Health Stream

INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

Issue 49 *Public Health Newsletter of the CRC for Water Quality and Treatment* March 2008

In this Issue:

Editor Martha Sinclair
Assistant Editor Pam Lightbody

CRCWQT Internet Address:
www.waterquality.crc.org.au

A searchable Archive of Health Stream articles, literature summaries and news items is available on the CRC Web page.

Waterborne Outbreak In Colorado

The town of Alamosa, Colorado has suffered an outbreak of *Salmonella* infections linked to the municipal water supply. The first case was reported on 14 March, and a public health emergency was declared by town and county authorities five days later when contamination of the water supply was confirmed. At that time 33 cases of illness had been identified among the exposed population of about 10,000 people. The Colorado Department of Public Health and Environment issued a Bottled Water Order, advising residents to use bottled water for cooking, drinking, brushing teeth, making ice, washing dishes and for adding to any food especially for the preparation of baby formula. They also advised that boiled tap water was safe to use for the above purposes if bottled water was not readily available. By 28 March the number of cases had grown to 276, with at least 72 confirmed by laboratory diagnosis. About two thirds of the victims are under 19 years of age, although all age groups in the community have been affected. Ten people are reported to have been hospitalized although none were reported as critically ill.

The town of Alamosa is the largest population centre in Alamosa county, one of six counties making up the San Luis Valley of Colorado. The town draws its water from a deep confined aquifer which is not believed to be subject to faecal contamination, and therefore it is suspected that a breach or cross-connection has occurred somewhere within the distribution system. Municipal authorities are reported to have ruled out sewage contamination, disgruntled employees or terrorism as possible causes of the incident, however the source of the contamination has not yet been identified. Checks for

cross-connections from businesses such as car washes are still being carried out. Like many groundwater sources in the US, the water supply for Alamosa is routinely distributed without disinfection although plans were being made to introduce chlorination to comply with the requirements of the Ground Water Rule (US EPA 2006).

On 21 March, in recognition of the importance of Alamosa to the economy of the surrounding region and the severe impact of the outbreak on emergency and health services, the Governor of Colorado declared the water contamination incident to be a Disaster Emergency. This triggered the release of disaster emergency funding and permitted the mobilisation of Colorado National Guard personnel to assist in relief efforts. The Alamosa Public Works department began a program of hyperchlorination and flushing of the water supply system on 25 March, and residents have been warned that tap water should be used only for toilet flushing during the clean-up period as the high chlorine levels may be irritating to the eyes and skin. It may require up to three weeks before the municipal supply is declared safe to drink once again although local authorities are hopeful it will be declared suitable for showering and other non-potable uses within a few days.

As of 25 March the only pathogen reported to have been identified from faecal specimens of victims was *Salmonella enterica* serotype Typhimurium. This bacterium is a common cause of enteric illness and is frequently associated with foodborne outbreaks. Waterborne outbreaks due to *Salmonella* species are relatively rare, accounting for only 15 outbreaks out of over 300 with identified microbial agents occurring in the US from 1971 to 2002. *Salmonella enterica* serotype Typhimurium can be carried by a range of animals and birds as well as by humans. The time lag between ingestion of *Salmonella* and development of symptoms such as diarrhoea or vomiting generally ranges from about 12 to 72 hours. Definitive identification of the organism in stool samples requires up to 7 days, so it is probable that the water contamination event in Alamosa may have occurred a week or more before recognition of the first cases in the community even if people visited a doctor promptly after becoming ill.

Camelford Investigation Reopened

Investigations into the aluminium contamination incident that took place in the town of Camelford in 1988 have been reopened after a British Coroner requested that police provide him with the file of evidence gathered during the initial investigation and appoint a senior detective to look into the allegations of a possible cover-up. The West Somerset Coroner is conducting inquests into the deaths of two women who lived in the Camelford area during the water contamination incident. Both women were affected by a rare form of Alzheimer's Disease and both reportedly had high levels of aluminium detected in their brain tissue at autopsy. One woman died in 2004 at the age of 58 while the other died in 2007 aged 91. The inquests were adjourned in December last year and are expected to resume following the completion of the police investigation.

The incident occurred when an inexperienced delivery contractor dumped 20 tonnes of concentrated aluminium sulphate solution into the wrong tank at the unmanned Lowermoor water treatment plant. This resulted in the distribution of contaminated water to a large area of north Cornwall. The event has often been referred to as the Camelford incident in reference to the town closest to the water treatment works. The affected area was estimated to have a resident population of about 12,000 people with an additional 8,000 summer visitors also being present. While the incident had the direct effect of introducing high levels of aluminium and sulphate into the water supply, the resulting low pH also caused corrosion of metal household plumbing components, and flushing operations to clear the contamination disturbed and resuspended sediments in the distribution system. People consuming the water may therefore have been exposed to elevated levels of a number of contaminants in addition to aluminium over a period of weeks to months.

Several reports on the incident have been produced by investigative committees set up by the UK government, the most recent being a sub-committee of the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT). This committee released a draft report in early 2005

but has not yet delivered its final report (1). The draft report concluded that although short-term adverse health effects had occurred at the time of the incident, it was unlikely that the exposures would result in long-term health effects. These findings have been rejected by some residents and activist groups, who believe that a diverse range of chronic health complaints experienced by exposed individuals are attributable to the incident. Allegations have also been made that government officials downplayed the incident in order to discourage negative publicity or criminal prosecution of the water authority because of the pending privatisation of the UK water industry. South West Water was prosecuted in 1991 for supplying water likely to endanger public health, and in 1995 out of court settlements were made with 148 people in a civil case.

The result of the autopsy on the 58 year-old former Camelford resident who died in 2004 was reported in the scientific literature (2). The authors noted that this report appears to be the first documented neuropathological examination carried out on a person who was exposed to the contaminated water and subsequently died of an unspecified neurological illness. The woman had suffered from worsening neurological symptoms for about two years before her death. The autopsy showed that the woman had a rare form of Alzheimer's Disease, and carried the APOE e4/4 gene which is known to be associated with early onset of the disease.

Analysis of the aluminium content of tissue samples from the frontal cortex of the brain was carried out at the request of the West Somerset Coroner. Five samples were analysed and were found to have aluminium contents of 3.24, 4.33, 5.71, 11.01 and 23 microg/g dry weight. Samples from three other people were also analysed for comparison; a person with classical Alzheimer's disease (aluminium concentration 2.46 microg/g dry weight), a person with neuropathology similar to the former Camelford resident but 80 years old at the time of death (two samples with 4.76 and 25.16 microg/g dry weight), and a case of depression without dementia in an elderly person (1.47 microg/g dry weight). The journal article does not state whether the 80 year-old person had any known unusual exposure to aluminium but as their brain tissue was apparently being used as a "control" for comparison purposes, one presumes they did not have such exposure.

Commenting on the results, the authors note that the aluminium content of healthy brain cortex is in the range of 0–2 mg/g dry weight, while values of 3–7 mg/g dry weight are typically seen in Alzheimer's Disease. The aluminium levels seen in two out of five samples from the Camelford resident exceed these values, and fall the range sometimes seen for aluminium encephalopathy syndrome or dialysis encephalopathy syndrome (3). They suggest that the high aluminium levels may be linked to the patient's past exposure to the Camelford incident, and advocate more studies on the cognitive functions of those exposed during the incident, and neurological examination of brain tissues of exposed people whenever such opportunities arise. However they make no comment on possible reasons for the high aluminium content in one of two samples from the patient who had similar neurological pathology but no stated history of unusual aluminium exposure.

The COT sub-committee met twice during 2007 and was made aware of the autopsy results of the first case at one of these meetings. It is not known when their final report will be delivered.

(1) See Health Stream Issues 25 and 37 for coverage of the 2005 Committee on Toxicity investigation and findings of the Draft Report.

(2) Severe cerebral congophilic angiopathy coincident with increased brain aluminium in a resident of Camelford, Cornwall, UK. C Exley, M and Esiri M. Journal of Neurology Neurosurgery and Psychiatry 2006;**77**:877–879.

(3) Aluminium encephalopathy syndrome occurs in children and infants with chronic renal insufficiency who have been treated with aluminium-containing drugs such as phosphate binders. In addition to high aluminium exposure these patients also have increased aluminium uptake and decreased excretion.

