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INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

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Report On Brisbane Fluoride Incident

An expert report into the fluoride overdosing incident in Brisbane in May this year has highlighted a series of problems with equipment and monitoring systems, as well as inadequate training, communication failures and poor management systems that collectively contributed to the incident. The report, by the International WaterCentre (IWC) in Brisbane, was commissioned by the Queensland state government and reviewed the following aspects of the event:

- the design and operation including the control systems of the fluoridation system at North Pine Water Treatment Plant;
- monitoring programs undertaken by various relevant agencies, including review of data collected;
- the communication and notification systems that are in place and their effectiveness;
- emergency response plans and their effectiveness;
- other fluoridation systems in operation in South East Queensland;
- national and international experience in fluoridation systems, particularly any insights in relation to best practice in systems and operations.

As reported in Health Stream Issue 54, the overdosing occurred after fluoride dosing equipment continued to operate during a scheduled maintenance shutdown of the plant. It was initially believed that a large volume of highly fluoridated water had flowed into the distribution system when the plant was restarted, possibly exposing up to 4000 households to elevated fluoride levels (initially reported as over 30 mg/L but later revised to 20 mg/L) for several hours. However subsequent investigations revealed that most of the affected water had been used for backwashing filters at the plant, and the potential for public exposure was much less than originally thought. The main findings of the IWC report are summarised here.

The North Pine Water Treatment Plant was originally commissioned in 1974 but has been upgraded a number of time since then. It treats water by a conventional process of chemical coagulation, sedimentation, rapid sand filtration and disinfection. Additional treatments are also used for removal of iron and manganese, cyanobacterial toxins and taste and odour compounds. The plant treats water from Lake Samsonvale (North Pine Dam) which is then blended with fully treated, fluoridated water from the Northern Pipeline Interconnector, which transports water from another water treatment plant on the Sunshine Coast. These supplies feed into the South East Queensland Water Grid, which supplies water to Brisbane, Ipswich and the Gold Coast. The Water Grid was formed in late 2007 as part of a major restructure of water supply arrangements in South East Queensland in order to provide improved water security to this rapidly growing region. The Water Grid Manager (a statutory authority) purchases bulk water from Seqwater (a state-owned entity responsible for managing bulk water supplies and water treatment) and water transport services from LinkWater (another state-owned entity responsible operating the major pipeline network). Treated water is then sold to local Retail Businesses by the Water Grid Manager. The fourth entity involved in water supply is WaterSecure, which supplies water to the Water Grid from the Tugun Desalination Plant and the Western Corridor Water Recycled Water Project.

The fluoridation system at the North Pine treatment plant was installed in late 2008, and adds a solution of sodium fluorosilicate to the treated and filtered water as it exits the plant through a large mains pipe. The sodium fluorosilicate solution is made up from the powdered form by automated equipment at the plant. The target level for fluoride dosing is 0.8mg/L for water supplied to consumers, and dosing levels are set taking into account blending of water with already fluoridated water from the Northern Pipeline Interconnector. The maximum regulatory limit under the Queensland Public Health Regulation 2005 is 1.5 mg/L. The dosing system was designed so that fluoride addition was controlled by three devices:

- a treated water flow meter which measures the rate of water flow in the mains pipe. The signal from this meter regulates the volume of fluorosilicate solution being added to the pipe. In the event of zero flow, no fluoride solution should be added.
- a flow switch which indicates a flow/no flow status. In the event of 'no flow' situation this switch also should prevent fluoride dosing from occurring.
- a fluoride analyser which continuously samples water drawn from the pipe about 50 metres downstream of the fluoride dosing point. This analyser had a primary alarm setting at a fluoride level of 1.0 mg/L (Hi alarm) and a secondary alarm setting at a fluoride level of 1.2 mg/L (Hi Hi alarm). The secondary alarm was also set to trigger an automatic shut down of the fluoride dosing equipment. The analyser reports fluoride levels up to a maximum of 3.0 mg/L. The treatment plant is operated by Seqwater, however the fluoride injection point, treated water flow meter and fluoride sampling point are located in a section of pipe owned and managed by LinkWater.

The time sequence of events as determined from written records, interviews with staff of relevant agencies and SCADA records from automated system monitoring is outlined below:

- Before 24 April - the investigation showed that at some time before the incident (date unknown) the 1.0 mg/L 'Hi alarm' on the fluoride analyser had been disabled, apparently due to repeated false alarms.

- 24 April - the flow switch was removed from the control loop as it had been repeatedly switching on and off erratically for several days (sometimes signalling "no flow" when water was flowing, or "flow" when water was not flowing). It appears that this action, taken by Seqwater maintenance staff in consultation with a contractor, was not communicated to operations staff.

- 27 April - the water treatment plant was shut down for maintenance. On the same day, operations and contractor personnel noted intermittent malfunctions of the treated water flow meter, with the meter sometimes registering water flow when none was actually occurring because of the plant shutdown.

- 28 April - the false flow readings from the malfunctioning treated water flow meter caused fluoride dosing to be triggered intermittently over a period of five hours. As the water in the mains pipe was not moving, it took some time for the added fluoride to diffuse along the pipe and reach the sampling point for the fluoride analyser.

- 29 April - early in the morning the fluoride analyser recorded a reading of 1.5 mg/L, which triggered the 'Hi Hi alarm' and a shut down of the fluoride dosing equipment. This alarm was recorded by the plant operator at Mount Crosby (the North Pine plant being unmanned at the time), but as the North Pine plant was shut down and not producing water, it was assumed to be a false alarm and no investigation was made. Later that morning a routine daily water sample was taken downstream of the fluoride dosing point by LinkWater and sent for laboratory analysis. The faulty flow switch was also repaired on 29 April but was not returned to service as it could not be recalibrated due to lack of flow in the water main.

- 30 April - two backwash cycles of the filters were run in preparation for restarting the plant. Fortuitously this water (approximately 800,000 litres in total) was taken from the pipe that now contained water heavily overdosed with fluoride, although the overdose problem remained undiscovered at this time. On the morning of the same day an operator at the North Pine plant filled in a routine form showing consumption of 16.09 kg of dry fluoride powder during the previous 24 hours. Given that the plant had not been producing water for three days, there should have been no need for the automated system to make fluoride solution from powder. During the later investigation, the operator stated that this anomaly had been reported to supervisory staff but no record of this report was found. On 30 April an analysis of flow records for the period 3.00am to 7.30am was made and a false flow reading of 50 megalitres was found. This apparently prompted recognition that there was a risk of fluoride dosing being triggered by a false flow signal. The fluoride dosing equipment was shut down at 2.00pm and then manually disabled at 5.38pm.

- 1 May - the plant operated for a short time only.

- 2 May - the plant resumed normal operations but without fluoride dosing.

- 11 May - the water sample taken on 29 April was found to contain 31.2 mg/L fluoride by the testing laboratory. The laboratory phoned LinkWater but the call was not answered. A message was left requesting a call back.

- 12 May - the laboratory reported the high fluoride reading to LinkWater by telephone and email. LinkWater acknowledged receipt of the message and passed the information to Seqwater, however LinkWater also questioned the accuracy of the analysis result and did not notify the Water Grid Manager within the timeframe required by relevant legislation.

- 13 May - at about 4.00 pm Seqwater formally declared an 'Incident' by verbal notification to the Water Grid Manager and Queensland Health, who in turn notified the Office of the Water Supply Regulator. The Emergency Response Plan was activated, with the Water Grid Manager acting as coordinator of the response. Directions were also issued to other water treatment plants operated by Seqwater that fluoride dosing equipment must be manually deactivated whenever plants were shutdown.

- 14 May - Seqwater and LinkWater undertook an investigation to establish the amount of fluoride that had been dosed during the plant shutdown and the probable distribution of the over-fluoridated water when the plant was brought on-line. However the initial review of SCADA records by Seqwater was limited in scope, and did not reveal that the affected water had been used for backwashing filters. Therefore erroneous advice was given to the Water Grid Manager that the water had been pumped out to the distribution system, potentially exposing about 4000 homes to water with high levels of fluoride for a period of about 3 hours.

- 15 May - Further analysis of records by Seqwater established that the over-dosed water had been pumped back into the plant on 30 April and used for filter backwashing. This meant that the suburbs previously identified (and publicly announced) as exposed were in fact not exposed. It was determined that most of the contaminated water had been used in the first backwash, with a small number of people on the plant site (in the plant buildings plus four houses) possibly exposed for a period of about one hour between the two backwash cycles. In addition, over-dosed water may have been supplied to a YMCA camp adjacent to the plant and 400 homes in a nearby suburb during the time between the triggering of the fluoride alarm on 29 April and the start of backwashing on 30 April, a period of approximately 31 hours. This revised assessment was subsequently delivered to the Water Grid Manager and then advised to the public.

