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## **Report On UK Aluminium Incident**

The UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) has released the draft version of a report into the July 1988 Lowermoor water contamination incident. 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 being present at the time of the incident, however not all people in the area would have consumed the contaminated water.

The Lowermoor water treatment plant received surface water from a nearby moorland reservoir. The treatment process comprised addition of aluminium sulphate coagulant and lime for pH adjustment followed by mixing in a flash mixer tank, and addition of polyelectrolyte to enhance coagulation. The water then passed to sedimentation tanks where the floc was allowed to settle and water was drawn off and passed through sand filters. The pH of the filtered water was then adjusted by addition of more lime, and chlorine gas was added for disinfection. The water then passed to a chlorine contact tank designed to ensure thorough mixing and a minimum chlorine contact time of 30 minutes. At the distal end of the contact tank, sulphur dioxide was added to reduce chlorine levels and phosphate was added to control iron levels. The treated water then moved to a

clear water storage tank before entering the distribution system.

The incident began at about 5pm on Wednesday 6 July 1988 when the delivery truck driver mistakenly deposited the aluminium sulphate solution into the chlorine contact tank at the treatment works. Within about three hours, the local water company, the South West Water Authority (SWWA), began to receive complaints from customers that their tap water tasted unpleasant and felt sticky to the touch. When SWWA investigated, they initially attributed the low pH and high aluminium sulphate content to a problem with lime dosing at the plant, and at about 11pm on 6 July they began flushing mains to remove the acidic water from the distribution system. The true source of the problem remained undiscovered until sometime on the morning of Friday 8 July when it was noticed that the level in the aluminium sulphate storage tank was low despite a delivery having been recorded on Wednesday. This failure to correctly diagnose the problem in the first few hours of the incident resulted in the entire load of aluminium sulphate being drawn into the distribution system during the intervening two days.

Over the months following the incident a number of residents of the area complained of symptoms including skin rashes, arthritic pains, sore throats, loss of memory and general exhaustion. These complaints were investigated by health authorities and the government appointed the Lowermoor Incident Health Advisory Group to report on the health effects of the incident. In two reports, delivered in 1989 and 1991, the Advisory Group concluded that there was no convincing evidence that harmful accumulation of aluminium had occurred, nor that there was a greater prevalence of ill health due to the toxic effects of the contaminated water. The reports acknowledged that the accident and subsequent events led to real mental and physical suffering in the community, but attributed the reported physical symptoms to the effects of ongoing worry and concern in some people rather than chemical toxicity arising from the incident.

This most recent investigation was announced in August 2001 by the UK Minister for Environment

Food and Rural Affairs. The COT was asked to convene a subgroup to carry out the investigation in response to continuing concerns from members of the local community that the health consequences of the incident had not been properly addressed. The Lowermoor Subgroup (LSG) comprised a public interest representative, two local representatives, a consultant physician, a paediatrician, and three scientists with expertise in toxicology and epidemiology. The terms of reference for the investigation were:

- to advise on whether the exposure to chemicals resulting from the 1988 Lowermoor water pollution incident has caused, or is expected to cause, delayed or persistent harm to human health; and
- to advise whether the existing programme of monitoring and research into the human health effects of the incident should be augmented and, if so, to make recommendations.

The draft report of the Lowermoor Subgroup, released on 26 January 2005, is the most comprehensive document ever compiled on the incident. Comprising some 448 pages, the report provides detailed descriptions of the water treatment works, the contamination incident, the assessment of human exposure, evidence from population studies and individuals, toxicological and epidemiological background information on the contaminants, the health implications of exposure to these contaminants, and an evaluation of the health effects of the incident. It also includes recommendations for future monitoring and research on the Lowermoor incident, and for the handling of any future chemical contamination incidents in water supplies.

In addition to compiling available water quality data from the time of the incident, the LSG commissioned new work on water quality modelling to assess the movement of contaminants through the water supply system and estimate the consequent human exposures. 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. The assessment of health impacts therefore considered the potential effects of exposure to aluminium, copper, lead, zinc, manganese, iron, sulphate and hydrogen ions. These contaminants were considered individually and the possible effects of additive or synergistic effects were also assessed. Estimates of human exposure were made for adults, toddlers and bottle-fed infants, assuming average or high intakes of tap water and maximum contaminant levels in tap water over the 28 days following the incident, and the subsequent 17 month period to the end of 1989. During its investigation the LSG visited the water treatment plant, held one public meeting in Camelford, and collected further evidence from local people during four subsequent visits by members of the Subgroup and secretariat staff.

The findings of the Lowermoor Subgroup report may be summarised as follows:

Who received contaminated water and how long was the water supply contaminated after the pollution incident?

- Due to the limited nature of the water quality sampling program carried out after the incident, and the large scale flushing which occurred to remove contaminants, it is not possible to determine whether any particular point in the Lowermoor distribution network received contaminated water. The exception to this is for specific points where monitoring data exist. However the available data are not adequate to describe the progress of the aluminium sulphate over time through the distribution system.
- Water quality data and modelling indicate that most of the excess aluminium sulphate left the treatment plant within 24 hours, and the period of contamination of the distribution system was short. However during the 6 months following the incident, 30% of water samples exceeded the 1984 WHO guideline value for aluminium (200 microgram/L), and 6% of samples taken in 1989 exceeded the guideline value. The LSG noted that the WHO guideline value is based on avoiding water discolouration and deposits in the distribution system, and does not relate to adverse health effects. No health-based guideline value for aluminium in water supplies has been set by WHO or other regulatory authorities.
- Levels of copper and lead were elevated for about one week following the incident, but very few water samples exceeded the WHO guideline value for zinc. The proportion of samples with manganese levels above the WHO guideline value increased in the month following the incident but then fell markedly. The proportion of iron samples exceeding the WHO guideline value increased in the month following the incident and remained high until the end of 1990.

On the basis of the toxicity data in the scientific literature and the estimated exposures, would the contaminants be expected to cause delayed or persistent harm to human health?

- The increased exposure to aluminium is not anticipated to have caused, and would not be expected to cause, delayed or persistent harm to health in adults or toddlers. However the possibility of delayed or persistent harm to health in bottle-fed infants, although unlikely, should be explored further.
- Copper, zinc and possibly sulphate exposures probably contributed to acute adverse gastrointestinal symptoms in the first week after the incident, but are not likely to have caused delayed or persistent harm to health.
- Exposure to elevated iron levels was unlikely to have caused any delayed or persistent harm to health.
- It is unlikely that the potential brief period of increased exposure to lead would have caused, or would be expected to cause, delayed or persistent harm to health. However given the undesirability of lead exposure in young children, the possibility of such effects in bottle-fed infants (potentially the highest exposure group) should be explored. It is not possible to say whether inorganic lead exposure may have any effect on cancer incidence.
- Similarly, exposure to manganese during and after the incident is unlikely to have caused delayed or persistent harm to health, however further monitoring of bottle-fed infants was recommended.