Dialysis encephalopathy syndrome may occur in patients who have received haemodialysis with water containing aluminium. Up to 150 litres of water may be used per dialysis treatment and the aluminium readily passes into the blood stream via the dialysis membrane, resulting in very high exposure. Excretion of aluminium is also often impaired in such patients. The condition was recognised in the 1970s but is now rare in developed countries due to the use of highly purified water for haemodialysis.

US EPA Publishes Draft CCL3

The US Environmental Protection Agency (EPA) has published the draft version of the Contaminant Candidate List 3 (CCL3) for public comment. The list was published on the Federal Register on 21 February 2008, marking the commencement of a 90-day public comment period. The development and publication of the list is a requirement of the US Safe Drinking Water Act (1996). The Act requires the EPA to develop and publish a list of drinking water contaminants that are presently not regulated but which may pose a risk to public health, and to make determinations on whether to regulate at least five contaminants from the CCL with a national primary drinking water regulation (NPDWR). Publication of the list and the determinations on whether or not to proceed with regulations for specific contaminants must occur once every 5 years.

Development of the list began in 2002 using a multi-step screening process. This process differed somewhat from previous methods of developing Contaminant Candidate Lists 1 and 2. The new process was developed after consultation with the National Academies of Sciences' National Research Council and the National Drinking Water Advisory Council. It was designed to apply a broader and more transparent and reproducible process to the development of future CCLs. First a very broad "universe" of about 7,500 potential drinking water contaminants was identified. Screening criteria were then applied which reduced this broad list to a "preliminary CCL" of 560 contaminants. The screening criteria included the potential for a given contaminant to occur in public water supply systems, and the potential for public health concern. Available information about these 560 contaminants was then more closely examined and evaluated to develop the Draft CCL3.

The development process included assessment of available information, internal (EPA) and external expert opinion and commissioned reviews, active surveillance for emerging issues and a formal public process seeking nominations of potential contaminants for consideration. Structured classification models were used to help evaluate chemical contaminants, while a decision tree approach was used for microbial contaminants.

The Draft CCL3 contains 104 contaminants comprising 11 microbial pathogens and 93 chemicals. The microbial contaminants are *Caliciviruses (including Norovirus), Campylobacter jejuni, Entamoeba histolytica, Escherichia coli (0157), Helicobacter pylori,* Hepatitis A virus, *Legionella pneumophila, Naegleria fowleri, Salmonella enterica, Shigella sonnei* and *Vibrio cholerae* The chemical contaminants include a range of industrial chemicals, pesticides /insecticides /herbicides /fungicides and their degradation products, food additives, pharmaceuticals, ingredients used in household products, and cyanobacterial toxins.

In addition to seeking comments on the process used to derive the Draft CCL3 and the specific contaminants listed, the EPA is also seeking comments and further data on particular topics. These are; occurrence data on pharmaceuticals and perfluorinated compounds in finished and ambient waters, and occurrence data and health effects data for *Helicobacter pylori*. The Final CCL3 will be developed after assessment of the comments on the draft list. EPA will then evaluate each contaminant to decide whether sufficient information is available to enable a regulatory determination to be made based on both the occurrence of the contaminant in water supplies and the potential for adverse health effects. If the information is not currently sufficient to enable a determination, EPA may then initiate a program to identify and conduct the necessary research to improve the knowledge base to a point where a determination can be made. For contaminants where sufficient information exists to make a determination, the EPA may decide to develop a drinking water regulation, or may decide that a regulation is not necessary. Comments on the Draft CCL3 must be submitted to the EPA by 21 May 2008.

Federal Register / Vol. 73, No. 35 / Thursday, February 21, 2008 /Notices 9628 - 9654

Information on the CCL3 may be found at:

http://www.epa.gov/safewater/ccl/ccl3.html

Nokia Boil Water Alert Ends

The boil water order for the Finnish town of Nokia was officially lifted on 19 February, more than 10 weeks after it was implemented in response to a waterborne disease outbreak caused by sewage contamination of the drinking water supply (1). Estimates of the number of people made ill by the contaminated water have ranged as high as 5000, making it the largest waterborne outbreak ever recorded in Finland. A cross-connection at the local sewage treatment plant allowed sewage effluent to enter the drinking water supply when maintenance works were being carried out. Investigations have revealed that the pipe connecting the two systems had been in place for 20 years, and contrary to the relevant regulations the valve controlling the connection permitted water to flow in either direction. According to newspaper reports the Finnish police are investigating two senior officials from the water authority for possible breach of duty in relation to the existence of the illegal pipe connection.

Following detection of the cross-connection a program of flushing and hyperchlorination (10 mg/L) was initiated to progressively decontaminate sections of the distribution system. The pH of the supply was also reduced from 8 to 7 to enhance disinfection. Residents and businesses were asked to run off water from all of their water taps to ensure that contaminated water was cleared from internal plumbing. Water authorities were initially hopeful that the water supply would be declared safe by 22 January, however water tests revealed the persistence of Norovirus in some areas of the city, requiring an extension of decontamination efforts for a further four weeks. The clean-up program was hampered by several mains bursts which stirred up sediment in the system and further disrupted water supplies to residents. Chlorination is being maintained at high levels (2.5 mg/L) even after lifting of the boil water order, and will be gradually reduced to the normal level of 0.5 mg/L or less.

(1) See Health Stream Issue 48 for a report on the Nokia outbreak.

News Items

CRC Occasional Papers and Research Reports

PDF versions of all CRC Occasional Papers and Research Reports are now available for downloading free from the CRC website. These papers and reports span a range of water quality issues and represent the output from the extensive research program undertaken by the CRC since its formation in 1995. Currently there are 8 Occasional Papers and 37 Research Reports available. More Research Reports will be added during 2008 as the CRC completes its 13-year research program.

http://www.waterquality.crc.org.au under Publications

Australian Guidelines for Water Recycling

Phase 1 of the Australian Guidelines for Water Recycling covering non-potable uses of recycled water was published in November 2006. Since then work has been continuing on development of three modules making up Phase 2 of the Guidelines. These modules comprise:

- Augmentation of Drinking Water Supplies
- Managed Aquifer Recharge
- Stormwater Re-use

The draft version of the module on Augmentation of Drinking Water Supplies underwent a public consultation process in 2007, and feedback from this process has been incorporated into the module. It is anticipated that all required stages of approval for this module by the Environment Protection and Heritage Council, the Natural Resources Management Ministerial Council and the National Health and Medical Research Council will be completed by 24 April, and the final document should be released during May.

A brief plain language booklet is also being prepared to provide an overview of the scope and content of the full guidelines, and highlight some of the main issues in water recycling.

Draft versions of the remaining modules on Managed Aquifer Recharge and Stormwater Re-use are also expected to complete the approval process on 24 April and will be made available on the News section of the Environment Protection and Heritage Council website shortly thereafter. These modules will be open for public comment for a period of two months.

http://www.ephc.gov.au/news.html

Revision of UK Water Regulations

The UK Drinking Water Inspectorate is proceeding with amendments to the Water Supply (Water Quality) Regulations 2000 governing drinking water supplies in England and Wales. The changes reflect a significant shift towards the preventive risk management approach adopted by the World Health Organisation in the 2004 edition of its Guidelines for Drinking-water Quality. This approach emphasises the identification and management of risks throughout the water supply system, whereas existing UK regulations have tended to promote a focus on water treatment and treated water monitoring. (See Health Stream Issue 47 for a summary of the amendments to the Regulations).

Water companies were required to begin raw water quality monitoring in compliance with the new amendments from 1 January 2008, and must submit risk assessments for each system by 1 October 2008. Current requirements for *Cryptosporidium* monitoring in supplies deemed to be "at risk" for this organism will be retained until 1 January 2009 when new monitoring programs based on the risk assessments will take over. Water companies have been asked to take the new requirements into account when preparing Draft Business Plans for submission to DWI in connection with the Periodic Review of Prices which will occur in 2009.