As is the case for most water quality incidents and waterborne disease outbreaks there were a number of contributory factors, both chronic and short term, which combined to permit this situation to occur. These included existing shortcomings in management and internal communication systems, failure of staff to respond appropriately to alarms and other clues that something was amiss, inadequate staff training and specific problems relating to equipment and monitoring. For example, while the plant had a sophisticated SCADA system, the recently added component relating to fluoridation had not been well integrated with the existing plant control system, and did not include interlocks between dosing and pumping systems which could have prevented this incident from occurring. The lack of interlock control on fluoride dosing is in breach of the Queensland Water Fluoridation Regulation 2008.

Despite general training in fluoridation systems and specific on-site training at the North Pine plant, operators appeared not to have a full understanding of the fluoride dosing control system as evidenced by the failure to respond to the ‘Hi Hi’ fluoride alarm, due to the belief that fluoride dosing could not occur when the plant was shut down. Recent experience of false alarms from the fluoride analyser may also have contributed to the lack of response. The analyser had in fact been serviced by a contractor due to the false alarm problem and was operating correctly, but operators were not aware of this. Operational staff had also not been informed that the flow switch had been removed from the control loop and therefore was not capable of controlling the fluoride dosing equipment. The failure to investigate the use of fluoride powder when the plant was not producing water was also a missed opportunity to detect and remedy the problem at an early stage.

Once the problem was discovered, notification of the relevant agencies was slower than it should have been, and the initial assessment of the distribution of the over-dosed water was inaccurate as only a partial review of available information was undertaken. Subsequent testing also revealed the first test result of 31.2 mg/L was inaccurate, with a duplicate sample tested by the same laboratory giving a result of 17 mg/L and a sample tested by another laboratory giving a level of 19.6 mg/L. The IWC review notes that the restructuring of the South East Queensland water supply system has been accompanied by a substantial expansion in requirements for water quality monitoring programs, and some concerns have been raised about the limited laboratory capacity available in the state and the current lack of a laboratory proficiency testing program.

The recent water reforms in Queensland include a requirement for large water suppliers to develop Drinking Water Quality Management Plans (DWQMP), consistent with the Australian Drinking Water Guidelines, by July 2011. Medium suppliers must have approved plans by July 2012 and small suppliers by July 2013. This process requires a systematic analysis of risks to water quality and development of ‘catchment to tap’ management plans. The rigour of this process should identify problems and potential hazards such as those which permitted the over-dosing incident to occur. While the DWQMP for the North Pine plant had not yet been developed, the plant did have an existing HACCP (Hazard Analysis Critical Control Point) plan. The elements of HACCP parallel the risk assessment and risk management components of a DWQMP, and if implemented correctly should also have been able to prevent this incident. However the HACCP plan for the plant had not been updated to include the fluoridation system. The IWC report also notes that the complexity of the water supply system in South East Queensland suggests that an integrated approach is needed to coordinate and integrate the DWQMPs for the different entities in the water supply chain to ensure the quality of water delivered to the public.

In the wake of the incident, the Office of the Water Supply Regulator issued a formal warning to Seqwater and also imposed requirements for a range of actions including review of operating procedures, implementation of interlock controls on fluoride dosing, additional staff training, improvements in communication and record keeping procedures and a consideration of an alternative location for fluoride dosing. LinkWater was issued with a warning letter requiring urgent replacement of the faulty water flow meter and a range of other actions relating to incident response, review of water quality data, more rapid turn-around times for laboratory testing and improved communication with Seqwater regarding shared infrastructure. An investigation by Queensland Health concluded that while Seqwater had breached the *Water Fluoridation Act 2008*, there was inadequate evidence to consider prosecution under the 'supply of unsafe water' offence. However, Seqwater failed to comply with the provisions of the *Water Fluoridation Regulation 2008*, and was issued with a remedial notice by Queensland Health that required implementation of various actions to ensure full compliance with regulatory requirements.

The International WaterCentre report and other reports relating to this incident are available at: www.nrw.qld.gov.au/compliance/wic/fluoride_incident.html

Water Problems Hit Alpine Resorts

Two popular alpine resorts in New South Wales Snowy Mountains region were recently hit by water quality problems at the height of the ski season. Up to 400 people at the village of Smiggin Holes became ill in a waterborne disease outbreak, while in a separate incident the nearby town of Jindabyne was issued with a precautionary boil water alert after a sewage spill into the local dam. Smiggin Holes is located within the Kosciuszko National Park close to the Perisher Blue ski fields. The water supply is drawn from an alpine creek in a pristine area and is pumped to a storage tank before being treated by UV irradiation and distributed to buildings in the village. It is believed an equipment malfunction caused the automated top-up of the tank to stop and this in turn caused an automatic shutdown of the UV unit. However an alarm which should have immediately alerted staff to the problem failed to trigger, and the water in the storage tank fell to a low level. When this was discovered the pump was turned back on to rapidly refill the tank, resulting in resuspension of sediment. The UV unit was not initially restarted, leading to distribution of untreated, high turbidity water for a short period of time on Wednesday 12 August. The first cases of illness occurred on 13 August, with the majority reportedly on 14 August. As cases occurred in several different ski lodges, a widespread exposure such as drinking water was suspected as the source rather than foodborne or person-to-person transmission which would have produced more localised disease clustering. Symptoms included cramps, diarrhoea and projectile vomiting, with a duration, in most cases, of 12 - 18 hours. A second wave of illness was suspected to be caused by food handlers who continued to prepare food while ill. A boil water alert was issued on the morning of Friday 14 August and remained in force for five days. Manual chlorine dosing also commenced on 14 August and continued for five days. Only a few affected people submitted faecal specimens for analysis and no causative microorganism was identified in faecal or water samples. Management practices are being reviewed as a result of the outbreak.

Jindabyne is outside the Kosciuszko National Park about 7 km away from Smiggin Holes (or 26 km by road) and is a popular accommodation venue for both the Perisher Blue and Thredbo ski areas. The town draws its water supply from Lake Jindabyne and there are two water treatment plants; one serving the main township and one serving the settlements of Jindabyne East and Berridale. The water supply is chlorinated before distribution to consumers, and is monitored weekly for chlorine residual in the distribution system. On Friday 7 August there was a sewer spill into Lake Jindabyne. This sewer spill polluted the lake and threatened water supplies. The sewage spill was caused by failure of a sewerage pump near the local bowling club. An alarm which should have alerted Snowy River Shire Council staff to a sewage overflow failed to trigger, possibly due to blockage by tree roots. As a result, the overflow continued over the weekend until it was detected by staff late on the afternoon of Monday 10 August.

Preliminary inspection showed the pump was in working condition but the operating switch was faulty, with one of three possible 'ON' settings not functioning. It appeared the switch had been turned to the non-functional position on Friday afternoon during a routine check of the facility by a worker who was not aware the switch was faulty. After discovery of the spill, the pump was immediately restarted and data logs checked to determine the duration of the overflow. It was estimated that up to 0.8 ML of raw sewage had overflowed and run into nearby Lake Jindabyne over a period of about 75 hours. The site of the spill was about 1.9 km from the drinking water intake for Jindabyne, and 3.3 km from the drinking water intake for East Jindabyne. Water samples were taken from the vicinity of the spill, from the Jindabyne drinking water intake, from a point about halfway between. A sample of chlorinated water was also taken from the water treatment plant. The NSW Department of Health was notified about the possible risk to the drinking water supply, and to recreational users of Lake Jindabyne.

A boil water notice was issued by the Snowy River Shire Council on Tuesday 11 August as a precautionary measure before the results of tests on the water samples were known. Hourly monitoring of free chlorine residual at the treatment plant was also instituted to ensure that disinfection levels were being maintained. Council officers telephoned every food and accommodation business in Jindabyne to make them aware of the problem and provide advice. Schools, childcare centres and medical centres were also individually contacted, and warning signs were displayed at the entrances to Jindabyne to alert visitors. Signs were also posted around the site of the spill, and recreational users were advised to avoid the affected area. No contamination of the treated water supply was detected during the incident, and the boil water notice was lifted on 26 August after consultation with NSW Health. The area of the lake worst affected by the spill was expected to remain cordoned off to exclude recreational use for a further 10 days. The pump station had already been earmarked for replacement in the near future due to ageing infrastructure, and a number of temporary measures are being considered by the local council to manage risks in the interim.