- Additive effects may have occurred for contaminants with potential to cause acute adverse gastrointestinal effects.
- The pH levels recorded were not low enough to cause reported symptoms of sore throat or skin irritation, however the high concentrations of sulphate and metals may have made the water more irritant than would be expected from the pH value alone.
- It is not anticipated that the combination of metals which occurred as a result of the pollution incident would have caused or would be expected to cause delayed or persistent additive or synergistic effects.

Are the symptoms or illnesses reported by individuals or identified from epidemiological studies considered to have been caused by delayed or persistent effects of the contaminants?

- Acute health problems included mouth ulceration, skin irritation and gastrointestinal symptoms such as diarrhoea and abdominal pain. These were reported to have occurred within hours or days of the incident.
- The chronic symptoms and illnesses most commonly reported fell into the categories of neuropsychological effects (including impaired memory and difficulty in concentrating), joint pain and/or swelling, nail problems, cancer and thyroid disease.
- A number of studies have been carried out to investigate the possible health impact of the incident. Outcomes assessed have included self-reported symptoms, routinely collected health statistics such as cancer incidence rates, hospital discharges and pregnancy outcomes, and the growth and educational needs of children. There have also been studies of neuropsychological parameters, and some tissue analyses have been performed. The design of many studies was poor with problems such as non-random selection of participants, inadequate or absent control groups, potential for bias due to prior media reporting, poor classification of exposure and lack of consideration of confounding factors.
- The estimated exposures to contaminants in the water supply was not considered to have been sufficient to cause neurotoxic effects, however one of the neuropsychological studies suggested subtle effects in tested individuals.
- The available toxicological data do not indicate that the levels of contaminant exposure during the incident would cause effects on joints, and no cause and effect relationship can be concluded.
- A consultant dermatologist examined individuals with nail and skin problems two years after the incident and concluded that the conditions seen were common and not likely to be related to the water contamination. No further information on skin or nail effects was contributed by epidemiological studies or toxicological reviews.
- Studies of cancer incidence and mortality showed no evidence of increased risk in the area affected by the incident. An investigation of a cluster of three cases of acute leukemia in Camelford children concluded that the evidence supported the hypothesis that leukemia incidence may be related to prior exposure to infectious agents. There was no evidence that the water contamination incident caused an increased incidence of infections.
- The review of toxicological evidence did not suggest any link between the water contaminants and adverse effects on the thyroid gland.
- A report by a homeopathic group concluded that some people had become sensitised to tap water, although this condition did not appear to fit the recognized medical definition of immune sensitisation. No conclusions could be drawn regarding these symptoms.
- The data on numbers of children with Special Educational Needs (SEN) did not show any consistent difference between the rates of SEN children in the school with the highest proportion of children from the affected area and other schools in Cornwall.

The Lowermoor Subgroup noted that during their investigation many people commented on the lack of reliable official information and advice at the time of the incident. Some had received inconsistent or conflicting advice, and many individuals were concerned and distressed about the possible health consequences of the incident for themselves and the community. Some expressed the opinion that the confusion and lack of communication in the months

following the incident contributed to the development of high levels of suspicion and scepticism which still persist in the local community today.

The LSG also made a number of recommendations for further research and noted that consultation with appropriate experts would be required to design and conduct suitable studies due to the complexities of such investigations.

- investigation and comparison of the neuropsychological status of groups of exposed individuals with and without symptoms, and an unexposed control group.
- studies of the cognitive, behavioural and educational development of children who were under 1 year of age at the time of the incident.
- an assessment of whether the prevalence of joint pains and swelling in the exposed population is higher than normal
- continuation of the monitoring of routine health statistics including cancer incidence and mortality, and cancer subgroups. This should continue until 2008, representing 20 years of follow up.
- further work on aluminium toxicity, including establishment of No Observed Adverse Effect Levels for a range of different salts and both acute and chronic exposures, mechanistic data on the neurotoxicity of aluminium, and further investigation of the bioavailability of aluminium and reasons for individual variation.

While acknowledging that significant improvements had occurred since 1998 in procedures for managing chemical incidents, the LSG highlighted additional measures which would facilitate future investigations:

- early identification of populations that may need to be monitored, including any significant transient populations such as holiday makers
- consideration of the effect of contamination on the intake of chemical species from food
- rapid, widespread dissemination of clear and accurate advice to the public, and continuation of a contact point for some time after the incident.

The conclusions of the Lowermoor Subgroup are consistent with those of the previous two

investigations by the Lowermoor Incident Health Advisory Group. These investigations also concluded that the short term exposures experienced during the incident were unlikely to cause persistent adverse health effects. The draft report of the Lowermoor Subgroup can be downloaded from the Committee on Toxicity website. The report is open for public comment until 22 April 2005.

[www.advisorybodies.doh.gov.uk/cotnonfood/lowermoor.htm](http://www.advisorybodies.doh.gov.uk/cotnonfood/lowermoor.htm)

## Walkerton Operators Sentenced

The Ontario Superior Court criminal trial over the fatal *E. coli* outbreak in the town of Walkerton in May 2000 concluded on December 20 last year with the sentencing of the two water system operators in charge of the Walkerton water supply. The former manager of the Walkerton utilities commission, Stan Koebel, was sentenced to one year in jail, while his brother, foreman Frank Koebel, received a sentence of nine months of house arrest. The brothers were initially charged with public endangerment, fraud and breach of trust, and faced possible jail terms of up to 10 years. However in a negotiated plea bargain, the charges were reduced to common nuisance (risking public safety by failing to monitor and treat the water properly) in return for guilty pleas from the accused. This lesser charge carried a maximum penalty of two years imprisonment.

Reactions to the sentencing have been mixed with some expressing the belief that the men had been made scapegoats for problems which extended far beyond their own responsibilities, while others thought the sentences too light considering the devastating impact of the outbreak that killed seven people and left many with lingering health problems. The plea bargain agreement entered into by the prosecution has also been criticised for endorsing a flawed statement of facts which contradicted the evidence heard at the Walkerton Inquiry. Health Stream is pleased to reproduce this commentary article on the issue by Professor Steve Hrudehy. Professor Hrudehy is professor of public health sciences at the University of Alberta and co-author of the book *Safe Drinking Water - Lessons From Recent Outbreaks in Affluent Nations*. He served on the Research Advisory Panel to the Walkerton Inquiry

but does not speak for the Inquiry. Professor Hrudey also served on the NHMRC Working Party which developed the 2004 edition of the Australian Drinking Water Guidelines, and is internationally recognized for his work on risk management for water supplies.