WHO Publications on Water Supply and Sanitation

2008 has been declared the International Year of Sanitation and the World Health Organisation is highlighting sanitation issues through a number of publications and events. Target 10 of the Millennium Development Goals (MDGs) agreed by the UN member states in 2000 is to "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation". A recent WHO publication "Global costs of attaining the Millennium Development Goal for water supply and sanitation" estimated that annual expenditure of US$54 billion is needed in developing countries to maintain current water and sanitation services and an additional US$18 billion per year is needed to extend them to meet the MDG.

www.who.int/water_sanitation_health/economic/

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.waterquality.crc.org.au/search.htm

Acute myocardial infarction mortality in comparison with lung and bladder cancer mortality in arsenic-exposed region II of Chile from 1950 to 2000.
Yuan Y, Marshall G, Ferreccio C, et al. (2007) American Journal of Epidemiology, **166**(12); 1381-91.

Risk of erectile dysfunction induced by well water consumption in Taiwan.
Hsieh F-I. Hwang T-S, Hsieh Y-C et al. (2008) Environmental Health Perspectives, **online 16 January** (doi: 10.1289/ehp.10930);

Drinking water constituents and disease.
Rylander, R. (2008) Journal of Nutrition, **138**(2); 423S-425S.

After the flood: an evaluation of in-home drinking water treatment with combined flocculent-disinfectant following Tropical Storm Jeanne -- Gonaives, Haiti, 2004.
Colindres RE, Jain S, Bowen A, Mintz E and Domond P. (2007) Journal of Water & Health, **5**(3); 367-74.

Time to re-evaluate the guideline value for manganese in drinking water?
Ljung K and Vahter M. (2007) Environmental Health Perspectives, **115**(11); 1533-8.

Engineered nanomaterials in soils and water: how do they behave and could they pose a risk to human health?
Boxall AB, Tiede K and Chaudhry Q. (2007) Nanomedicine, **2**(6); 919-27.

Occurrence and co-occurrence of perchlorate and nitrate in California drinking water sources.
Kimbrough DE and Parekh P. (2007) Journal / American Water Works Association, **99**(9); 126-132+12.

Web-based investigation of water associated illness in marine bathers.
Turbow DJ, Kent EE and Jiang SC. (2008) Environmental Research, **106**(1); 101-109.

Occurrence and potential human-health relevance of volatile organic compounds in drinking water from domestic wells in the United States.
Rowe BL, Toccalino PL, Moran MJ et al. (2007) Environmental Health Perspectives, **115**(11); 1539-46.

Epidemiology and aetiology of diarrhoeal diseases in adults engaged in wastewater-fed agriculture and aquaculture in Hanoi, Vietnam.
Do TT, Bui TTH, Molbak K et al. (2007) Tropical Medicine & International Health, **12**(Suppl 2); 23-33.

Estimation of the consumption of cold tap water for microbiological risk assessment: an overview of studies and statistical analysis of data.
Mons MN, van der Wielen JML, Blokker EM et al.. (2007) Journal of Water & Health, **5**(Suppl 1); s151-70.

Chromium

Cancer mortality in a Chinese population exposed to hexavalent chromium in drinking water
Beaumont, J.J., Sedman, R.M., Reynolds, S.D., Sherman, C.D., Li, L.H., Howd, R.A., Sandy, M.S., Zeise, L. and Alexeeff, G.V. (2008) Epidemiology, **19**(1); 12-23.

There is good evidence from human and animal studies to classify hexavalent chromium (Cr^{+6}) compounds as carcinogenic when inhaled, however there is less evidence of the carcinogenicity of Cr^{+6} when ingested. Large numbers of people are potentially exposed to Cr^{+6} in drinking water, with Cr^{+6} detected in about one-third of 7000 drinking water sources surveyed by the State of California (detection limit 1 microgram/L) although at relatively low levels (85% less than 10 microgram/L). A study published in 1987 in Liaoning Province, China found elevated mortality rates for total cancer, stomach cancer and lung cancer in communities with Cr^{+6} – contaminated water. The concentrations of Cr^{+6} in drinking water wells were relatively high, ranging up to 20 mg/L and for some wells the water was noticeably yellow due to the presence of chromium. The study reported rates but did not report statistical measures of association or precision. The purpose of this present study was to reconstruct the data and estimate rate rations (RRs) and confidence intervals (CIs) for the associations reported in the 1987 study.

Information was obtained on cancer mortality, population sizes and water contamination in 9 geographic regions (5 exposed to Cr^{+6} and 4 unexposed regions) near a ferrochromium factory from reports of investigations by the local heath department (the Jinzhou Health and Anti-Epidemic Station) from 1965-1986, from data supplied by one of the Jinzhou investigators to a U.S. consulting firm in 1995, and from official census and population growth reports. This information was used to: (1) describe the chronology, hydrogeology and level of Cr^{+6} contamination of drinking water in the study regions, (2) estimate population sizes and numbers of cancer deaths in the 1970-1978 mortality observation period and (3) calculate RRs for comparison of cancer mortality rates in the Cr^{+6} –exposed study regions (combined) to rates in the Cr^{+6} –unexposed study regions (combined) and Liaoning Province.

The rate of mortality from cancer of all types in the 5 study regions with Cr^{+6} in drinking water was found to be only slightly and non-significantly elevated in comparison with the rate in the 4 nonexposed study regions (RR = 1.13; 95% CI = 0.86-1.46) and compared with the rate in the entire province (1.23; 0.97-1.53). The rate of mortality from stomach cancer in the 4 exposed regions with complete stomach cancer rate data was significantly elevated compared with the rate in the unexposed regions (1.82; 1.11-2.91) and in comparison with the rate in the entire province (1.69;1.12-2.44). The rate of mortality from lung cancer was negligibly elevated in comparison with the nonexposed regions (1.15; 0.62-2.07) but more substantially elevated in comparison with the entire province (1.78; 1.03-2.87). Mortality from cancer at sites other than the stomach and lung were not elevated in the 3 exposed regions with complete rate data compared with either the nonexposed study regions (RR = 0.86; 0.53-1.36) or the entire province (RR = 0.92; 0.58-1.38).

Although there are limitations with this study, the results of this analysis are consistent with the original 1987 study that rates of mortality from all cancer, lung cancer and stomach cancer were higher in Jinzhou-area regions with Cr^{+6} contaminated drinking water that in the general population of the province. The mortality from cancers other than stomach and lung was not found to be increased in regions with Cr^{+6} contaminated water.

Comment The authors note that this study is limited by its ecological nature, however the findings are supported by the results of a recently completed 2-year study by the US National Toxicology Program which found clear evidence of carcinogenicity for Cr^{+6} in drinking water in mice and rats.

Cryptosporidium

Outbreak of waterborne cryptosporidiosis associated with low oocyst concentrations.
Neira-Munoz, E., Okoro, C. and McCarthy, N.D. (2007) Epidemiology & Infection, **135**(7); 1159-64.

In the UK water treatment plants assessed as having a significant risk of *Cryptosporidum* contamination have been required to carryout 24-h monitoring since April 2000. Monitoring is against a standard of less than 1 oocyst/10 L of water. This paper describes an outbreak of cryptosporidiosis in a population served by a mixture of water from a groundwater source and a surface water treatment plant at significant risk where continuous monitoring samples never exceed the treatment standards.

There were 35 cases of laboratory confirmed cryptosporidiosis in the catchment area of the Portsmouth office of the Hampshire and Isle of Wight Health Protection Unit (H & IOW HPU) reported between 1 November and 31 December 2002 compared to the usual levels of about 11 cases during this period. There are five water treatment plants that serve the area covered by the Portsmouth office of the H & IOW HPU. Four of them supply ground water and one a mixture of surface and groundwater. The latter supply has been assessed as posing a significant risk of *Cryptosporidum* and is continuously monitored. A case was defined as any person who was resident in the catchment area of the Portsmouth office of the H & IOW HPU with diarrhoea with onset between 1 November and 31 December 2002 and laboratory confirmed *C. hominis* infection. An epidemic curve was plotted and the distribution of cases in relation to water supply areas was mapped. The local water company's 24-h *Cryptosporidium* monitoring program results were reviewed. A case-control study was conducted. Cases included children, civilian adults and naval personnel and controls were frequency matched within these three groups. Cases and controls were administered a questionnaire to assess recent exposures.