New NDMA Source Identified

Researchers in SA Water Corporation have discovered that rubber seals and other rubber components of water supply pipelines may release substantial quantities of N-nitrosodimethylamine (NDMA) into the water supply (1). NDMA is used as a plasticiser in the manufacture of rubber and polymers, and in a range of other manufacturing processes. It may also be formed as a byproduct of water disinfection with chlorine-based disinfectants, particularly chloramine. NDMA is carcinogenic in experimental animals and has been classified as a probable human carcinogen by the International Agency for Cancer Research. Recent research has indicated that NDMA may be leached from rubber products including rubber nipples on infant feeding bottles and pacifiers, however this is believed to be the first literature report of significant amounts of NDMA leaching into drinking water from rubber components of distribution systems.

The discovery was made following commissioning of a new branch main off an existing chlorinated water supply system. After initial disinfection of the new main, a series of water quality tests were undertaken to confirm that physical, chemical and microbiological parameters were within potable water guidelines. These tests showed lower than expected disinfectant residuals and higher NDMA levels than any previously found in South Australian water supplies in an investigative monitoring program conducted by SA Water Corporation since July 2006. Research has also been conducted on the effect of disinfection and water treatment processes on NDMA formation. There is currently no guideline value for NDMA in the Australian Drinking Water Guidelines (ADWG), but a guideline value of 10 ng/L has been set in the Australian Guidelines for Recycled Water for augmentation of drinking water supplies with recycled water (2).

It was found that NDMA levels were reduced by prolonged flushing of the new main but still remained higher than those in the existing pipe system. An investigation was undertaken to assess whether any of the materials used in the new pipeline were the source of the NDMA. The materials tested included pipe joining lubricant, PVC pipe sections and end pieces, and rubber sealing rings. Samples of each material were immersed for 24 hours in chloraminated water from an existing water supply and in milli-Q water as a control. The water was then analysed for NDMA. Detectable levels of NDMA were found only in water that had been in contact with the rubber sealing rings, and NDMA was present in both milli-Q and chloraminated water samples. Further experiments were undertaken by immersing rubber seals in mill-Q water for 24 hours followed by chloraminated water for 24 hours. Results showed that NDMA was being released from the rubber into the milli-Q water and subsequent exposure of the rubber to chloraminated water did not significantly increase the NDMA levels. Thus the NDMA was pre-formed in the rubber material rather than being generated by reaction with the disinfectant. Testing of rubber rings and rubber inserts from gate valves from a number of different manufacturers revealed that all released NDMA, although there was considerable variation in the amounts released.

To increase the understanding of the significance of NDMA in Australian water supplies Water Quality Research Australia recently funded a project entitled 'Occurrence and management of NDMA and other nitrogenous disinfection by-products in Australian drinking and recycled waters'(3). The aims of the project are:

- To clarify the occurrence of NMDA and other nitrosamine compounds in chloraminated drinking water, chlorinated recycled water and supplies with new rubber surfaces in contact with potable water.
- To work with water utilities who have elevated levels of nitrosamines to implement minimisation strategies.
- To prepare a generic national report on occurrence.
- To develop a guidance manual to aid water utilities in the minimisation of nitrosamine production.

1) A new source of NDMA in potable water supplies. Morran J, Whittle M, Leach J and Harris M. (2009) Water **36**(5): 9-101.
2) A Guideline Value for NDMA will be proposed under the current cycle of the ADWG rolling revisions, which will soon be published for public consultation.
3) If interested in participating in the WQRA project, please contact gayle.newcombe@sawater.com.au

News Items

Guidelines for Stormwater Recycling and Managed Aquifer Recharge Released

The Environment Protection and Heritage Council has released the final two modules of the Australian Guidelines for Water Recycling (AGWR):

- Stormwater Harvesting and Reuse - this module provides guidance on managing potential public health and environmental risks associated with the non-potable reuse of roofwater collected from nonresidential buildings and urban stormwater from sewered areas, including stormwater collected from drains, waterways and wetlands.
- Managed Aquifer Recharge - this module covers the use of aquifers to store water derived from either sewage or stormwater for later use or for environmental benefit. It focuses primarily on the protection of aquifers and the quality of the recovered water in managed aquifer recharge projects.

The new modules underwent final ministerial approval processes in July and were released on 21 August. This now completes the majority of the work program begun on late 2003 to develop comprehensive national guidelines on water recycling. The remaining component is final approval of the electronic Decision Support Tool (DST) which has been developed to support implementation of the Guidelines. The DST is expected to be released before the end of the year. The AGWR are available from: http://www.ephc.gov.au

Swine Flu Fears Lead to Holy Water Ban

Some Roman Catholic churches in Tokyo, Japan are reported to have emptied holy water basins due to fears that worshippers may spread 'swine flu' (influenza virus H1N1) when dipping their fingers into the water. Virus particles from the hands of one person could potentially be spread to the hands of others who subsequently use the same water. Infection could result if the second person then touches the mucous membrane of their nose, mouth or eyes before washing their hands. According to a report from Reuters News Agency, priests have also been asked to wipe their hands with disinfectant towels before distributing communion wafers.

From the Literature

Web-bonus articles

Summaries of these additional articles are available in the web page version of Health Stream and are included in the searchable archive at:

www.wqra.com.au/WQRA_publications.htm

Effect of arsenic exposure during pregnancy on infant development at 7 months in rural Matlab, Bangladesh.
Tofail F, Vahter M et al. (2009) Environmental Health Perspectives, **117**(2); 288-293.

Arsenic levels in ground water and cancer incidence in Idaho: An ecologic study.
Han YY, Weissfeld JL, Davis DL and Talbott EO. (2009) International Archives of Occupational and Environmental Health, **82**(7); 843-849.

Outbreak of cryptosporidiosis associated with a splash park - Idaho, 2007.
(2009) Morbidity and Mortality Weekly Report, **58**(22); 615-618.

Main Source of Drinking Water and Familial Aggregation of Kashin-Beck Disease: A Population Based on Case-Control Family Study.
Zhang Y, Guo X, et al. (2009) Annals of Epidemiology, **19**(8); 560-566.

Legionella control by chlorine dioxide in hospital water systems.
Zhang Z, McCann, C, et al. (2009) J American Water Works Association, **101**(5); 117-127.

Maternal and early life exposure to manganese in rural Bangladesh.
Ljung KS, Kippler MJ, et al. (2009) Environmental Science and Technology, **43**(7); 2595-2601.

Massive outbreak of viral gastroenteritis associated with consumption of municipal drinking water in a European capital city.
Werber D, Lausevic D, et al. (2009) Epidemiology and Infection, 1-8.

Indirect potable reuse: A sustainable water supply alternative.
Rodriguez D, Van Buynder P, et al. (2009) Int J Environmental Research and Public Health, **6**; 1174-1209.

Control of health risks in drinking water through point-of-use systems.
Liu R and Qu J. (2009) Chinese Science Bulletin, **54**(12); 1996-2001.

First Molecular Detection of Group A Rotaviruses in Drinking Water Sources in Beijing, China.
He XQ, Cheng L, et al. (2009) Bulletin of Environmental Contamination and Toxicology, 1-5.

Public health strategies for western Bangladesh that address arsenic manganese, uranium, and other toxic elements in drinking water.
Frisbie SH, Mitchell EJ, et al. (2009) Environmental Health Perspectives, **117**(3); 410-416.

Solar disinfection of drinking water (SODIS): An investigation of the effect of UV-A dose on inactivation efficiency.
Ubomba-Jaswa E, Navntoft C, et al. (2009) Photochemical and Photobiological Sciences, **8**(5); 587-595.

Arsenic

Arsenic in groundwater in New England - point-of-entry and point-of-use treatment of private wells.

Moller, T., Sylvester, P., Shepard, D. and Morassi, E. (2009) Desalination, **243**(1-3); 293-304.