### ***Contaminating the facts***

In May 2000, contaminated drinking water killed seven people and sickened 2,300 others in Walkerton, Ontario. Yesterday, former Walkerton water-treatment employees Stan and Frank Koebel were sentenced for their role following a trial and plea bargain. But rather than bringing closure for victims, the resolution of this criminal case will serve to spread misinformation. The truth about the Walkerton tragedy is well known thanks to subsequent investigations. That truth is distorted by the "facts" attested to in the Koebels' plea bargain.

The Walkerton tragedy could have been averted or substantially reduced by competent employees. You would not know this from reading the plea-bargain agreement. Citing a Health Canada expert, the agreement states that even had the Koebel brothers increased the chlorine level in Walkerton's water system dramatically, it "would not have prevented this tragedy." The Crown misinterpreted this unsubstantiated claim to conclude: "It therefore cannot be said that the criminal conduct of Stan Koebel and Frank Koebel ... their failure to properly monitor, sample and test the well water ... was, in law, a significant contributing cause of the deaths and injuries."

This statement is wrong in fact. The Health Canada expert cited is a well-qualified epidemiologist who conducted a disease outbreak investigation that provided essential evidence to Justice Dennis O'Connor's Walkerton Inquiry, which delivered its conclusions in 2002. She also ventured opinions on the limitations of the water treatment system for disinfecting the pathogens that caused the outbreak. But she was silent on the key issue of "chlorine residual monitoring" for judging disinfection performance. Indeed, she acknowledged her limited expertise on the subject, admitting her comments on the capability of the Walkerton water system

following May 2000 were made "from what I understand of drinking water disinfection ... I'm not a specialist in that."

The Walkerton Inquiry relied on an expert panel from the Canadian Water Network, including water treatment engineer Dr. Peter Huck and public health microbiologist Dr. Pierre Payment, for evidence on disinfection. These experts made clear that, even though the Walkerton system likely could not add enough chlorine to cope with the manure contamination, public exposure to contaminated water could have been substantially reduced if the operator had been monitoring chlorine residuals.

When chlorine is added to water, it reacts with contamination. Any chlorine remaining is the chlorine residual. Justice O'Connor observed: "One of the purposes of measuring chlorine residual is to determine whether contamination is overwhelming the disinfectant capacity of the chlorine." He went on to find: "The scope of the outbreak would very likely have been substantially reduced if the Walkerton PUC operators had measured chlorine residuals at Well 5 daily, as they should have, during the critical period when contamination was entering the system."

Frank Koebel's job as operator foreman was to ensure the chlorine residual was measured daily. Yet the Inquiry found "virtually all of the entries on the 1999 daily operating sheets are false. Fictitious entries in the daily operating sheets continued until the outbreak in May 2000." At least eight days without valid monitoring passed between the contamination influx and the boil water advisory issued by the health unit, after illness was already widespread.

Ignorance was the major cause of this failure, in other words. The Koebel brothers were so poorly trained, despite being certified competent by the Ontario Ministry of Environment, they did not understand disinfection and were unlikely to respond correctly to monitoring. On this point Justice O'Connor noted: "It would have been a relatively simple process for a competent water operator to interpret the implications of the lack of a chlorine residual, turn off the well, and alert the community to the problem." Countless teenage lifeguards routinely measure chlorine

residuals at swimming pools because a pool should be closed if no chlorine residual can be achieved.

The plea bargain presents the tragedy as an act of God, something that no person, no matter how competent, could have prevented once rain washed manure into Walkerton's Well 5. But this is fiction. It may serve the Koebel brothers and the Ontario government who certified them, but it is a travesty for the victims of Walkerton, for Ontario taxpayers who paid millions to learn the truth through the Walkerton Inquiry, and for competent water treatment operators everywhere.

The Koebel brothers never intended to harm their friends and neighbours. Yet handing them the responsibility to supply safe water without the necessary knowledge and support systems made failure likely, if not inevitable. If we refuse to accept that the tragic consequences of May 2000 were caused by individual misdeeds that were enabled by a colossal failure of public institutions, we commit an act of denial that surely risks future disasters.

This article previously appeared in the Canadian National Post newsletter on 21 December 2004. The Walkerton outbreak and subsequent judicial inquiry have been reported in Health Stream (Issues 18-21, 25, and 26).

## Ohio Outbreak Investigation

A joint investigation by the Centers for Disease Control and Prevention, the Ohio Department of Health, the Ohio Environment Protection Agency and several other state agencies, has concluded that groundwater contamination was the cause of the gastroenteritis outbreak on South Bass Island last year. About 1450 people became ill after visiting the island between July and September 2004 (reported in Health Stream Issue 35).

A case-control study was used to investigate associations between illness and suspected risk factors. A case was defined as a resident of the island who had experienced the onset of gastroenteritis symptoms between 30 May and 8 September, or a visitor who had experienced onset of symptoms in the same time period and within two weeks of visiting the island. Interviews were conducted with

100 cases and 117 controls who had not been ill. Statistical analysis showed a significant association with drinking tap water on the island (matched Odds Ratio = 4.3; 95% confidence interval 2.2-9.3;  $p = 0.000005$ ). There was also a significant dose-response with the amount of tap water consumed. There was no association between illness and swimming either in swimming pools on the island or in Lake Eyrie. Affected people reported a median duration of illness of four days, with a range of up to 52 days. The number of people submitting faecal specimens for pathogen testing has not been reported, however 16 samples were positive for *Campylobacter* spp., 9 samples were positive for Norovirus, 3 for *Giardia* spp. and one for *Salmonella typhimurium*. This mixture of pathogens including the human-specific Norovirus suggested exposure to sewage as the likely source of infection.

The investigation included an extensive assessment of the hydrogeology of the island, and the operation of water supply and wastewater systems. The bedrock of the island is composed of fractured limestone and dolomite covered by a thin surface layer of soil with an average thickness of less than 1 metre. The water table is only 1.5 to 2 metres below ground level in some areas of the island. Two aquifers underlie the island; the shallow South Bass aquifer and the deeper Salinas Group aquifer. Both aquifers are also hydrologically connected to Lake Eyrie. Due to the thin soil and fractured underlying rock, surface water can penetrate rapidly to the aquifers with little filtering action from the soil. Thus microbial and chemical contaminants from the surface of the island can readily enter the groundwater.