There were 29 cases that met the case definition. All cases were genotype 1. There was a peak in incidence in the fourth week in November with 14 cases reporting onset of illness during this week. The water company's continuous monitoring recorded *Cryptosporidium* oocyst levels of less than 1/10 L of water throughout October and November. For 49 of the days in this period 0 oocysts/1000L were detected from the daily filtered water samples, while 4 oocysts per 1000L were detected on 10 days, and 5 oocysts and 8 oocysts on two other days. Twenty-four of the cases lived in the water distribution area which receives mixed surface and ground water. The other five cases were recorded in an area that usually receives groundwater but received temporary supplies from the plant associated with the other cases during the outbreak period. No cases were recorded in the areas which received water from the plants using only ground water. The only exposure found to have a strong positive association with reported cryptosporidiosis was quantity of water consumed at home. There was no association found with consumption of bottled water or water consumed outside the home. In a multivariate model, only water consumed at home and use of swimming pools were strongly associated with reported *Cryptosporidium* infection. Mean water consumption at home was 6.5 glasses per day among cases and 3.2 among controls. There were 39% of cases and 17% of controls who reported using swimming pools.

The descriptive and epidemiological findings of this study strongly implicate drinking water in causing an outbreak of cryptosporidiosis in this population. There may have been some transmission via swimming pools during the outbreak particularly among children, but there is no evidence that pools were the main or sustaining cause of the outbreak. This Portsmouth outbreak is believed to be associated with the lowest reported oocyst concentration in the literature. There was no evidence of problems with water turbidity or pH that might have affected the operation of the conventional sand filtration water treatment process, and no recent work had been carried out on the water reservoir. This outbreak suggests that disease burden in sources at risk meeting the current standard may not be negligible and work to estimate it needs to be a priority. The evidence base for the current standards of water quality for *Cryptosporidium* is questionable and needs review. Additional infrastructure and process regulations may be needed for identified at-risk sources as well as monitoring.

<u>Comment</u> No mention is made of any problems with the distribution system which may have allowed contamination to enter the treated water supply, but

presumably this possibility was also investigated. Volunteer infection studies for Cryptosporidium parvum (which infects cattle, sheep and humans) have shown large variations in infectivity between different strains. Only one strain of C. hominis (which infects only humans) has so far been tested in volunteers - this strain showed a low infectious dose with 40% of volunteers who received 10 oocysts subsequently developing diarrhoea.

Disinfection Byproducts

Occurrence of *N*-nitrosamines in Alberta public drinking-water distribution systems.
Charrois, J.W., Boyd, J.M., Froese, K.L. and Hrudey, S.E. (2007) Journal of Environmental Engineering, **6**(103-14.

The regulatory and health risks focus associated with exposure to disinfection by-products (DBPs) has historically centred on halogenated compounds. This preoccupation was partly due to the availability of analytical techniques to detect these groups of compounds as well as their relatively high abundance in drinking waters. Epidemiological studies have found low but consistent associations between increased consumption of disinfected drinking water and chronic adverse outcomes such as urinary bladder cancer, however probable agents are yet to be identified. Chlorination and chloramination also produce non-halogenated DBPs. *N*-nitrosamines are an emerging class of non-halogenated DBPs that are acknowledged as carcinogens at realistic exposure concentrations. If exposure to *N*-nitrosamines in drinking water is shown to be a human health risk then they will need to be minimised wherever they occur at unacceptably high levels. The main objectives of this study were to develop an efficient solid-phase extraction (SPE) method for *N*-nitrosamines to enable rapid processing of multiple samples and to evaluate select public drinking water distribution systems in Alberta for the occurrence of eight *N*-nitrosamine species.

Samples were collected from utilities that either used chlorination or chloramination-based disinfection processes. Water treatment plants that served a majority of Alberta's population were selected. Inclusion criteria for facility selection included a history of elevated trihalomethanes (THMs) or haloacetic acids (HAAs) and/or naturally high ammonia concentrations in groundwater sources. A dual media (Ambersorb® 572 and LiChrolut® EN), off-line, solid-phase extraction method that use a modified commercially-available extraction manifold combined with GC-MS ammonia positive chemical ionization quantitative method for analysing *N*-nitrosamines in drinking water was developed.

There were 23 locations from 20 Alberta distribution systems sampled with samples analysed for eight *N*-nitrosamines species during the summer of 2004. It was found using the manifold system that up to ten samples per day could be extracted by one person. Of the samples collected, 6 of the 20 distribution systems had a least one location where *N*-nitrosodimethylamine (NDMA) was detectable. Toxicologically, NDMA is more potent than "traditional" DBPs such as THMs and HAAs. Of the utilities with detectable NDMA concentrations, 5 of 6 used chloramination. Only one of eight chlorination-only utilities had detectable NDMA. Detectable NDMA concentrations were found to range from 1.3 ng/L to 100 ng/L. Distribution system A (chloramination) had the highest NDMA concentrations which ranged from 66 ng/L in the middle of the system to 100 ng/L at the furthest extreme of the system. Other *N*-nitrosamines were detected in 2 of the 20 distribution systems. *N*-Nitrosomorpholine (NMor) and N-nitrosopyrrolidine (NPyr) were detected at concentrations up to 3 ng/L and 4 ng/L, respectively.

In this survey an SPE manifold system was successful in reducing sample processing times. This survey suggests that most of Alberta's drinking water supplies do not contain concentrations of *N*-nitrosamines in excess of the Ontario's drinking water quality standard of 9 ng/L, although temporal and/or seasonal trends were not evaluated. Those locations identified as having high *N*-nitrosamines concentrations need to have resources allocated to evaluate appropriate treatment processes and source water quality so informed decisions can be made as to the necessary actions required to reduce *N*-nitrosamines in drinking water. DBP research also

needs to focus on the identification and control of precursors that can lead to extreme *N*-nitrosamines concentrations in drinking water. Disinfection with chloramines has often been used instead of chlorination because of the tendency to produce less chlorinated DBPs such as THMs and HAAs, however ironically in an attempt to reduce regulated DBP concentrations, alternative disinfection processes such as chloramination have in some instances been found to generate unregulated DBPs such as *N*-nitrosamines that may be of equal or greater concern to public health.

Endotoxins

Estimation of endotoxin inhalation from shower and humidifier exposure reveals potential risk to human health.
Anderson, W.B., Dixon, D.G. and Mayfield, C.I. (2007) Journal of Water & Health, **5**(4); 553-572.

Endotoxins are part of the outer membrane of the cell wall of most Gram-negative bacteria and some cyanobacteria. This paper investigated the potential exposure to endotoxin in drinking water via inhalation of aerosols from showers and humidifiers. The literature contains relatively few studies describing outbreaks of adverse health effects associated with aerosolised endotoxin, however many incidents may go unreported due to the non-specific symptoms experienced at low doses (impaired breathing, cough and quickly resolving fever). Reported incidents have been associated with high levels of bacteria or endotoxin in water and situations where aerosols have been effectively generated.

In order to put the risk associated with waterborne aerosolised endotoxin into perspective it is useful to examine other airborne endotoxin exposure sources. Exposure in the occupational setting has generally been associated with organic dusts of various kinds. An analysis of occupational studies shows the lowest dose reported to be associated with a statistically significant health effect (FEV_1-forced expiratory volume or volume of air exhaled in 1.0 s –the first second) is 0.1 to 2 ng/m^3. This corresponds to 1 to 20 endotoxin units (EU)/ m^3 and is consistent with other studies showing effects at 40 to 53 EU/m^3.

Controlled laboratory endotoxin inhalation studies in human volunteers have found indicators of immunological activity and mild symptoms such as shortness of breath occur at doses around 5 micro g and a dose of about 50 micro g is required to elicit symptoms such as chills and fever. These doses have been assumed to correspond to roughly 50,000 and 500,000 EU, respectively. Responses are highly variable, probably reflecting the variability of individual physiology, the type of bacteria from which the endotoxin is derived, and the size of particles as well as the respired dose. People with asthma and other allergic respiratory conditions generally show a stronger adverse response to endotoxins.

There are several factors that need to be considered when estimating human exposure to endotoxins, these include body weight, sources of inhalation, endotoxin concentrations in those sources, inhalation rates as well as both exposure frequency and duration. Although water is used in many ways in households, most of these uses would be unlikely to generate aerosolisation of a non-volatile compound such as endotoxin under typical conditions. Water-related exposures that may result in endotoxin aerosolisation include showers, humidifiers, hot tubs, saunas, and pools in which fountains, showers or aeration are present.