Arsenic concentrations in groundwaters in the US are mostly low, but levels greater than 10 ppb (the current US Environmental Protection Agency maximum contaminant level (MCL) for arsenic) are prevalent in some regions including New England and several southwestern states. There are currently no federal requirements to monitor arsenic levels in private wells and owners are responsible for the quality and safety of their well water. Point-of-entry (POE) and point-of-use (POU) arsenic removal systems may be an effective treatment option for individual households and small communities using groundwater in these areas. Devices based on fixed bed arsenic adsorption technology on hybrid hydrous iron oxide/polymer media (ArsenX$^{np®}$) have advantages over other technologies such as ion exchange (needs regular regeneration) or reverse osmosis (reject water may be wasted). The functional service life of hybrid hydrous iron oxide/polymer media systems depends on the concentration of different arsenic species in the water (arsenate and arsenite), the cumulative volume of water filtered, the pH and the presence of other ions such as silica and phosphate. Using data from field studies with a variety of water conditions, it is possible to predict the service life of the units with reasonable accuracy for a particular water quality.

A study was conducted based on data collected from a water sampling and testing service provided to customers in eastern New England who had installed devices of the npXtra™ System (containing ArsenX$^{np®}$ medium). These systems contain two media columns in series with a sampling point located between the columns so that partially treated water can be sampled in addition to untreated and treated water. Samples of untreated, partially treated and treated water were collected at the time of installation from 236 POE and 39 POU systems over an 18 month period from November 2005 until

August 2007. After 6 months (for POU) or 9 months (for POE) customers were sent a sample kit and asked to submit water samples, with 62 supplying samples. Of the tested well waters (untreated), 77% had arsenic concentrations less than 50 ppb which was the USEPA MCL for arsenic until January 2006, and 22% had levels below 10 ppb. About 9% of the samples had levels greater than 100 ppb arsenic with only five sites exceeding 300 ppb. The highest arsenic levels were found in New Hampshire and Maine while on average New Jersey had the lowest concentrations. The largest number of tested private wells having arsenic levels above the 10 ppb MCL occurred in Maine. The collected data was generally consistent with the findings of US and state Geological Surveys of the region.

During the 1.5 years of operation, some of the first installed systems started to show arsenic breakthrough in partially treated water samples, indicating that the first media column was nearing saturation. This was consistent with predictions based in water quality characteristics. Generally it appears that when arsenic levels are below 50 ppb, the POU/POE units will last at least 1.5 years. However, when waters have pH values higher than 8.5 and arsenic levels above 100 ppb, the life of the POE and POU systems are shorter, often 10-12 months. Premature exhaustion of the ArsenX$^{np®}$ media can also be due to elevated silica and phosphate levels in the water. An unexpected early breakthrough can also occur when arsenic exists in arsenite form which adsorbs more poorly to the medium than arsenate.

Periodic arsenic analysis of the customers waters have shown that the POE and POU systems operate as predicted and meet the requirements of the customers in terms of arsenic removal and ease of operation. No physical problems such as flow, back pressure build-up or blocking of the systems have been reported. Only 10 of the systems have needed to be replaced since becoming operational which corresponds to 4.2% of all the devices installed.

<u>Comment</u> *The authors note that only 52% of the expected number of water samples have been returned by customers, but it is not known whether all customers received the sampling kits. The effectiveness of POU/POE devices for reducing arsenic exposure can only be assessed by a longer term study so that the willingness and/or ability of customers to maintain systems in good working order is evaluated. This is particularly important when failure/exhaustion of the water treatment device is not detectable by the consumer in terms of clogging or poor aesthetic water quality.*

<u>Biofilms</u>

Incorporation of natural uncultivable Legionella pneumophila into potable water biofilms provides a protective niche against chlorination stress.

Giao, M.S., Wilks, S., Azevedo, N.F., Vieira, M.J. and Keevil, C.W. (2009) Biofouling, **25**(4); 345-351

Biofilms are ubiquitous in drinking water distribution systems (DWDS), and may protect microorganisms from stresses such as exposure to biocides. Public health issues may arise from pathogens in biofilms and because of the increased resistance to biocides that may be developed by pathogens. Resistance to chlorine, the most commonly used disinfectant in DWDS, has been observed. *Legionella pneumophila* has been sporadically isolated from DWDS. It is believed that a relationship with other environmental microorganisms, such as amoebae, may be required for *L. pneumophila* to multiply. The ability for *L. pneumophila* to become incorporated into biofilms is well documented in various studies. However these studies relied on standard plating procedures for quantification which do not detect microorganisms that are in a viable, but non-cultivable (VBNC) state i.e. they are not able to grow on the artificial media normally used but still retain viability and recover their activity when favourable conditions are found. More recent molecular techniques have been developed and improved to detect specific pathogens in biofilms including peptide nucleic acid probes combined with fluorescence in situ hybridisation (PNA-FISH). The aim of this study was to examine the effect of different chlorine concentrations on *L. pneumophila* associated with drinking water biofilms and to compare the numbers obtained by standard culture methods with the numbers obtained with PNA-FISH when a PNA probe highly specific for *L. pneumophila* was used.

Biofilms were formed using a two stage chemostat model system. The first stage consisted of one 1-litre seed vessel and the second stage consisted of three 1-litre vessels running in parallel but connected in series with the seed vessel. The apparatus was autoclaved before filling with filter-sterilised tap water. A microbial consortium was isolated from tap water by filtration with a 0.2 micron pore size filter, and used to inoculate the seed vessel. After 2 days batch growth the seed vessel was changed to continuous mode with dechlorinated filter-sterilised tap water being fed in at 50ml/hour, with incubation at 35 degrees C and stirring at 300rpm. Water flowing out of the seed vessel was fed to the three second stage vessels along with sterilised tap water to give a dilution rate of 0.2 per hour. These vessels were stirred at 300 rpm and maintained at 15 degrees C. Chlorine was added to two of the vessels at concentrations of 0.2 mg/litre and 1.2 mg/litre respectively. After 10 days of operation unplasticised polyvinylchloride (uPVC) coupons (1 cm square) were immersed as a substrate to grow biofilms. The coupons were removed after 1, 2, 4, 8, 16 and 32 days, gently rinsed to remove planktonic cells attached to the surface of the biofilm and scraped to quantify sessile cells. At day 0 (when coupons were immersed) and at all subsequent sampling times, water samples were taken from the seed and biofilm-growing vessels for total cells, heterotrophic cells (HPC) and cultivable *L. pneumophila* quantification. After the biofilm was completely removed from coupons, quantification of total cells, HPC and cultivable *L. pneumophila* was undertaken. In addition, total *L pneumophila* were quantified using the highly specific PNA probe.

The number of total planktonic cells in general was not significantly different (*p* greater than 0.05) between the seed vessel, and the three biofilm-growing vessels. When results for different concentrations of chlorine were compared, it was seen that HPC numbers decreased significantly with an increase of chlorine concentration (*p* greater than 0.05); the concentration of cells being almost 1-log lower in the chlorinated vessels. The quantification of cultivable *L. pneumophlia* was not possible for any samples from the seed vessel and the two biofilm growing vessels. Variation in the total number of cells was plotted and it was found that most of the total cells and total *L. pneumophila* (calculated using the *L. pneumophila* specific PNA probe) attached during the first few days and then fluctuated within a narrow range (*p* greater than 0.05). Biofilms formed under chlorinated conditions were quantitatively and structurally similar to the biofilms formed when no chlorine was added. However, coupons removed from the non-chlorinated vessel appeared slimier than the coupons grown with chlorine. This may have been due to the formation of an extracellular polymeric substance (EPS) which may protect the biofilms from adverse external conditions. Diffusion through a biofilm with a scarce EPS matrix will be faster and deeper than for a thicker matrix and result in loss of cultivability when biofilms are formed in chlorinated water.

The total number of *L. pneumophila* quantified using the PLPNE620 PNA probe did not vary significantly with time for all concentrations of chlorine used, suggesting that chlorine had little effect on the ability of this pathogen to become incorporated into the biofilm. For all biofilm formation conditions, the percentage of total *L. pneumophila* was on average about 20% of the total cells. It was not possible to confirm if *L. pneumophila* was present in a viable state, as no cultivable *L. pneumophila* was recovered from any of the samples. However, cells were detected by PNA FISH with intact rRNA and these cells may still be viable and capable of infection. It is likely that cultivable *L. pneumophila* present in the biofilm remained undetected due to the overgrowth of other species in the agar medium.

It was shown that environmental *L. pneumophila* can reach up to 25% of the total microbial community of a biofilm even when chlorine is present. To prevent disease outbreaks due to *L. pneumophila*, efforts need to concentrate on preventing *L. pneumophila* from re-entering an infectious state and therefore residual disinfection levels need to be maintained through the entire DWDS network to prevent resuscitation of *L. pneumophila* via contact with amoebae. Biofilms appear to play a key role in sustaining the survival of bacterium under stressful conditions and therefore ensuring that cells can replicate again as soon as more favourable conditions are available.