Public water supplies on the island include the treated municipal supply drawn from Lake Eyrie that serves the main township of Put-in-Bay, and a number of transient, non-community supplies located outside the township which use groundwater (1). There are also many private wells used as drinking water sources by households outside the town limits. Some properties connected to the town water supply also have well water supplies which they use for toilet flushing and geothermal heating/cooling. The town area is served by a central sewerage system, with the

remainder of the island relying on a variety of on-site sewage treatment systems.

There was no evidence of malfunction in the municipal drinking water treatment plant, and water quality in the distribution system was compliant with US EPA standards, however four physical cross-connections to plumbing supplied by auxiliary household wells were detected. A total of 112 samples from 18 transient non-community public water systems were analysed, and all systems were found to have at least one sample positive for an indicator organism. Sixteen had positive detections for organisms other than total coliform bacteria, with *E. coli* and *Campylobacter*-like organisms being the most commonly detected.

In order to assess the groundwater quality over the whole of the island, a systematic sampling program for private wells was conducted in September 2004. Wells with recorded information on well depth and aquifer were preferentially chosen for sampling, and tests were carried out for total coliforms, *E. coli*, *Salmonella*, *Campylobacter*, nitrates and chlorides. Of the 76 wells tested, 78 % were positive for total coliforms and 31.6% were positive for *E. coli*. No *Campylobacter* or *Salmonella* were detected. The risk of *E. coli* contamination was inversely correlated with well depth, with all wells less than 30 feet deep and 60% of wells less than 50 feet deep testing positive for this faecal indicator. However the results indicated that both aquifers were contaminated with *E. coli*. The report noted that many wells have casing installed only to a depth of 25 feet or less, and the lower portion of the wells form many connections which permits water movement between the aquifers. Increased pumping of groundwater for use during the summer holiday months would also have contributed to movement of water and increased infiltration of lake water into the aquifers.

Some historical water quality data was available for private wells from samples taken during well construction or alteration, and whenever properties were sold. This showed an increasing percentage of samples positive for total coliforms and/or *E. coli* during the first seven months of 2004 compared to the three previous years. Rainfall records showed

unusually high rainfall in the North Central region of Ohio (where South Bass island is located) during May 2004, with over 8 inches of rain recorded compared to the long term average of about 3.5 inches for this month. June rainfall was about 20% above the long term average.

The investigation concluded that the outbreak was due to faecal contamination of groundwater on the island but no single source or isolated pollution event was identified. The hydrogeological characteristics of the area render the aquifers very vulnerable to surface water infiltration, and historical records indicate that faecal pollution of groundwater has occurred a prolonged period. The heavy rainfall in the two months prior to the outbreak may have led to an influx of higher levels of contamination, leading to the outbreak. Inadequate sewage disposal systems were considered to be the most likely source of pollution, although some contribution from infiltration of lake water could not be ruled out.

A number of measures have now been taken to prevent further outbreaks and deal with problems identified during the investigation:

- A backflow prevention program has been implemented for the Put-in-Bay water supply. Premises connected to the town supply which have an auxiliary well testing positive for *E. coli* have been ordered to abandon their well, and others have been required to fit approved backflow prevention devices.
- All but one of the transient non-community water systems have been ordered to cease using the water for human consumption due to unsatisfactory microbiological test results. The single remaining system will be required to implement additional measures before the 2005 tourist season begins.
- All transient public water systems on the island have been designated as surface water sources for the purposes of water treatment and will be required to comply with US surface water treatment rules (ie filtration and disinfection) within 18 months. In the interim these supplies are required to implement continuous disinfection of well water using chlorination and ultraviolet light but may use this water only for

washing dishes and showering. Bottled water must be provided for drinking, making ice, brushing teeth and food preparation, and there must be a continuous advisory to the public warning them not to use well water for these purposes unless it is boiled. Alternatively, premises may abandon their well water supply and connect to the municipal water supply or install an approved hauled water system.

- A number of businesses with package sewage treatment plants have been ordered to apply for appropriate permits. These systems were not believed responsible for the outbreak but were discovered to have been operating without proper discharge permits.

In view of the number of businesses and homes planning to connect to the public water supply system, the Put-in-Bay water treatment plant is to be upgraded in capacity and the distribution system extended to serve a larger area. A bulk water station will also be built to serve residents and businesses which opt for a hauled water service. The expansion will take up to three years to complete.

While initial actions have focused on providing safe public water supplies, it has also been recognized that a long term plan for wastewater (sewage) management is needed for the island. Options may include expanding the existing central sewerage system to provide services to a wider area, and using new technologies for on-site systems to minimise impacts on groundwater.

(1) The US EPA defines *Public water systems* as those which provide water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year. There are three types of public water systems:

- *Community Water System*: A public water system that supplies water to the same population year-round.
- *Non-Transient Non-Community Water System*: A public water system that regularly supplies water to at least 25 of the same people at least six months per year, but not year-round. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.
- *Transient Non-Community Water System*: A public water system that provides water in a place such as a gas station or campground where people do not remain for long periods of time.

## News Items

### ADWG Update

The NHMRC recently released the 2004 *Australian Drinking Water Guidelines* incorporating the Framework for the management of drinking water quality. Print copies of the ADWG 2004 edition can now be purchased from the AWA Bookshop. ([www.awa.asn.au/bookshop/](http://www.awa.asn.au/bookshop/)). The PDF version can be downloaded free of charge from the ADWG page on the NHMRC website (see below).

To aid in the implementation of the guidelines, the NHMRC is developing an *Electronic Decision Support Tool* to assist local drinking water managers to develop management plans tailored specifically to their community. The draft version of the EDST was released for public comment on 12 March, and the submission period for comments closes on 27 May 2005. A series of workshops in Queensland, Tasmania, and Victoria have been planned for March and April to provide stakeholders with an opportunity for discussion and direct input to the final development of the EDST. The CRC for Desert Knowledge and the CRC for Water Quality and Treatment are also collaborating on a pilot project to assess the applicability of the tool in small remote indigenous communities.

Also open for public comment is Chapter 8 of the ADWG *Drinking Water Treatment Chemicals*. This Chapter provides guidance on chemicals used during the storage, treatment, and distribution of drinking water, quality assurance procedures, and the requirements for gaining approval of these chemicals. The deadline for submissions is 8 April 2005.