A theoretical assessment of endotoxin exposure from shower and humidifier (ultrasonic and impeller) aerosols was undertaken based on information available in the literature. Only those conditions resulting in acute health outcomes were considered. It was concluded that respirable aerosol production from showering is probably too low to produce effects under normal circumstances, but if endotoxin levels in the water are increased (eg following shutdown and subsequent restart of biological drinking water filters without backwashing, or occurrence of cyanobacterial blooms in source water) then adverse health effects may be possible. Humidifiers that create aerosols by ultrasonication may produce large amounts of respirable endotoxin in short periods of time, even if bacteria are not growing in tanks or reservoirs. Impeller type humidifiers generate fewer particles of respirable size

resulting in a 15 to 30% reduction in inhaled endotoxin dose. This assessment suggests that humidifiers could potentially be associated with adverse health effects even at endotoxin concentrations typically found in drinking water distribution systems (25EU/ml). If these predictions are confirmed by studies under controlled laboratory conditions, it may be advisable to reassess the design and operation of humidifiers. The potential for aerosolisation of whole bacteria should also be examined.

Lead

Assessment and management of tap water lead contamination in Lower Saxony, Germany.
Zietz, B.P., Lass, J. and Suchenwirth, R. (2007) International Journal of Environmental Health Research, **17**(6); 407-18.

Significant negative correlations between children's mental development and environmental lead exposure have been reported, and prenatal exposure to lead appears to reduce intellectual development in children. Some studies have indicated that children with moderately elevated levels of blood lead suffer from slight renal effects and hearing impairment. In the general population, lead exposure even at low levels has been associated with an increase in blood pressure. In adults associations between blood lead levels and an increased all-cause and cardiovascular mortality was recently seen in a study on blood lead levels well below 10 micro g/dl. Metal corrosion in the peripheral water distribution system, especially household plumbing is an important source of lead exposure from drinking water in some systems. In Germany installation of lead plumbing has not been permitted since 1974. At present the limit of lead in tap water in Germany is 25 microgram/L however in the year 2013 the limit will be lowered to 10 microgram/L. This study was undertaken to assess the present state and geographical distribution of drinking water contaminated with lead in Lower Saxony, Germany and to promote the replacement of lead pipes.

Free examination of drinking water was offered to the study target group which included private households with young women or families with children in Lower Saxony living in buildings constructed before 1974. Participants were provided with a sample bottle and asked to collect a cold tap water sample in their household after nocturnal stagnation at the tap from which they usually took their drinking water. The first 1000 ml was flushed before filling the bottle with 125 ml of water. All households also completed a questionnaire to assess factors of interest regarding installation, building and uptake of tap water. Water samples from the target group were measured for lead concentration. In samples with lead concentrations greater than 10 microgram/L the elements Cu, Fe, Mn and Zn were determined as well as Al, As, Cd, Cr, Ni, Sb and Se.

Measurements of lead in drinking water samples taken from buildings open to the public were extracted from official records. All local public health departments were asked to complete a detailed questionnaire on water testing performed since 2003, and to gather information from the public water suppliers on how many lead service lines exist. Lastly a working group on 'lead replacement' was formed with representatives of all relevant parties (e.g. tenant and landlord federations, handicraft, building and health administration) to ensure a smooth information flow between parties and to promote acceptance for the replacement of lead pipes especially in landlord/real estate owner federations and building administrations.

There were 2436 tap water samples collected from households. Of these 6.49% had lead concentrations exceeding 10 microgram/L (recommended limit of the WHO) and 2.79% had concentrations above the current German drinking water ordinance (25 microgram/L). The mean lead concentration was found to be 4.1 microgram/L, the geometric mean 1.1 microgram/L and the median lead concentration 0.5 microgram/L. There were 58.8% of the values below the detection limit (0.83 microg/L). The frequency of samples exceeding regulatory limits was variable from one region to another. From the questionnaire there were 12.9% of participants who stated that their domestic installation was made of lead. Of the 158 households with lead concentrations greater than 10 microgram/L, 44.9% were stated to have lead

plumbing and 40.5% were stated to have copper pipes. Of those stated to have lead plumbing (*n*=314), 22.5% had lead concentrations above 10 microgram/L and 10.5% above 25 microgram/L.

Multi-family houses were more often affected by elevated lead concentrations than single- and double-family houses. Buildings constructed until the year 1939 had a higher fraction of elevated lead concentration in relation to the stated construction year compared with buildings constructed between 1940 and 1973. In the subset of samples measured for concentrations of other elements, more than 10% of the nickel or iron concentrations were elevated above the limit of the German drinking water ordinance. Test results were obtained for 1314 buildings in 45 local public health departments in Lower Saxony, and 4.72% had lead concentrations above 10 microgram/L.

From the data gathered from the first and second parts of the project, about 4-5% of all buildings/dwellings in Lower Saxony have elevated lead concentrations of greater then 10 microgram/L in their tap water. The results found here are in a similar range compared to other German studies on lead contamination of tap water. It therefore can be concluded that lead pipes are still a problem in many households in Lower Saxony and further efforts need to be made on a regional basis to hasten the replacement of lead piping.

Microcystins

Occurrence of microcystins in 33 US water supplies.
Haddix, P.L., Hughley, C.J. and LeChevallier, M.W. (2007) Journal American Water Works Association, **99**(9); 118-125+10.

Microcystins are a group of cyclic peptide compounds which are produced and released by a number of cyanobacterial genera. Microcystins cause liver toxicity in humans and other mammals, and it has been suggested they may contribute to increased cancer risks among populations consuming contaminated water. The microcystin class of toxins is predominantly intracellular and therefore water treatment processes designed to remove intact cells by coagulation, sedimentation and filtration provide the greatest defence against them. The World Health Organization (WHO) has established a provision drinking water level of 1 microgram/L (usually measured as microcystin-LR (m-LR)), which is intended to be safe for life long exposure. Australian guidelines recommend a maximum contaminant level of 1.3 m-LR equivalents. This paper summarises the findings of a survey of microcystins in 33 US water treatment plants drawing water from lakes or reservoirs.

Surface grab samples or plant effluent samples (200 mL) were collected by plant personnel. Nearly all of the sites were located in the northeastern and midwestern United States. Samples were collected twice a month with a total of six to seven samples taken at each site during the summer of 2003. Microcystins were extracted from water samples using a method which released cell-bound toxins, and quantified using a commercial enzyme-linked immunosorbent assay (ELISA) kit. Experiments with spiked samples showed that the efficiency of recovery varied in different water matrices, with a mean of 13% recovery for raw waters (n=97) and 5% for treated waters (n=23). Reported toxin levels were therefore corrected based on these mean recovery rates.

Microcystins were detected at least once in all raw water sources (mean 0.307 microgram/L, maximum 5.646 microgram/L). Although 87% of raw water samples contained toxins, most (93.2%) were below the WHO guideline of 1 microgram/L. Plant effluent samples were tested only if microcystins had been detected in the corresponding raw water samples. Detectable toxin levels were found in 30% of the 77 effluent samples tested, but none exceeded the WHO guidelines. Two raw water sources (Lake R-1 and Reservoir R-2) were found to have mean toxin concentrations exceeding 1 microgram /L over the monitoring period (early July to late October), and six other sites had peak readings above the guideline value. Fertiliser run-off from residential lawns beside the lake may have contributed to cyanobacterial growth in lake R-1, and the water treatment plant for this system was not operational during the summer,

probably causing decreased flow of water through the lake. Reservoir R-2 may have been prone to contamination from sewage overflows, and this source was taken out of supply in September 2003 due to high manganese and odor problems. This reservoir had been treated with copper sulphate algicide in spring 2003, but this was apparently unsuccessful in controlling algae growth.

This study showed that microcystins can be detected in both raw and finished water using commercially available ELISA kits. Comparison of aggregate results for raw and treated water samples suggests that conventional water treatment processes produce almost 10-fold reduction in microcystins. Concentrations of toxins were generally low, however impounded surface water with low circulation and nutrient input may be at risk for developing toxic algal blooms as seen for two sites here.

Norovirus

Gastroenteritis outbreak caused by waterborne norovirus at a New Zealand Ski Resort.
Hewitt, J., Bell, D., Simmons, G.C., Rivera-Aban, M., Wolf, S. and Greening, G.E. (2007) Applied and Environmental Microbiology, **73(**24); 7853-7857.