Comment The authors note that the initial incubation of the seed vessel at 35 degrees C would have favoured the growth of L. pneumophila. Such temperatures would seldom be found in most drinking water distribution systems.

Boil Water Notices

A water contamination incident in Oslo, Norway during October 2007; a basis for discussion of boil-water notices and the potential for post-treatment contamination of drinking water supplies.

Robertson, L., Gjerde, B., Hansen, E.F. and Stachurska-Hagen, T. (2009) Journal of Water and Health, **7**(1); 55-66.

In Oslo, Norway, a post-treatment water contamination incident occurred during October 2007 in which low numbers of *Giardia* cysts and *Cryptosporidium* oocysts were detected in the distribution network supplied from a source in which these parasites are rarely found. The incident began on 5 October 2007, when a pharmaceutical company which receives mains water supplied from Oset water treatment works reported to Oslo VAV (Oslo City Council Department of Water and Sewerage) that between 18 September and 3 October coliform bacteria had been detected in 9 tap water samples analysed by the company. In response to this, on 8 October, Oslo VAV took 3 water samples from different points in the water distribution network in the immediate area around the pharmaceutical company facilities. Two of the samples were bacteriologically negative, however one sample was positive with 9 coliforms and 1 *E. coli* per 100ml. A repeat water sample was taken from the site of positive sample and also found to be positive for coliforms, enterococci and *E. coli*. On the basis of these results, 3 further water samples were taken for bacteriological analysis and 1 10L sample for parasitological analysis, and a boil-water notice was then issued for a restricted area (3 streets) in the immediate surroundings of the affected locality. The 10L water sample was very dirty (high content of debris and algae) and 1 presumptive *Giardia* cyst (but apparently empty with no internal structure visible) was detected. Further sampling then took place from the previous sampling sites and from 10 new sites and tests found possible coliforms however colonies were small and atypical. A further 4 10L samples were taken from the distribution network for parasitological analysis and again the water was noted as being particularly dirty. The parasitological analysis revealed one negative sample, one *Giardia*-positive sample (1 cyst per 10 litres) and two *Cryptosporidium*-positive samples (1 or 2 cysts per 10 litres). A crisis meeting was held and it was decided that a boil water notice should be issued for all areas of the city supplied with water from Oset treatment works effective from the morning of 17 October. A wide spread sampling regime was instituted from 17 to 21 October, when on the basis of results obtained, the boil-water notice was rescinded. The sampling regime was then gradually and systematically reduced.

PCR conducted of earlier samples positive for *Cryptosporidium* revealed *C. hominis*, a species which generally only occurs in humans. This together with bacteriological findings indicated that this was probably a post-treatment contamination event with faecal matter of human origin. The contamination event may have occurred in the water distribution system at an individual location and was likely a one-off incident, possible associated with maintenance work, rather than a severe or continuous fault within the distribution network. PCR of oocysts in a later sample identified *C. parvum* and may indicate contamination from either human sources or from animals; this may have been an entirely separate incident to the initial contamination event.

The boil water notice was issued here in the absence of any increase in the incidence of illness with only relatively low numbers of parasites detected in water samples. From 145 water samples (10-litre sample volumes) taken between 17 and 29 October, only 11 were positive for *Cryptosporidium* with only 1 or 2 oocysts per sample detected. Even allowing for limited recovery efficiencies it is likely that levels in drinking water did not exceed 4 oocysts per 10 litres. Reservations have been expressed about the use of such notices and it has been proposed that the implementation of boil-water notices associated with suspected contamination of public water supplies by

Cryptosporidium is rarely a good practice. A guidelines paper by UK researchers proposed factors in favour of issuing a boil-water notice as follows: a history of waterborne outbreaks associated with the same source; high oocyst counts in consecutive samples; other evidence of treatment failure; a relatively high turbidity in treated water for that supply; a groundwater source and demonstration of oocyst viability. None of these criteria were met in the Oslo incident however there were factors which supported the issuing of a boil-water notice which together suggested the possibility of a post-treatment contamination event. These included detection of both Cryptosporidium and Giardia, presence of coliforms or other bacteria and presence unusual amounts of particulate matter in water samples.

It has been suggested that a 'step-wise' boil-water recommendation could be issued in some instances when numbers of parasites detected are very low and it could be directed only at those consumers at particular risk such as the immunocompromised, the elderly and very young and those who believe they have particularly high water intake. It is proposed that unless a gross contamination event has occurred requiring immediate action, then it is essential that all the relevant information is considered when deciding whether or nor to issue a boil-water notice. The information required not only includes data on oocyst or cyst counts but archived data, other microbiological data and biophysical and environmental data. Often information on viability or genetic data may be delayed or unobtainable and often decisions will have to be made without such information. The decision on when to rescind a boil-water notice may not be easy to make. There should be a clear understanding when issuing a boil-water notice regarding the criteria which should be fulfilled in order for it to be removed.

Despite water treatment works installing the most state-of-the-art technologies in order to inactivate or remove *Cryptosporidium* oocysts and *Giardia* cysts, if there are any inadequacies within the water distribution systems including: aging or improperly maintained infrastructure, such as pipelines or seals, or inadequate securing of the water supply during maintenance work, then there is the potential for contamination of drinking water supply with these parasites. Analysis of post-treatment contamination outbreaks with parasites indicates that these have often resulted from cross-connection between potable water pipes and sewerage pipes, although agricultural sources of contamination have also occurred. In the Oslo incident there was no evidence of failure in the distribution network; factors that were investigated included construction work in the area, work on the distribution network itself and loss of water pressure due to fire department activity.

Cancer

Cigarette smoking and drinking water source: Correlation with clinical features and pathology of superficial bladder carcinoma.

Serretta, V., Altieri, V., Morgia, G., Allegro, R., Ruggirello, A., Di Lallo, A., Carrieri, G. and Melloni, D. (2009) Urologia Internationalis, **82**(3); 318-323.

Transitional cell carcinoma of the bladder (TCCB) arises from cells in the bladder lining (urothelium), and is usually the most common form of bladder cancer. Cigarette smoking is a known cause of bladder cancer and the risk of TCCB increases with the number of cigarettes and the duration of smoking. A number of water contaminants including disinfection byproducts have also been suspected to play a role in TCCB but none have been proven as yet. This study investigated cigarette smoking and drinking water supply, comparing bottled mineral water to chlorinated water in the same geographic region and the correlation with clinical features and pathology of superficial bladder carcinoma.

This study was undertaken between May 2002 and August 2003 in southern Italy with 577 patients from forty urological units. Patients were undergoing transurethral resection (TUR) for Ta-Tl stage tumours grades G1-G3 and TCCB. Detailed information was collected about age, sex, active and passive cigarette smoking and water source via a structured questionnaire. Patients were excluded if they were unable to specify their smoking habits, the water source and length of consumption, or if they had not been living in southern Italy all their life. Data was also collected on residency, employment and hair dye use. The duration of smoking, the number of cigarettes per day and their type (with or without filter) were recorded. Information collected on water supply included the source of water, unique or mixed to other sources and the length of consumption from each source.

Of the 80 women in the study 33 (41.3%) were classified as current or former smokers and 396 (79.7%) of the 497 men were classed as current or former smokers. There were 88 (25.1%) patients who were exposed to passive smoke and 15 (17%) that had never smoked. Statistical analysis found that the percentage of patients with recurrent tumours increased from 24 (20.2%) to 44 (41.9%) (*p* less than 0.0001) among smokers for less or more than 30 years, respectively. There was no difference found between current and former smokers and no specific correlation with the number of cigarettes per day.

There were 249 (45%) patients who only drank bottled water, 177 (32%) who drank municipal water, 38 (7%) who drank artesian well water, 7 (1%) who drank spring water and 89 (16%) with a mixed water source. A chlorinated water supply was more frequent in never smokers than in smokers (p=0.015). T1 tumours (cancer that has begin to grow into the connective tissue beneath the bladder lining) occurred statistically more frequently (p=0.02) in patients drinking chlorinated municipal water than Ta tumours (cancer just in the innermost layer of the bladder lining), suggesting a possible role of disinfection by-products in promoting bladder cancer aggressiveness. Therefore patients drinking chlorinated water for a long period should also be considered at higher risk. The activity/effect of water pollution is possibly weaker than that of cigarette smoking and not easily detected in smokers due to a masking effect caused by the stronger factor.

