of nitrification and provide guidance retention time necessary to prevent severe nitrification.

ACKNOWLEDGMENT

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