Noroviruses (NoVs) are a common cause of outbreaks of viral gastroenteritis, and in New Zealand in 2006 there were approximately 200 recorded NoV outbreaks with nearly 4,000 associated cases. NoV has a low infectious dose and persists in the environment which allows for its spread in water as well as by food and direct person-to-person transmission. This paper describes the virological investigation and briefly the epidemiological and environmental investigations of an outbreak of NoV gastroenteritis at a New Zealand ski resort.

Public health authorities were informed on 27 July 2006 of a possible outbreak of gastroenteritis among staff and visitors at a popular ski resort. On 25 July, 48 staff were absent from work due to acute gastrointestinal illness, and on 26 July this had increased to 83. Three small outbreaks of gastroenteritis among groups who had recently visited the resort were also reported to the public health authorities on 26 and 27 of July. A retrospective cohort investigation was conducted among ski resort staff using a standardised questionnaire assessing exposure between 22 and 25 July 2006. Illness incidence among skiers at the resort was assessed from complaints to the resort management, notifications from general practitioners, and self-reporting following media publicity of the outbreak. A case was defined as a resort staff member or visitor who developed diarrhoea or vomiting on or after the 21 July 2006. Information about the design and management of the water supply and the sewerage systems was gathered from the ski resort management. The restaurants, child care and health care faculties at the resort were also inspected.

Faecal samples were collected from 31 staff, visitors and apartment dwellers with recent symptoms of acute gastroenteritis. There were an additional 42 faecal samples collected from the community via family physicians from patents with gastroenteritis apparently unrelated to the resort outbreak. Faecal samples from outbreak cases were referred for microbiological and virological analysis. Before the outbreak the water supply was monitored weekly for the presence of total coliforms and *Escherichia coli.* After a positive result for total coliforms on 27 July, water samples were collected from four points along the water supply for additional coliform and *E coli* testing and for NoV analysis. Water was also sampled from a suspected contaminated source stream later in the investigation. Water samples were concentrated by ultrafiltration and then real-time reverse transcription-PCR (RT-PCR) was used for rapid detection of NoV from both water and faecal samples. Samples that were positive for NoV were further characterised by DNA sequencing.

There were a total of 218 cases identified (115 ski resort staff and 103 visitors) in this outbreak. Staff who reported drinking water at the staff cafeteria on 24 or 25 July 2006 were found to be twice as likely to develop acute gastroenteritis than those who did not (relative risk, 2.0; 95% CI: 1.5 to 2.8). There were no other exposures associated with a statistically significant increased risk of illness. The questionnaire did not distinguish between

consumption of hot and cold water, and this may have reduced the relative risk estimate as boiling would have inactivated pathogens. The usual water supply for the resort originated from a small lake fed by a spring. The water was filtered and UV treated before distribution to buildings in the resort. Although no problems with the water supply were reported during the initial investigations it later emerged that additional water had been pumped to the lake from a stream in order to augment the supply. Environmental investigations revealed that on 22 to 23 July, a septic tank had become blocked and had overflowed at the resort. The point of the sewage overflow was above the stream and it is possible that sewage may have reached the water extraction point in the stream. Intake from the stream continued for 3 days after the outbreak was recognised.

Water samples taken on 27 July were found to have significant levels of *E. coli* (range, 7.4 to 220 per 100 ml) from the four points along the water supply including the lake, storage tanks and the main building which housed the restaurants and child care and health care services. NoV GI was found in 11 of the 31 faecal samples of cases. There were also cases identified of rotavirus (1 case), *Cryptosporidium* (4 cases) and *Campylobacter* (2 cases). Three of the 42 community cases of acute gastroenteritis were positive for NoV GI. Water samples taken on 27 July from the tap in the main building and from the source stream on 3 August were positive for NoV GI. The NoV GIs that were detected in the faecal samples from the outbreak cases and the community cases and from the main building tap and source stream water were typed as GI/5.

This is currently the largest reported NoV outbreak in New Zealand. The investigations provided evidence that the water supply for the ski resort was contaminated with human sewage. The virological identification of NoV GI/5 in faecal samples from cases of gastroenteritis and from the water supply provided a linkage between cases and the source water and this data was critical to confirming the source of the outbreak. This is also the first report of the use of ultrafiltration combined with quantitative real-time RT-PCR and DNA sequencing for the investigation of a waterborne NoV outbreak.

Outbreak Analysis

Fault tree analysis of the causes of waterborne outbreaks.
Risebro, H.L., Doria, M.F., Andersson, Y., Medema, G., Osborn, K., Schlosser, O. and Hunter, P.R. (2007) Journal of Water and Health, **5**(SUPPL. 1); 1-18.

In order to formulate effective outbreak or contamination event prevention strategies, the key and potential threats to water quality need to be identified. As failures can occur across different stages of the drinking water system from source to tap, multi-barrier approaches to safe drinking water have been used. The multi-barrier approach includes the key elements of source water, treatment, distribution, management and response. Multiple events can concurrently contribute towards outbreaks of waterborne disease and the multi-barrier approach provides multiple levels of protection which when combined may reduce the risk of outbreaks or contamination events. This paper examines the causal factors involved in enteric disease outbreaks related to public drinking water supplies in the European Union (EU).

A search was conducted for publications on outbreaks of enteric waterborne disease associated with EU public drinking water supplies. There were 86 outbreaks identified between the years 1990-2005. Fault tree analysis (FTA) was used to further investigate the relevance of specific outbreak causal factors. At the top of the fault tree is the outbreak; all preconditions for the outbreak are determined until the primary causes are identified (base events). All events are joined by a series of gates and branches; an AND gate requires all input events to occur and an inclusive OR gate requires one or more input events to occur. The main assumption is that faults such as outbreaks happen when multiple events take place. A generic outbreak fault tree was developed which used the key elements of the multi-barrier approach to fit all outbreaks of enteric disease related to drinking water. A scoring system was developed where base events (if reported to occur) were given a

proportional score between 1 and 100 according to the magnitude of its contribution towards the outbreak. Base events scores for each outbreak add up to 100. The fault tree was discussed and validated at a meeting of seven experts from five EU countries.

A total of 61 outbreaks had sufficient information to permit application of the fault tree, and collective decisions by at least three reviewers were made on scores for base events. There were numerous causative events associated with the outbreaks examined (mean of 3.25 events per outbreak, range 1-10 events). Only 13 of the 61 outbreaks were considered to arise from a single base event. Distribution system causative events occurred in 19 outbreaks and were often solitary events contributing towards the occurrence of individual outbreaks (mean contributory score of 87.42). Source water contamination and treatment system failures occurred frequently, each in 41 outbreaks and together in 34 outbreaks. There were 19 outbreaks in which the presence of livestock in the catchment area along with rainfall led to surface water run-off and ingress contaminating groundwater or surface water sources. There were 23 protozoan outbreaks where at least one treatment causative event occurred and of these 90% were filtration deficiencies. In contrast to this for bacterial, viral, gastroenteritis and mixed pathogen outbreaks, 75% of treatment events were due to disinfection deficiencies. For 11 of the outbreaks, no/inadequate comprehension or no action upon existing/previous water quality monitoring results was recorded. Of the source water base events, 'groundwater abstraction/design/barrier failure' received the highest mean contributory score of 35.61 and all of the 20 treatment base events for groundwater outbreaks were chronic in nature (ie absence of adequate treatment rather than temporary failure of treatment). Most of the surface water outbreak treatment events were the result of chronic filtration deficiencies.

This analysis of a variety of public drinking water supply outbreaks has lead to the identification of key causative factors involved in enteric disease outbreaks. This fault tree analysis could be modified to suit different water systems, pathways and causative factors that include human factors and mechanical failures and additional point and non-point contaminant sources. Such analyses could be used by individual water companies to priorities areas of concern and assist in distribution of resources for outbreak prevention strategies. The authors note that the analysis is limited to the information recorded in published literature and available outbreak investigation reports, so some contributing factors may have been missed if they were not recorded in these information sources.

Pathogens

Assessment of source water pathogen contamination.
Dechesne, M. and Soyeux, E. (2007) Journal of Water and Health, **5**(SUPPL. 1); 39-50.