The results of this study need to be confirmed by larger trials investigating bladder cancer outcome in relation to tumour risk factors as well as to several lifestyle factors. If the observations found in this study are confirmed then long-term smokers and patients drinking chlorinated water may be candidates for adjuvant therapy and a closer follow-up schedule due to the risk of cancer recurrence.

Cryptosporidium

Multiple risk factors associated with a large statewide increase in cryptosporidiosis.

Valderrama, A.L., Hlavsa, M.C., Cronquist, A., Cosgrove, S., Johnston, S.P., Roberts, J.M., Stock, M.L., Xiao, L., Xavier, K. and Beach, M.J. (2009) Epidemiology and Infection, 1-8.

In August 2007, 56 cases of cryptosporidiosis were reported to the Colorado Department of Public Health and Environment (CDPHE), more than 4.5 times the expected number for the month. No common exposure source was evident for these cases. An investigation was then conducted by CDPHE, local public health agencies and CDC to identify risk factors for sporadic transmission that were associated with this large statewide increase in incidence.

A confirmed case for the purpose of this investigation was defined as a Colorado resident who had a positive *Cryptosporidium* laboratory stool test in June-October 2007 and onset of gastrointestinal symptoms from 1 August to 17 September 2007. A control was defined as a Colorado resident who had experienced no gastrointestinal symptoms from 1 August 2007 to time of interview (15 September – 3 November 2007). Two controls were match by age range and geographic area to each case-patient. Only one person per household was interviewed as a case (the case with the earliest onset date) or control. A standardised questionnaire was developed and administered by telephone. Case-patients and matched controls were asked about possible exposures during the 2 weeks prior to the case-patient's onset of symptoms. The exposures assessed in the questionnaire included food and water consumption, recreational water exposure, child care and household exposures, farm and animal contact, person-to-person contact and travel history during the likely period of exposure.

Out of 90 potential cases meeting the onset date criteria, 47 cases were enrolled in the study. The case patients interviewed resided in 15 different counties, and included 24 adults and 23 children. There were 92 matched controls interviewed. A further 25 cases could not be contacted, controls were not able to be recruited for 8 cases, 7 cases were excluded due to uncertainty about their illness onset dates and 3 refused to participate. *Cryptosporidium* infection was significantly associated with attending child care outside the home or having children in child care outside the home during the 2 weeks before illness [matched odds ratio (mOR) 2.5, 95% confidence interval (CI) 1.1-5.6]. Contact with a child in child care or a child in diapers was also a significant risk factor for infection (mOR 2.5, 95% CI 1.2-4.9). Consumption of produce obtained from a farm or farm stand had a protective effect (mOR 0.3, 95% CI 0.1-0.8). Exposure to untreated drinking water from a lake, river or stream (mOR 3.3), any recreation water exposure (mOR 1.8) and attendance at a social event (mOR 0.5) all approached significance at P less than 0.05. There were 17 stool specimens from case-patients analysed and 13 (76.5%) were positive for *Cryptosporidium* by direct immunofluorescent assay (DFA). Genotyping of 11 positive specimens was undertaken, (two specimens were not genotyped due to low numbers of oocysts) and *C. hominis* was identified in all specimens. Subtyping analysis identified three distinct subtypes however there was no geographic clustering by subtype.

The evidence suggests that at least three separate chains of transmission for *Cryptosporidium* in Colorado accounted for the increased number of cases rather than a single source of infection. While recreational water is a major risk factor for summertime infection, other routes of exposure such as drinking untreated water and child-care program use also present a risk. Public health officials therefore need to continue public education that addresses multiple transmission routes for *Cryptosporidium* and appropriate prevention measures to avoid future transmission.

<u>Endemic Disease</u>

Drinking water residence time in distribution networks and emergency department visits for gastrointestinal illness in Metro Atlanta, Georgia.
Tinker, S.C., Moe, C.L., Klein, M., Flanders, W.D., Uber, J., Amirtharajah, A., Singer, P. and Tolbert, P.E. (2009) Journal of Water and Health, **7**(2); 332-343.

It has been suggested that low-level or transient contamination of distribution systems could potentially lead to substantial endemic disease transmission. Studies in Canada have suggested that distribution systems may contribute to endemic drinking water-related gastrointestinal illness (GI). Results from studies in Russia and Sweden have found an association between distance from the treatment plant and incidence of GI illness and studies in the United Kingdom and Sweden have found an association between pressure-loss events in the distribution system and incidence of GI illness. It is not currently feasible to measure the frequency and magnitude of contamination events in a distribution system and therefore indicators of potential contamination may be a helpful alternative. Residence time, or water age, is the amount of time water spends in the distribution system between the treatment plant and the consumer and is a function of flow rate, distance from the treatment plant, storage, system demand and distribution system architecture, and other factors. The longer the water is in the distribution system the more likely it is to become contaminated. This study used residence time estimates to assess the association between distribution system contamination and endemic GI illness among the population served by two large drinking water utilities in metropolitan Atlanta, Georgia USA.

Emergency department (ED) data from 1993-1994 on visits from all of the hospitals operating within the five-county Atlanta area and from hospitals outside the study area that contributed a substantial number of visits by five-county residents (a total of 28 hospitals) were collected. The information from the hospitals included medical record number, date of admission, International Classification of Diseases, 9th Revision (ICD-9) diagnosis codes, zip code of residence, payment method and age or date or birth. Residence time was estimated using hydraulic models from two (Utility 1 and Utility 2) of the six major utilities serving Atlanta and its suburbs. Each of these two utilities operates two treatment plants that supply water to their respective distribution pipeline networks. These hydraulic models simulated the flow patterns of water throughout the distribution systems over a typical diurnal water usage cycle, taking into account pipe layout and characteristics, system storage, customer water usage and utility operating rules. Data was obtained from the 2000 US Census regarding zip code level demographic characteristics, including median income and percentage minority. The average water residence time for each zip code was estimated. Water residence time estimates were not available for Utility 1 for 1993-1995 and 2004. Residence time was divided into time exposure categories including: short water residence time = less than or equal to 10th percentile of all water residence time estimates; intermediate = 11th to 89th percentile; long = greater than or equal to 90th percentile. The relationship between water residence time and risk for GI illness was assessed using logistic regression models, controlling for potential confounding factors including: patient age and markers of socioeconomic status (SES).

There were 27 hospitals that provided data on 2,092,735 non-injury ED visits in the service areas of the two utilities. A total of 164,937 (7.9%) of these visits were for GI illness. There were no reported drinking waterborne disease outbreaks in metro Atlanta during the study period. The average residence time from the first hydraulic model from Utility 1, for the years 1996 through 1998, was 24.7 hours (standard deviation (SD)= 16.1 hours) and from the second model from Utility 1, for the years 1999 through 2003, 32.8 hours (SD = 18.2 hours). The average water residence time for Utility 2 was 23.3 hours (SD = 23.5 hours). Those with zip codes closest to the treatment plants tended to have shortest residence time as expected. There was no difference in the rate of ED visits for GI illness among those living in zip codes with short residence time compared with those living in zip codes with intermediate residence times (odds ratio (OR) for Utility 1 = 1.00, 95% confidence interval (CI) = 0.96, 1.03; OR for Utility 2 = 0.99, 95% CI = 0.96, 1.03). There was a modest increased risk found for ED visits for GI illness among those living in zip codes with the longest residence time compared with those living in zip codes with intermediate residence times (OR for Utility 1 = 1.07, 95% CI = 1.03, 1.10; OR for Utility 2 = 1.05, 95% CI = 1.02, 1.08). The strength of the association between water residence time and risk for ED visits for GI illness varied by year for both utilities, however there was no overall pattern apparent in the year-specific results. The results for Utility 2 when stratified by season and age suggested stronger associations between long water residence time and GI illness during non-summer months and among children 18 years and younger.

The results of this study suggest that people served by drinking water that has spent the longest time in the distribution system may have a slightly increased risk of ED visits for GI illness compared with those who receive water than has spent less time in the distribution system. Distribution system contamination may possibly occur from low-pressure events, leaks and cross-connections with non-potable water sources. Even if a disinfectant residual is present, it may not be sufficient to inactivate a large influx of pathogens especially at the far ends of the distribution system where the residual may be low. This study also highlights the usefulness of hydraulic models. These models should continue to be used to inform health studies and identify areas of vulnerability with the ultimate aim to improve distribution system integrity, decrease the water age where possible and deliver safe water to consumers.