The PDF version of the ADWG and related documents can be downloaded from the ADWG page on the NHMRC website. For further information on the *Australian Drinking Water Guidelines* and associated documents, contact Mr Phil Callan by phone on (02) 6289 9105, or by email on [Philip.Callan@nhmrc.gov.au](mailto:Philip.Callan@nhmrc.gov.au). For information on how to make a submission, see the *Public consultation* section of the web page: [www.health.gov.au/nhmrc/publications/synopses/eh19syn.htm](http://www.health.gov.au/nhmrc/publications/synopses/eh19syn.htm)

### Naegleria Court Case

The court case brought by the families of the two young Arizona boys who died in October 2002 of *Naegleria fowleri* meningitis associated with a groundwater supply is expected to proceed to trial in the next few months. The families have filed a civil suit against the privately owned Rose Valley Water Company and the City of Peoria, claiming that the pathogen was in a well operated by the city and that they failed to adequately chlorinate the water prior to delivering it to the Rose Valley water system. A pre-trial conference is scheduled for late April. (See Health Stream Issue 28 for a report on the incident).

### Mycobacterium Infections From Foot Spas

Health authorities in Santa Clara County, California have reported an upsurge in mycobacterial skin infections associated with the use of whirlpool foot baths in nail salons. While a few cases were reported early in 2004, almost 100 additional cases were identified between December 2004 and mid-February 2005 bringing the total to 143 cases. Once established, mycobacterial skin infections are notoriously persistent, and prolonged antibiotic therapy of up to 12 months may be required to eliminate the organism. The infections manifest as boils and skin ulcers on the feet and lower legs, and in some cases may cause significant scarring. Cases in the current outbreak have been associated with 33 different salons in Santa Clara County.

A number of mycobacterial species are opportunistic pathogens and are commonly present in tap water, soil and in the environment. They grow readily in warm, moist, aerated and nutrient-rich environments such as spas, and can be difficult to eliminate from equipment. A survey of foot baths prompted by an outbreak in 2000 in California found mycobacterial species present in 29 of 30 baths tested. The only negative sample came from a new foot bath that had been in use for only 11 days. New regulations adopted after this outbreak required more thorough cleaning and disinfection of foot spas. It is not clear whether the current outbreak represents an unusually high occurrence of the infection in Santa Clara County or merely heightened awareness and reporting. Mycobacterial infections of this type are not required to be reported under health regulations.

### From the Literature

#### *Web-bonus articles*

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

[www.waterquality.crc.org.au/pubs](http://www.waterquality.crc.org.au/pubs)

#### **Ingested arsenic, cigarette smoking, and lung cancer risk: a follow-up study in arseniasis-endemic areas in Taiwan.**

Chen CL, Hsu LI, Chiou HY, Hsueh YM, Chen SY, et al. (2004) *Journal of the American Medical Association*, **292**(24); 2984-90.

#### **Prevalence of chronic diseases in adults exposed to arsenic-contaminated drinking water.**

Zierold KM, Knobloch L, and Anderson H (2004). *American Journal of Public Health*, **94**(11); 1936-7.

#### **Environmental factors and Parkinson's disease: a case-control study in the Tuscany region of Italy.**

Nuti A, Ceravolo R, Dell'Agnello G, Gambaccini G, et al. (2004) *Parkinsonism & Related Disorders*, **10**(8); 481-5.

#### **Campylobacteriosis, Eastern Townships, Quebec.**

Michaud S, Menard S and Arbeit RD (2004) *Emerging Infectious Diseases* **10**(10) 1844-47.

#### **Remote site production of sterile purified water from available surface water.**

Taylor MA, Alambra EF, Anes J, Behnke J, et al. (2004) *Prehospital and Disaster Medicine* **19**(3) 266-277.

#### **Endocrine disruptors in the aquatic environment: the Austrian approach – ARCEM**

Bursch W, Fuerhacker M, Gemeiner M, Jungbaer A, et al. (2004) *Water Science and Technology* **50**(5) 293-300.

#### **Microalbuminuria three years after recovery from Escherichia coli O157 hemolytic uremic syndrome due to municipal water contamination.**

Garg AX, Clark WF, Salvadori M, (2005) *Kidney International* **67** 1476-1482.

Arsenic**Effect of sodium arsenite on peripheral lymphocytes in vitro: individual susceptibility among a population exposed to arsenic through the drinking water**

Mahata J, Ghosh P, Sarkar JN, Ray K, Natarajan AT, Giri AK (2004) *Mutagenesis*, **19**(3); 223-9.

Previous studies have reported that more than 6 million people in nine affected areas of West Bengal, India are exposed to As-contaminated drinking water. Around 300,000 of these people show signs of As toxicity; however there is considerable individual variation even among family members with the same apparent levels of arsenic exposure. The cause of this variation is still not known, however it is assumed that genetic variation may play an important role.

The aim of this study was to determine whether genotoxic effects differed in the lymphocytes of 6 people from a control village (no exposure to arsenic), 6 asymptomatic people (arsenic exposed but without skin lesions) and 6 symptomatic people (arsenic exposed with arsenic-induced skin lesions) after *in vitro* treatment with sodium arsenite. The arsenic exposed individuals were selected from eight families in one village, with four of the families contributing both symptomatic and asymptomatic individuals. The participants were adults aged 20 to 55 years, and had been drinking arsenic-contaminated water for more than 10 years. Three males and three females were included in each group.

Participants were examined for clinical symptoms of As toxicity and were interviewed using a structured questionnaire to obtain information on socio-demographic characteristics, addiction, medical treatment, residence and duration of drinking water to assess for confounding factors. Arsenic exposure was assessed by measuring arsenic in nails and hair (indicative of long term exposure) and urine (indicative of current exposure). Lymphocytes were cultured under standard conditions and exposed to varying concentrations of sodium arsenite for 48 hours *in vitro*. Colchicine was added to arrest growing cells in metaphase, and cells were then fixed

and stained. For each person, 100 metaphase cells were examined for chromosomal aberrations.

The percentage of aberrant cells in lymphocyte cultures from both arsenic exposed groups was significantly higher than in the control group even in the absence of sodium arsenite exposure. The percentage of aberrant cells was also significantly higher in the symptomatic group than the asymptomatic group. Exposure to increasing concentrations of sodium arsenite resulted in a dose-related increase in aberrant cells in all groups. The lymphocytes of the control group showed more sensitivity to sodium arsenite than either the symptomatic or asymptomatic groups as judged by a higher prevalence of aberrant cells. The authors suggest that long-term exposure to As may have caused lymphocytes in the exposed group to respond less after *in vitro* treatment with arsenite than the unexposed control group.