This paper reports on a study of pathogens in 11 source waters in five European countries and one source water in Australia. The study used a structured framework for the evaluation of source water quality. The following pathogens were considered due to their high risk to human health and potential presence in source waters used for drinking water supply: *Cryptosporidium* and *Giardia*, *Campylobacter* and *E. coli* 0157:H7 and enterovirus and norovirus. The assessment process begins with a detailed survey to characterise the properties of the catchment and the potential sources of human and animal faecal contamination. It is essential to consider variations in water quality and circumstances which may trigger hazardous/peak events as well as understanding baseline conditions. A monitoring programme has to be designed specifically for each system, especially for peak contamination assessment. Monitoring for pathogens (*Cryptosporidium*, *Giardia*, *Campylobacter* and *E. coli* 0157:H7 enterovirus and norovirus), faecal indicators (*E. coli*, *Clostridia*, Total Coliforms, Enterococci) and physico-chemical characteristics (turbidity, conductivity, temperature, pH) is recommended. Water flow also should be evaluated to distinguish baseline from rain event contamination. For assessment of baseline water quality, a full year of monthly sampling is recommended, while for peak contamination, monitoring of at least two full events is advisable.

This methodology was applied to twelve water sources. For each system, pathogen variability, pathogen concentration mean and standard deviation were determined in baseline and rainy conditions. Concentrations were found to vary greatly within and between systems. No pathogens were detected in the two groundwater systems assessed. Surface reservoir water quality was often found to be better than river water quality. Hydrological peak events produced higher faecal indicator concentrations in surface water whereas groundwater appeared unaffected. The results were not as clear for pathogens and reasons suggested for this include: non-representative rain event sampling, performance of analytical methods hindered by high turbidity, and the effect of dilution on concentrations. Faecal indicators were mostly found to be well correlated with each other and with turbidity. However there was no recurring evidence of correlation for pathogens either with each other or with faecal indicators or turbidity. It appears that faecal indicators and turbidity are poor surrogates for pathogen presence and concentrations.

Assessing the source water quality is important as it will influence requirements for treatment, treatment efficiency and the resulting health risk that is associated with the finished water. The variability seen here among systems shows the importance of running local monitoring programmes for use in risk assessment. Pathogen detection methods are currently not optimal due to the sensitivity of analytical techniques and a lack of knowledge about the viability and infectivity of cysts and viruses. The data required for risk assessment needs to be of good quality as this may have substantial implications in the statistical risk assessment calculations.

Comment This paper reports on one aspect of the MicroRisk Project – a European collaboration undertaking a range of projects on quantitative assessment of microbiological safety of drinking water. See http://www.microrisk.com for details.

Rainwater

Quantitative microbial risk assessment with respect to Campylobacter spp. in toilets flushed with harvested rainwater.

Fewtrell, L. and Kay, D. (2007) Water and Environment Journal, **21**(4); 275-280.

In the United Kingdom increasing pressure on water supplies has resulted in the adoption of rainwater harvesting to provide in-house water for toilet flushing and other nonpotable uses in some instances. Such practices may become more widespread as water shortages continue. This paper examines the possibility of *Campylobacter* infection resulting from the use of rainwater harvesting for toilet flushing in the home in the United Kingdom through a health impact assessment (HIA) and quantitative microbial risk assessment (QMRA).

A literature review was undertaken of rainwater harvesting and the possible health impacts by searching a number of web-based databases for key words. Reference lists of each document were searched for relevant references. The possible health impacts identified were investigated by additional literature searches. The HIA was conducted on a hypothetical population based on a newly built estate in south of England comprising 1868 houses with a total population of 4483. It was assumed that an in-house rainwater harvesting system was installed in each house when constructed. The rainwater system consisted of an underground tank with a filter preventing leaves and other solids from reaching the tanks. Mains top-up, where required was direct to the storage tank. All houses were assumed to have separate plumbing so the harvested supplies could be used for toilet flushing. The identified health impacts were measured using disability-adjusted life years (DALYs). DALYs combine years of life lost (YLL) as a result of premature mortality, with years lived with disability (YLD), standardised using severity weights ranging from 0 (perfect health) to 1 (dead).

A number of possible hazards associated with rainwater harvesting were identified including: risk of infection from ingestion of aerosols produced from toilet flushing, direct ingestion of rainwater via the garden tap, inadvertent ingestion of rainwater through cross-contamination with drinking water supplies and ingestion of garden produce contaminated as a result of watering with harvested water. The main source of pathogens in harvested

rainwater in the United Kingdom is likely to be bird faeces. The two most commonly studied and most frequently isolated pathogens are *Salmonella* spp. and *Campylobacter* spp. *Campylobacter* spp was used to illustrate this QMRA as it has a lower infectious dose from water than *Salmonella* spp. and has been isolated from rainwater supplies and implicated in illness from rainwater supplies used for drinking water. *Campylobacter* is the most commonly reported cause of gastroenteritis in England and Wales, and campylobacteriosis is characterised by severe diarrhoea and abdominal pain and may results in severe secondary adverse health outcomes.

The dose-response and exposure data used here were based on published values in the literature. *Campylobacter* concentrations were assumed to range between 0 and 0.56/100 mL with a homogenous distribution within water. It was assumed that *Campylobacter* spp. will be present between 0 and 10% of the time. The volume of water ejected during a typical flush that is likely to reach a susceptible host was assumed to be between 0 and 0.25 mL, with a mean of 0.1 mL. It is assumed that people are exposed to flush aerosol 5% of the time. A range of between three and six flushes/day was assumed. Every household member was thought to be equally susceptible apart from children under 1 who do not flush the toilet. The analysis was therefore only conducted on a population of 4432.

Over a year, an estimated 0.023 cases (mean) of campylobacteriosis were predicted resulting in a mean DALY score of 6.8×10^{-5} for the case study population. When the estimate for salmonellosis for toilet flushing is added in, the overall DALY score for the case population is 7.4×10^{-5}. In the 2004 WHO guidelines for drinking water quality, the tolerable disease burden from drinking water has been suggested to be no more than 1×10^{-6} DALYs per person per year. This equated to a DALY score of 4.5×10^{-3} for the case study population – therefore the estimated disease burden from using rainwater to flush toilets is nearly two orders of magnitude less than the tolerable limit. The likely increase in risk from using rainwater instead of potable water to flush household toilets is therefore considered to be negligible.

Reclaimed Water

Quality of reclaimed waters: a public health need for source tracking of wastewater-derived protozoan enteropathogens in engineered wetlands.
Graczyk, T.K. and Lucy, F.E. (2007) Transactions of the Royal Society of Tropical Medicine & Hygiene, **101**(6); 532-3.

This mini-review summarises the public health importance of protozoan enteropathogens and the need for research into the effectiveness of engineered wetlands for reducing numbers of these organisms in reclaimed water. *Cryptosporidium parvum*, *Giardia lamblia* and human virulent microsporidia are all human enteropathogens that cause considerable morbidity in healthy people, in particular children, and may cause mortality (e.g. *Cryptosporidium* and Microsporidia) in the immunosuppressed. The transmissive stages of these pathogens (oocysts, cysts and spores) are environmentally robust and are therefore ubiquitous in aquatic habitats. Water resources used for drinking and recreational purposes are frequently found in the same watersheds where treated effluents from wastewaters are discharged. Monitoring of drinking, recreational and wastewaters for these pathogen has been rare in the past but a range of molecular techniques are now available for identification, enumeration, viability assessment and source tracking. A recent study by the same authors has shown that reed bed discharges can contribute to microbial build up in reclaimed water but these pathogens may not necessarily originate from the wastewater received by these wetlands as has been presumed previously. There is evidence that wildlife in constructed wetland systems may support the propagation and transmission of anthropozoonotic protozoan enteropathogens entering the wetlands.

The demand to providing microbiologically safe reclaimed water is growing as the population grows worldwide, and constructed wetlands are increasingly being used for secondary or tertiary treatment of municipal sewage. These reed bed systems discharge

to waters used for drinking water abstraction or recreational uses in many developing and developed countries. More research is needed into the effectiveness of wetlands for reduction of pathogenic protozoa and appropriate indicators for these pathogens need to be developed to ensure the quality of reclaimed water.

Water Consumption

Drinking water consumption patterns in British Columbia: an investigation of associations with demographic factors and acute gastrointestinal illness.
Jones, A.Q., Majowicz, S.E., Edge, V.L., Thomas, M.K., MacDougall, L., Fyfe, M., Atashband, S. and Kovacs, S.J. (2007) Science of the Total Environment, **388**(1-3); 54-65.