<u>Norovirus</u>

An analysis of water quality in the Colorado River, 2003-04; An investigation into recurring outbreaks of norovirus among rafters.
Jones, E.L., Gaither, M., Kramer, A. and Gerba, C.P. (2009) Wilderness and Environmental Medicine, **20**(1); 6-13.

Rafting down the Colorado River through the Grand Canyon in Arizona USA is a popular tourist activity, with more than 22,000 people making the trip each year. Rafting trips commonly last 7 to 10 days. Since 1994, six outbreaks of norovirus have been recorded among rafters, with over 400 people affected by gastroenteritis. Four of these outbreaks occurred consecutively during the years 2002-2005. The severity of gastroenteritis is exacerbated due to the high temperatures during the rafting season which increases dehydration due to vomiting and diarrhoea. Sanitation is limited on the river, and normal outbreak control measures are difficult or impossible to apply during an outbreak among river rafters. Those that are ill can not be effectively isolated from those that are well. Trips can not be stopped while rafters recover and therefore vomiting and defecation accidents in rafts or into the river occur, potentially causing high levels of environmental contamination. As the river is used for drinking, cooking, and wash water, this contamination is problematic. This study investigated the water quality along the Colorado River between Glen Canyon Dam and the convergence of the Colorado River with Diamond Creek, near Peach Springs, Arizona to assess the potential causes of these norovirus outbreaks.

During the summers of 2003 and 2004, water and wastewater samples were analysed to determine whether there was ongoing contamination of the river from sources such as wastewater treatment plants. In July 2003, effluent samples were taken from the Page, AZ, Wastewater Treatment Plant and the Glen Canyon Dam Wastewater Treatment Plant. During the same month, drinking water from a spigot at the Lee's Ferry boat launch (where most rafting trips begin) was sampled. One additional effluent sample was obtained in August 2003 from the Wahweap Wastewater Treatment Plant. In May 2004, Colorado River water samples were collected from 5 points along the river between Lee's Ferry and Bright Angel Creek confluence. In July 2004, 6 wastewater samples were taken from the Glen Canyon Dam Wastewater Treatment Plant and Colorado River water at the Lee's Ferry boat launch was sampled. Stool samples from ill rafters and composite stool samples from on-board toilet-cans were analysed for the presence of norovirus during the 2003 and 2004 outbreaks. The parameters examined included: the presence of human norovirus by reverse transcriptase-polymerase chain reaction (RT-PCR), coliforms and *Escherichia coli* (most probable number per 100 mL), temperature, turbidity and pH.

Field samples taken in July and August 2003 all were negative for the presence of human noroviruses. All of the samples taken in May 2004 from the Colorado River were negative for norovirus. Of the water samples taken in July 2004, the sample from Lee's Ferry was negative for noroviruses, one of the two samples collected from the secondary clarifier at the Glen Canyon Dam Wastewater Treatment Plant was positive for human norovirus and two samples of treatment plant effluent collected after disinfection both showed the presence of *E. coli*, although levels were within regulations for recreational water (less than 200 faecal coliforms/100 mL). Of the 6 composite stool samples from one trip with ill passengers in September 2003, 1 sample tested positive for norovirus. Of the stool samples from individual rafters tested for norovirus, 2 of the 3 were positive. Only 2 composite stool samples were tested from the June 2004 outbreak and both were negative.

Water samples from along the Colorado River collected during non-outbreak periods were negative indicating that there is not an ongoing high level of norovirus contamination. Water testing did not identify any sources of contamination. Potential sources of norovirus outbreaks among rafters may include: drinking contaminated river water, consuming contaminated foodstuff, rafter importation of the virus and subsequent person-to-person spread and contaminated fomites (objects contaminated with virus), campsites or equipment. It is probable that outbreaks are the result of more than one source of norovirus however the source of several of the outbreaks is unknown. Continued examination of the epidemiology of norovirus outbreaks among rafters is required and this may improve the understanding of noroviruses and aid in the prevention of and response to norovirus outbreaks.

<u>Outbreaks</u>

Rainfall and outbreaks of drinking water related disease and in England and Wales.

Nichols, G., Lane, C., Asgari, N., Verlander, N.Q. and Charlett, A. (2009) Journal of Water and Health, **7**(1); 1-8.

Studies in the US and Canada have indicated a relationship between waterborne outbreaks and heavy rainfall in the preceding period. This current study examined outbreaks in England and Wales that were caused by public or private drinking water supplies to investigate the relationship between rainfall and outbreaks of drinking water related disease.

A case-crossover design was used with the 90 days before the outbreak representing “cases” and the same 90 day period in the previous five years representing “controls”. Cases were waterborne outbreaks reported during the years 1910-1999 where the location and time of the outbreak was known. Information came from Medline, Communicable Disease Reports, unpublished reports held by the Health Protection Agency Centre for Infections and published papers. Data collected for each outbreak included: geographical location, average incubation period of the pathogen, season, water supply (private water supply, mains), water source (surface, ground), rainfall implicated (yes, no) and whether the exact date of first symptoms in infected individuals was known or estimated.

Daily precipitation data were collected on-line from the British Atmospheric Data Centre. Each outbreak location was cross-referenced against a list of available rainfall stations for the United Kingdom. There were two approaches used to examine the relationship between outbreaks and rainfall. The first approach focused on total rainfall in a particular period and the second on excessive rainfall events. The first approach determined the cumulative rainfall in four time periods prior to each outbreak (1-7, 8-14, 15-21, 22-28 days prior to the outbreak) for the outbreak year and the self-control period by averaging over the five non-outbreak years. Rainfall was categorised into four groups (0 to 10 mm, greater than 10 to less than 20 mm, greater than 20 to less than 40 mm and greater than 40 mm). The second approach was used where an excessive rainfall event was defined as rainfall on a day preceding an outbreak exceeding the upper limit of the 95% reference range. The number of excessive events was determined for both the outbreak year and the control year prior to the outbreak.

Between 1910 and 1999 in England and Wales, there were 111 outbreaks identified to be associated with consumption of drinking water. There were 22 outbreaks excluded because the location was not known, the date was not known or there was no available rainfall data. Therefore the study included 89 outbreaks however the exact date of onset was not known for 18 of these outbreaks. There was a significant association found between rainfall in outbreak years as compared to the control years for all four one week periods before the outbreak date and a significant association between cumulative rainfall of over 40 mm in the previous 7 days (days 1-7) and outbreaks (p = 0.001). There was an excess of outbreaks compared to controls for all four one week periods in the greater than 40 mm rainfall group. There was a significant excess of low weekly rainfall (less than 20 mm per week) for the days 8 to 28 in the outbreak compared to the control years (p =0.002). When cumulative rainfall was greater than ten and less than or equal to 20 millimetres the risk of outbreaks was lowest and when rainfall was greater than forty millimetres the risk was highest, irrespective of the time period. The rainfall exceedance during the period before the start of outbreaks was calculated. The odds ratios of rainfall exceedance between matched outbreak and non-outbreak years were not statistically significant for any single day before the outbreak. However, the cumulative odds ratio was higher than 1 for all days up to day 30, nearing statistical significance for days 6 and 10. The main exceedance over control years was found to occur in the first ten days.

There were 30.3% of outbreaks that had less than 20 mm rainfall in the three weeks prior to the week before the outbreak compared to 10.1% in control years. Also, 14.6% of outbreaks had a period of rainfall in excess of 40 mm in the outbreak week compared to 2.2% of control weeks. These results imply that the attributable fraction of outbreaks associated with a sustained period of low rainfall is 20%, while the attributable fraction for periods of heavy rainfall is 10%. Low rainfall may contribute to source water contamination in a number of ways including a relative increase in the proportion of sewage effluent in rivers, opening of water channels allowing groundwater contamination, and increased run-off in subsequent rain events due to drying of soils. Therefore when drinking water providers are formulating Water Safety Plans and assessing the health impacts of climate change, interventions should focus on periods of low rainfall as well as risks following heavy rain.

Pharmaceuticals

Estimation of the cancer risk to humans resulting from the presence of cyclophosphamide and ifosfamide in surface water.

Kummerer, K. and Al-Ahmad, A. (2009) Environmental Science and Pollution Research, 1-11.

Since the 1980s a number of reports have been published on the occurrence of pharmaceuticals in natural surface waters and the effluent from sewage treatments plants. In recent times, pharmaceuticals have been detected in groundwater and drinking water, but little is known about their potential risk to human health. Cyclophosphamide (CP) and ifosfamide (IF) are among the most widely used cytotoxic compounds in chemotherapy of cancer and in the treatment of autoimmune diseases. CP and IF are known to be mutagenic, genotoxic, fetotoxic and teratogenic and human carcinogens. CP and IF were found to be poorly eliminated in biodegradability laboratory tests as well as in a municipal sewage treatment plants. Both compounds and their metabolites are likely to be released into surface waters and to persist in the aquatic environment. This study reports a rough risk assessment of the cancer risk to humans resulting from the presence of CP and IF in surface water.