Comparison of the two arsenic-exposed groups showed arsenic levels in urine tended to be higher for asymptomatic participants than for symptomatic participants, although the difference was not statistically significant. Symptomatic individuals had significantly higher levels of arsenic in their hair and nails compared to asymptomatic people. This suggests there may be genetic polymorphisms in arsenic metabolism that lead to differences in sensitivity and susceptibility between asymptomatic and symptomatic individuals. Asymptomatic individuals show no visible dermal signs of arsenic toxicity, however they may still be affected subclinically. Further studies are underway to characterise the genetic differences that may be responsible for these differences in susceptibility.

Cancer**Household water source and the risk of childhood brain tumours: results of the SEARCH International Brain Tumour Study**

Mueller BA, Nielsen SS, Preston-Martin S, Holly EA, Cordier S, Filippini G, Peris-Bonet R, Choi NW (2004) *International Journal of Epidemiology*, **33**(6); 1209-16.

Pregnant women are reported to drink more water, and bathe and shower more frequently than non-pregnant women, thus increasing their exposure to water contaminants via consumption, inhalation, and dermal absorption. Some studies have suggested pregnant women who drink nitrate-contaminated water may be at increased risk of spontaneous abortion or giving birth to infants with congenital malformations, especially of the central nervous system. It has also been suggested there may be an association between high levels of nitrate in drinking water and increased mortality and incidence of some cancers and lesions. The maximum allowable nitrate level for drinking water according to World Health Organization and EU standards is 50mg/L nitrate ion.

This paper describes an international study of childhood brain tumour (CBT) cases identified in 9 centres from 7 countries. Cases were identified from children diagnosed with primary malignant tumour of the brain or cranial nerves and included children and adolescents, identified in population-based cancer incidence registries in each area during the years 1976-1994. A total of 1218 subjects (74%) were enrolled from 1640 eligible cases identified. A similar recruitment rate was achieved for controls with 2223 (75%) of the 2950 eligible control families enrolled. However due to lack of information on water sources from some centres, this paper describes results from only 836 cases and 1485 controls.

Women participating in the study were questioned about household water sources from one month before pregnancy to one year after birth. Water sources were classified as public water, wells, spring water, and other. Women were also asked to estimate the proportion of bottled water used. The primary residential water source during the month before pregnancy was used as the 'peri-conception' water source for estimating exposure. Dipstick measurements of nitrates and nitrites in household water were made for some women.

In addition to the centre, sex and age at diagnosis, the year of diagnosis, maternal prenatal smoking, and mother's educational level were considered in the statistical analysis. All risk estimates were adjusted for age, sex and diagnosis year.

Public water supplies were used as the primary source for the peri-conception month by the majority (80-98%) of participants in all study regions. Most women also reported using public supplies as the sole household water source throughout pregnancy. The use of well water and bottled water varied between regions.

Significantly increased risks of CBT associated with use of well water as a sole source of household water throughout pregnancy were observed for Canada (OR = 5.3, 95% CI: 1.2-23.1) and the Seattle region (OR = 2.6, 95% CI: 1.3-5.4). However a significantly decreased risk for sole use of well water (OR = 0.2, 95% CI: 0.1, 0.8) was seen in the Los Angeles region. Risk estimates for the other regions were neither significantly increased nor decreased. However, the risk of CBT associated with use of any other water source (other than public, well or spring) or mixture of water sources in France was very high (OR = 9.6, 95% CI: 0.99-10.2). When subjects whose mothers reportedly drank any bottled water during pregnancy were excluded, the risk of CBT associated with reliance on well water was further increased in Canada (OR = 6.1, 95% CI: 1.4, 27.0) and Seattle (OR = 3.0, 95% CI: 1.4, 6.2). The risk estimates for other regions did not change substantially.

Analysis for association of CBT with nitrate or nitrite levels estimated from dipstick readings showed no association with nitrate exposure, and a weak non-significant association with increasing nitrite levels. For the subgroup with nitrate and nitrite levels measured in residential tap water, the study found 63% of cases and 56% of controls had nitrate levels below the level of detection. The presence of nitrate at any level was not associated with an increased risk of CBT. The risks of CBT associated with the presence of detectable nitrite were increased, but not significantly. When analysis was restricted to 131 cases and 241 controls whose mothers reported they had not used any bottled water during their pregnancies, the risk of CBT associated with detectable nitrates at any level were not significantly increased or decreased. However the risk of CBT associated with a nitrite level of greater than or equal to 5mg/l was high (OR = 5.2, 95% CI: 1.2-23.3).

When histological tumour group-specific analyses were conducted (assessed as astroglial, PNET or other tumours), only an increased risk in astroglial tumours was associated with measurable nitrite levels at the pregnancy residence (OR = 4.3, 95% CI: 1.4-12.6 for 1- less than 5mg/l nitrite; OR = 5.7, 95% CI: 1.2-27 for greater than or equal to 5mg/l nitrite).

These results suggest a possible association between CBT (specifically astroglial tumours) and well water content/use in some regions. The study is limited however by the accuracy of recall of participants, who in some cases were interviewed years after the index pregnancy. Only the type of water source was assessed, not individual water consumption levels. Similarly the semi-quantitative measurement of nitrate and nitrite levels in water may have been done several years after the pregnancy, and measurements were available for only 28% of subjects. A further limitation noted by the researchers is that community supply drinking water is commonly a combination of multiple sources. There also are many differences between public water supplies and private wells, including routine disinfection procedures (with potential for byproduct formation) and relative level of monitoring by public health agencies. Private wells may potentially be contaminated with nitrates, pesticides, and other contaminants, some of which may be associated with childhood cancer risks. Homes with wells or with higher levels of tap water nitrate or nitrite, may be more likely to be located in or near agricultural areas. Parental employment in agriculture, and exposure to farm animals has been associated with CBT in both this, and other studies.

### Cryptosporidium

#### **How clean must our drinking water be: the importance of protective immunity.**

Frost FJ, Roberts M, Kunde TR, Craun G, Tollestrup K, Harter L and Muller T. (2005) *Journal of Infectious Diseases* **191**: 809-14.

A prospective study was carried out in 3 distinct geographic sites in the US. Two sites (A and B) were located in the same city but had different drinking water supplies, with both supplies being drawn from unfiltered chlorinated surface water sources with

protected catchments. The third site (C) was located in a city 280 miles away, was supplied with chlorinated groundwater. Water treatment at Site A was upgraded in February 2001 with the addition of ozonation and filtration. The study targeted both young children and elderly people as these groups are at increased risk of gastroenteritis. To be eligible for the study households had drink tap water and contain at least one child between 2 and 10 years of age or one adult of 65 years or older.