In Canada there have been several epidemics of waterborne gastrointestinal illness in recent years that have caused considerable morbidity. Estimates of drinking water consumption patterns are useful for studies on waterborne illness as well as for waterborne risk assessments and the formation of water quality guidelines. This study was undertaken to: describe the drinking water consumption patterns of residents of the province of British Columbia (BC), Canada, including the amount of water consumed daily and the use of bottled water and in-home treatment methods; to examine the association between water consumption patterns and various demographic characteristics of the residents, and to determine whether residents' consumption of water from different sources and in three different regions of BC, was associated with the occurrence of acute gastrointestinal illness in the previous month.

From June 2002 to June 2003 a retrospective, cross-sectional telephone survey was administered to selected residents of BC within one urban region (Vancouver, large water system with protected surface water supplies treated with chlorine), one rural region (East Kootenay, predominantly small water systems with unprotected surface water sources), and one semi-urban and rural region (Northern Interior, predominantly multiple, small water systems with deep wells). The survey questionnaire asked respondents if they had experienced any vomiting or diarrhoea in the previous 28 days. Respondents were considered to be acute gastrointestinal illness cases (AGI) if they reported vomiting or diarrhoea in the four weeks prior to the interview. Respondents who did not report vomiting or diarrhoea as well as those identified as having chronic gastrointestinal illness (GI e.g. from pregnancy, medication use, food allergies or physician diagnosed medical conditions) were included as non-cases. Respondent were also asked to report the amount of water consumed in total in the home during the 24 hours prior to the interview. Water consumption included plain water and water used in the preparation of cold beverages but did not include water used in the preparation of hot beverages and food. Respondents were also asked about the source of home water. There were also questions on international travel, region of residence and demographic characteristics.

There were 4612 surveys completed with 98.3% of respondents answering the question on amount of water consumed per day. Total daily intake ranged from zero to thirty-six 250 mL servings per day with a median value of four 250 mL servings (1.0 L). Using a multivariable least squares regression model of the amount of water consumed, bottled water users consumed more water per day than non-bottled water users and water consumption was slightly higher on weekdays compared to weekend-days. Adults with higher education levels consumed more water per day than the adults with less than high-school education. For those over approximately 25 years, females consumed more water per day than males. The use of water treatment devices was associated with an increase in the amount of water consumed per day in both sexes. There were about 23% of respondents (981/4306) who were classified as "bottled water users". Daily water intake among bottle water users ranged from one-half to twenty-eight 250 mL servings with a median of five 250 servings (1.25 mL). Bottled water use was higher among municipal water users than private water users. There was high use of bottled water in all income categories above the lowest income category, and about 47% of respondents (2146/4610) reported using in-home water treatment. The most common

were jug filters (53%), followed by boiling (15.5%) and tap filters (14%). A lower prevalence of in-home water treatment was found in the rural area of East Kootenay and Northern Interior than in Vancouver, and among residents with private water supplies than residents with municipal supplies. There were about 10% of respondents (451/4612) who reported a gastrointestinal illness that met the case definition. The odds of reporting AGI in the previous 4 weeks increased as reported water intake increased. Males were less likely to report AGI than females and the odds of AGI decreased with increasing age.

In this study bottled water consumption and the use of water treatment devices were common and found to be associated with various demographic characteristics, region of residence and type of water source. AGI was significantly associated with the amount of water consumed in this analysis however a causal effect cannot assumed since no temporal relationship can be established. Data on water consumption related to the day prior to interview whereas illness data related to any time during the previous four weeks. Thus increased water consumption could have been a response to dehydration associated with AGI rather than a cause of AGI. The results of this study highlight the non-uniform nature of drinking water consumption characteristics among subpopulations and these differences may represent differences in risk of exposure to waterborne hazards.

Water Quality

Pediatric emergency department visits for diarrheal illness increased after release of undertreated sewage.
Redman, R.L., Nenn, C.A., Eastwood, D. and Gorelick, M.H. (2007) Pediatrics, **120**(6); e1472-e1475.

Past practices of permitting combined sewers that carry both stormwater and sewage may result in wet weather flows that exceed the processing capacity of the sewage treatment plant. In the US some state regulators permit bypass of part of the normal sewage treatment process when such high flows occur, so that a fraction (up to 20%) of the sewage stream receives only primary treatment. This partially treated effluent is then blended with secondary treated effluent and disinfected before discharge to waterways. Such practices may result in increased pathogen concentrations in receiving waters as most pathogen removal during sewage treatment occurs during secondary treatment steps.

This study was undertaken to determine if there is an association between secondary sewage bypass and emergency department (ED) visits for gastroenteritis among children in Milwaukee, Wisconsin, metropolitan area. A retrospective observational time-series analysis was conducted. Data was obtained for a 3-year period, from January 2002 to December 2004, from the computerised billing system at the Children's Hospital of Wisconsin (CHW). The primary outcome variable was the daily number of visits for diarrheal illness to the CHW. The main independent variable was the occurrence of a secondary sewage bypass event in the 3 to 7 preceding days as report by the Milwaukee Metropolitan Sewage District. Information was recorded on the event date and volume of sewage diverted, counts of faecal coliforms in the plant effluent, and also when available counts of *Giardia* cysts in the effluent as well as daily rainfall totals at General Mitchell International Airport in Milwaukee. An autoregressive integrated moving average (ARIMA) model was used. To adjust for potential confounding, variables for season (winter versus nonwinter) and mean rainfall in the 3 to 5 days before each day in the model were included. Separate models were generated for visits from zip codes that used Lake Michigan drinking water sources and also for those whose drinking water came from other sources.

Over the study period there were 6 large sewage bypass events identified. Levels of faecal coliforms in discharged effluent were elevated after all events but were within permissible limits. Increased levels of *Giardia* cysts were found in the effluent as well. During the study period, a mean of 5.0 daily visits for gastroenteritis was found from the people who lived in zip codes that used Lake Michigan drinking water and 1.2 from those who lived in zip codes outside the Lake Michigan water service area. A similar ratio

between the two areas was found for all visits to the hospital. The ARIMA models found significant increases of 2.5 (95% CI: 0.4 to 4.9) and 2.7 (95% CI: 0.0 to 5.9) emergency department visits by people who lived in zip codes that used Lake Michigan drinking water following the 2 largest bypass events after adjusting for season and rainfall. This was a relative increase of about 50% in the period 3 to 7 days after the bypass events (equivalent to 26 additional cases over the 3 year period). There was no significant increase after any of the events from the people who lived in zip codes that used non-Lake Michigan drinking water sources.

An association was found in this study between the release of partially treated sewage into a drinking water sources in metropolitan Milwaukee and an increase in child ED visits for gastroenteritis. This suggests there are potentially harmful effects of such practices. Even though the data is limited and a causal relationship is not established here, the results suggest a need for additional research as bypass events occur frequently for some water sources. More data is required as the Environmental Protection Agency recently proposed revisions to its peak wet-weather policy that would establish national standards to allow this practice.

Comment *The fact that the ratio for all hospital visits (for all types of illness) between different water supply areas was the same as for gastroenteritis visits suggests there is no major difference in childhood gastroenteritis rates between the two areas - the ratio more likely reflects differences in population size and perhaps proximity to the hospital. This paper does not state the absolute number of ED visits for gastroenteritis however in developed countries this condition is usually responsible for 10-20% of paediatric emergency department visits. It is stated that about 45,000 ED visits occur each year at the hospital so the total number of gastroenteritis cases in the 3-year study period may have been in the order of 13,500 to 27,000 visits.*

Health Stream is the quarterly newsletter of the *Health and Aesthetics* Program Group of the CRC for Water Quality and Treatment. 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 on the Web page of the CRC. Summaries of Web-bonus articles are available only in the electronic version.

To be placed on the **print version mailing list** for Health Stream please send your postal address details to:

Pam Lightbody
Epidemiology and Preventive Medicine
Monash University - Central & Eastern Clinical School
Alfred Hospital, Melbourne VIC 3004
AUSTRALIA

Phone +61 (0)3 9903 0571
Fax +61 (0)3 9903 0576
Email pam.lightbody@med.monash.edu.au

To be placed on the **email notification list** for Health Stream, please fill in the form on our website under *Publications, Join Our Mailing List:*

http://www.waterquality.crc.org.au

Established and supported under the Australian Government's Cooperative Research Centres Program.