The amount of CP and IF excreted by patients on chemotherapy depends on factors such as the characteristics of the patient or the time of administration. A range of 10% to 40% excretion of non-metabolised substance has been reported, so an excretion rate of 20% for non-metabolised drugs was assumed for the study. Based on consumption data for CP and IF, this rate was used to calculate the predicted environmental concentration (PEC). Data from different sources ware used in the calculation using two different approaches: (1) the calculation of a nationwide $PEC_{regional}$ in surface water from the total annual amounts of CP and IF used in Germany and (2) PEC_{local} using (a) expected and (b) measured CP and IF concentrations in the effluent of a municipal sewage treatment plant (STP). This plant receives effluents including hospital effluents from a large university hospital and a hospital specialising in anti-cancer treatment. As no data was available for CP and IF oxidation in drinking water processing, and as CP and IF were not adsorbed onto sewage sludge, no elimination of CP and IF during drinking water processing was assumed. Therefore the maximum possible ingestion of CP or IF was calculated assuming that 2 L of water a day of unprocessed surface water were drunk over a life span of 70 years for adults. The lowest dose of CP/IF given within anti-cancer therapy was compared with this calculated maximum drinking water dose.

The annual amounts of CP and IF consumed in Germany were calculated to be 288 kg of CP and 433 kg of IF. These results were then used to calculate the PEC. The $PEC_{regional}$ in surface water in Germany was 0.6-0.7 ng/L for CP and 0.6-1.0 ng/L for IF. PEC_{local} was calculated from the measured and expected concentrations in the effluent from the communal STP. Based on the calculated consumption, the concentration was 5.6 ng/L for CP and 10.9 ng/L for IF. Using the highest STP effluent concentrations, the calculated results were 4 ng/L for CP and 206 ng/L for IF.

The possible intake of CP and IF from surface water versus administration in anti-cancer treatment (i.e. the risk ratio) was then calculated. In Germany the cumulative intake of CP and IF by an adult consuming 2 L of unprocessed surface water as drinking water per day over a 70 year life span was on average, 30.7 - 35.8 micro g for CP and 30.7 - 51.2 micro g for IF. Local intake was estimated to be much higher, 205-286 micro g for CP and 558-10,530 micro g for IF. The nationwide intake of IF and CP using unprocessed surface water for drinking is less than 1×10^{-6}, in relation to intake by therapy taking the lowest and the highest intake dose with surface water and a dose of 10 g (relative risk 1.5) and 51 g (relative risk 100) during anti-cancer treatment. Compared with the intake by therapy, the additional intake of CP and IF due to their discharge into surface water and subsequent use as unprocessed drinking water is low. Previous studies of hospital staff who administer CP or people involved in manufacture of this drug have not shown increased cancer risks although estimated exposure levels were much higher than those estimated here for drinking water.

This study shows the present limitations of risk assessment for carcinogenic compounds in the environment and especially for cytotoxics and mutagens where the necessary data are missing. The risks associated with these compounds are higher for newborns and children than for adults, however due to the lack of data these risks can not be fully assessed. The authors recommend that such data should be collected, and that measures be taken to reduce the input of CP and IF and other carcinogenic pharmaceuticals into waste water and surface water. In the short-term, measures such as collection of unused and outdated drugs may be useful. In the longer term, more advanced water treatment methods may need to be assessed. Alternatively, it has been proposed that the biodegradability of pharmaceuticals should be considered during their development to avoid future problems from environmentally persistent compounds in water supplies.

Rotavirus

Detection of infectious rotavirus in naturally contaminated source waters for drinking water production.

Rutjes, S.A., Lodder, W.J., Van Leeuwen, A.D. and De Roda Husman, A.M. (2009) Journal of Applied Microbiology, **107**(1); 97-105.

To assess the public health risks of rotavirus due to drinking water consumption, conventional cell culture methods and PCR amplification were combined to produce a cell culture- PCR (cc-PCR) assay which was optimised for the detection of infectious environmental rotavirus strains in naturally contaminated source waters that were used for drinking water production. Such cc-PCR assays have been successfully used for the detection of several other enteric viruses in environmental samples. Combining cell culture methods and molecular detection methods such as RT-PCR enables the detection of infectious virus particles without incubation periods of several days to weeks normally needed for detection by cell culture alone.

Water samples were collected from source water for drinking water production at three locations in The Netherlands. Four samples (up to 6000 litres) were taken from a reservoir close to Amsterdam throughout the year 2003, 12 monthly samples were taken in 2004 from the river Maas upstream of a source water intake area, and one source water sample was taken from the IJsselmeer (a shallow freshwater lake) in March 2005. A 1200 litre volume of partially-treated drinking water was sampled in 2003. Rotaviruses were concentrated from 600 litres of surface water by negative membrane filtration and ultrafiltration (UF). The numbers of infectious virus particles were estimated as most probable numbers (MPN) by the presence/absence of virus genomes in the cultured samples.

Rotavirus replication was detectable by RT-PCR between 4h and 7 days after infection, and detection was optimal 24 h after infection of differentiated human colon adenocarcinoma cell line (CaCo-2) cells. One source water concentrate and one partially-treated drinking water concentrate were seeded with an amount of rotavirus. Seeded virus was detected in the partially-treated drinking water concentrate but not in the source water concentrate which indicates that the characteristics of the water sample influenced the ability of the virus to infect the cells or multiply in the cells. In the concentrates without seeded rotavirus no RT-PCR signal was detected.

The presence of infectious rotavirus was studied in the 12 source water samples with relatively high levels of faecal contamination taken from the river Maas. In 92% (11/12) of the samples, infectious rotavirus was detected in concentrations that ranged from 0.19 (0.011-0.87) to 8.3 (1.8-34.0) infectious PCR detectable units (IPDU) per litre. The total number of rotavirus genomes was also estimated as MPN by RT-PCR (ie direct detection of viral genomes without cell culture). In all samples, rotavirus RNA was detected in concentrations ranging from 108 (25.7-311) to 3203 (589-13184) PDU per litre. In 45% of the water samples, rotavirus genomes were 1000 to 3200 times more abundant than infectious rotavirus particles. This ratio was found in the months of February to June. In one sample (9%), rotavirus genomes were 3200 to 10,000 times more abundant than infectious viruses. For the remaining 45% of the samples, rotavirus genomes were less than 1000 times more abundant. The lowest ratio of viral genomes to infectious viruses was found in December and was between 10 and 32.

Assays for infectious enteroviruses were also carried out for comparison as these viruses are specified as index-pathogen for the presence of infectious pathogenic viruses in water in the Dutch Drinking Water Directive 2006. Infectious enteroviruses were tested by plaque assay of duplicate samples taken at the same time and place as the 12 river Maas source water samples. The mean infectious enterovirus concentration was 1.8 plaque forming unit per litre (PFU/litre), which was not significantly different from the concentration of infectious rotavirus (mean 2.1 IPDU/litre). The presence of rotavirus was also studied by cc-PCR in four source waters with relatively low levels of faecal contamination. None of the four samples had infectious enterovirus or rotaviruses detected by plaque assay and cc-PCR respectively. In two of the four water samples, rotavirus RNA was detected in concentrations of 98 and 91 PDU/litre.

This study demonstrated the large degree of variability in ratios of rotavirus RNA detected by purely molecular methods versus infectious virus particles detected by cell culture-PCR. This underlines the importance of detecting infectious viruses instead of viral RNA when estimating the risks to public health.

Comment *This paper builds on laboratory studies of infectious versus PCR-detected enteroviruses by several members of the same research group reported in Issue 54 of Health Stream. Again it illustrates how Quantitative Microbial Risk Assessment based solely on detection of pathogen genetic material without assessment of infectivity may greatly overestimate health risks.*

Health Stream is the quarterly newsletter of Water Quality Research Australia. Health Stream provides information on topical issues in health research which are of particular relevance to the water industry, news and updates on the recent literature. This newsletter is available free of charge to the water industry, public health professionals and others with an interest in water quality issues. An electronic version of the newsletter and a searchable archive of Health Stream articles are available via the WQRA Web page. Summaries of Web-bonus articles are available only in the electronic version.

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