Participants recorded symptoms of illness for two separate six month periods; Phase 1 June-November 2000 (before Site A water treatment was upgraded) and Phase 2 June-November 2001 (after the water treatment upgrade at site A). Illnesses were defined as (1) diarrheal (at least one episode of soft or loose stools), (2) gastrointestinal (nausea, any vomiting or abdominal cramps) or (3) other symptoms (fever, chills, headache or cold). Six or more symptom-free days were required to separate episodes. A single episode could be counted in more than one category of illness.

Serum samples were collected during each phase from elderly participants and from the parents of children taking part. The samples were analysed by Western blotting for IgG antibodies against the 15/17- and 27-kDa *Cryptosporidium* antigen groups. The intensity of the bands on the immunoblot was scored relative to a known positive control, and classified as non-detectable, very weak (detectable but less than 20% of the positive control), or moderately strong (20% or more relative to the positive control). Immunoblot analysis was done by a technician who was not aware of the location, demographics, risk factors or illness status of participants. Poisson regression analysis was used to examine the relationship between serological response and risk of illness. The incidence density was defined as the number of new illness events divided by the fraction of the year for which diary records were available. Groups were compared by dividing the incidence density for the exposed group by the illness density in the reference group to give an illness density ratio (IDR). A statistically significant IDR less than 1.0 represents a protective effect.

A total of 196 people participated in both phases of the study (95 from site A, 37 from site B and 64 from site B), and an additional 64 people took part only in Phase 1 and 66 only in Phase 2. When data from all sites were combined, there was no change between Phase 1 and Phase 2 in the percentage of people with undetectable, very weak or moderately strong serological responses for either the 15/17- or 27-kDa antigens. 44.4% of participants reported an enteric illness (diarrheal or gastrointestinal) during the study. Initial analysis showed no significant difference in IDRs for people with non-detectable responses and very weak responses, therefore these two groups were combined for further analyses.

Poisson regression for serological responses to the 15/17-kDa marker showed significantly reduced IDRs for both diarrheal and gastrointestinal illnesses in those with a moderately strong serological response compared to those with non-detectable or very weak serological responses (adjusted for area, age, sex and phase of study). There was a protective dose response trend with increasing duration of illness (a stronger degree of protection was seen against longer duration illnesses). For "other illnesses" no protective effect was observed. For the 27-kDa marker the adjusted IDRs were less than 1.0 but were not always statistically significant, and there was not a clear dose response trend.

The authors note that this is the first study to suggest that a moderately strong serological response to a *Cryptosporidium* antigen is associated with a decreased risk for enteric illness. If this is a true protective effect and is specific for *Cryptosporidium*, it would suggest that this organism is responsible for a large fraction of gastroenteritis in the community. However previous studies have also shown that strong serological responses can occur in the absence of clinical illness. A number of outbreak investigations involving drinking water supplies have shown decreased risk for residents relative to visitors, again suggesting that low levels of exposure may confer a partially protective immunity.

In discussing the role of drinking water as a source of infections causing either clinical illness or protective immunity, the authors argue that efforts to further

reduce *Cryptosporidium* exposure from water supplies may have the paradoxical effect of increasing overall illness rates in the community. While avoidance of high level exposures is needed to prevent drinking water outbreaks, frequent low level exposure may enhance population immunity while causing few cases of clinical disease. Epidemiological studies of cryptosporidiosis have shown that person-to-person contact, public swimming pools, and some foodstuffs are important sources of exposure. Exposure from these sources will continue to occur, and they may be a more frequent source of high numbers of oocysts than drinking water supplies.

The authors speculate that the emergence of *Cryptosporidium* as a significant epidemic disease in developed countries may have resulted from loss of widespread immunity as a consequence of declining levels of exposure due to improved sanitation and drinking water treatment. They caution that the benefits of protective immunity from low level pathogen exposures need to be considered by public health regulators in addition to risks of illness from water supplies.

*Comment* The presentation of data in this paper does not allow the reader to distinguish the patterns of serological responses observed in the different groups in the two phases of the study. It is not clear whether the changes to drinking water treatment at Site A were associated with changes in seropositivity levels. Such a change would be expected if drinking water was a significant source of exposure for this population. The authors argument regarding protective immunity may be valid however current US risk assessment practices for water supplies are based on the predicted frequency of infections rather than illness.

#### Disinfection Byproducts

#### **Chlorination by-products (CBPs) in drinking water and adverse pregnancy outcomes in Italy.**

Aggazotti G, Righi E, Fantuzzi G, Biasotti B, Ravera G, Kanitz S, Barbone F, Sansebastiano G, Battaglia MA, Leoni V, Fabiani L, Triassi M, Sciacca S (2004) *Journal of Water & Health*, 2(4); 233-47.

Chlorination as a means of drinking water disinfection is used because of its low cost and ease of use. Certain chlorination by-products (CBPs) are produced during the disinfection process, which may be potentially harmful to human health. Trihalomethanes (THMs), such as chloroform, dichlorobromomethane, dibromochloromethane and bromoform, are the most studied by-products and are considered as an index of the total amount of halogenated CBPs when chlorine or sodium hypochlorite are used for water treatment.

Many water utilities are adopting chlorine dioxide as the main water disinfection treatment in order to reduce the amount of THMs produced. Disinfection with chlorine dioxide forms only low amounts of THMs, but produces other CBPs, mainly chlorite and chlorate, which have been shown to induce oxidative stress and alteration in haematological parameters in animals. Other studies on laboratory animals have reported both reproductive and foetal development toxicity associated with exposure to CBPs.

A number of population-based epidemiological studies have suggested an association between chlorinated drinking water exposure and adverse pregnancy outcomes, such as miscarriage, intrauterine growth retardation, still birth, preterm delivery, birth defects, small for gestational age (term-SGA) and low birth weight. However, these studies have also presented several methodological limitations to CBP exposure assessment, such as ecological and residual confounding due to unmeasured personal characteristics such as alcohol intake, smoking habits and exposure to environmental tobacco smoke.

This study aimed to evaluate the association between exposure to THMs and chlorite/chlorate during the last trimester of pregnancy, and pregnancy outcomes such as preterm delivery and small for gestational age at term (term-SGA). A case control study with incident cases was undertaken in nine Italian towns between Oct 1999 and Sept 2000. The study focused on preterm delivery and small for gestational age at term (term-SGA) children born to mothers who were of Caucasian race, Italian citizens and resident in the nine cities and surrounding areas. Only livebirths

were included. Eligible preterm cases were singleton children born between the 26th and 37th not completed week of pregnancy. Term-SGA cases were born from the 37th completed week and weighed under the lowest 10th percentile of weight according to standard values defined by the Italian Society of Paediatrics. Newborns with congenital malformations and chromosomal abnormalities evident at birth were excluded.

Controls were enrolled among singleton babies born in the same hospitals within a few days (the same day or the day after) after the cases' delivery with a gestational age greater than 37th completed week and a weight greater than or equal to the tenth percentile. The same exclusion criteria were applied to the controls. Subjects were recruited during their hospital stay just after delivery. Exposure was assessed by applying a questionnaire on mothers' personal habits during pregnancy and by direct water sampling at mothers' homes. A total of 1713 subjects were enrolled in the study and completed the questionnaire, but only 1,194 supplied a home tap water sample for analysis.

This study did not show a significant association between exposure to THMs and either term-SGA or preterm birth. It did however observe high levels of chlorite in drinking-water samples, and a non-significant association with term-SGA newborns was seen in those with high chlorite levels in tap water (200 microgram/L or greater) and high inhalation exposure.

The authors suggest several explanations for the association noted in this study between chlorite and term-SGA. First, the direct action of high levels of chlorite could cause developmental effects in newborns. Second, chlorite could be representative of other CBPs formed by chlorine dioxide or of residuals of chlorine dioxide itself. Lastly, the association could be affected by confounding due to some true determinant of term-SGA. The analysis was adjusted for several personal habits, however there may be other unknown environmental, behavioural or socio-economic factors which might be involved in the occurrence of term-SGA and

present in areas where drinking water treatments form high levels of CBPs.

The majority of subjects in this study were not regular municipal tap-water drinkers (87.5%), although many (69.7%) indicated that they drank water-based beverages such as tea and coffee. With regard to inhalation and dermal exposure, a higher risk of term-SGA was noted when subjects were exposed to chlorite via inhalation, however chlorite is an inorganic compound which is not considered to be particularly volatile. Higher risk levels were not seen in those drinking tap water with high chlorite levels compared to non-drinkers of tap water.

*Comment* The discrepancies between risks for ingestion and inhalation exposures argue against chlorite being responsible for the weak association with term-SGA.

#### **Haloacetic acids in drinking water and risk for stillbirth**

King WD, Dodds L, Allen AC, Armson BA, Fell D, Nimrod C (2005) Occupational and Environmental Medicine, **62**(2); 124-7.

Five of six previous studies have reported an increased risk of intrauterine death, stillbirth or miscarriage in relation to trihalomethanes (THMs) in drinking water supplies. However it is recognised that THMs are a proxy measure for exposure to a range of disinfection by-products and not necessarily the by-product of primary concern. Other disinfection by-products found in drinking water, such as haloacetic acids (HAA) have not been investigated previously in relation to risks of stillbirth.

A population-based study was conducted to investigate the effects of HAA compounds in drinking water on risk of stillbirth. Stillbirths occurring in two provinces of Canada between 1999 and 2001 were identified via the perinatal databases in each province. Cases were women who had stillborn infants, defined as death of a fetus weighing 500 grams or more at delivery. 112 women participated out of 184 approached. Controls were recruited from a random sample of all live births for the same time interval. To increase statistical power

attempts were made to recruit controls per case. A total of 398 controls were recruited from 580 approached. Eligibility criteria were: residency in the study area for at least the first five months of pregnancy, delivered in the study area, and resident in the study area at the time of recruitment.

A telephone survey collected information on water consumption, and other water use behaviours. For participants served by public water supplies, tap water samples were collected for HAA analysis. For those with private water supplies (wells), HAA levels were assumed to be nil. Water samples were taken at approximately one year after the time when the subjects were 4-5 months pregnant. For subjects who had moved home since 4-5 months of pregnancy, a surrogate sample was collected from a public building close to the subject's former residence. An estimate was made of by-product levels in the distribution system at each subjects place of employment. Individual exposure estimates were based on ingested volumes of water, and for THMs only, inhalation and dermal exposures.

Among both cases and controls, more than 10% of subjects were exposed to total HAA in household water above 60 micrograms/L. The risk of stillbirth was examined in relation to exposure to total HAAs (the sum of 9 compounds), dichloroacetic acid, trichloroacetic acid and brominated HAAs. After adjustment for total THM exposure, there was no significant association between any of the HAA exposure measures and stillbirth risk. Although this study had relatively low response rates (61% in cases and 68% in controls), the authors do not believe this has impacted on the validity of the observations as those invited to take part were unlikely to be aware of either the specific study hypothesis or the level of chlorination by-products in their water. Therefore it is not likely that non-response was differentially related to exposure levels in cases and controls.

*Comment* The authors note that total THM and total HAA levels in drinking water were highly correlated, however estimated individual exposures to the two classes of DBP showed less correlation due the significant contribution of the inhalation and dermal routes of exposure for THMs but not HAAs.

Gastroenteritis**Self-reported diarrhea in a control group: a strong association with reporting of low-pressure events in tap water.**

Hunter PR, Chalmers RM, Hughes S and Syed Q. (2005) *Clinical Infectious Diseases* **40**:e32-4 (15 February)

This brief paper describes a strong statistical association between self-reported diarrhea and reported low water pressure at household taps. The population described consists of 427 people who were enrolled as controls in a case-control study of cryptosporidiosis conducted in England and Wales from Feb 2001 to May 2002 (a paper comparing cases and controls to determine risk factors for cryptosporidiosis was published in 2004). This new paper reports a separate analysis of the risk of diarrhea in controls only. Cases and controls had completed a postal questionnaire covering drinking water, recreational water, contact with people with gastroenteritis, travel etc. for the 2 week period prior to the questionnaire.

Among the controls, 28 people reported they had diarrhea in the 2 weeks prior to completing the questionnaire, and 395 did not report diarrhea in the 2 week period. Four people did not answer the question, and were excluded from analysis. Statistical analysis of the relationship between exposures and risk of diarrhea showed four variables to be significant in a logistic regression model. Higher risks for diarrhea were associated with feeding a child under 5 years of age, contact with another person with diarrhea, and for reported loss of water pressure at home. A significantly reduced risk of diarrhea and a dose-response effect was seen for frequency of yoghurt consumption.

The association between loss of water pressure at home and diarrhea was very strong (Adjusted OR 12.496, 95% CI 3.493-44.707, p less than 0.001). In discussing the result the authors comment that most reported episodes of pressure loss were associated with reported disruption of the water supply, and infer that these episodes therefore represent mains bursts with contamination of the water supply. They

note that their data do not provide information on the temporal relationship between pressure loss and diarrhea, only that both events occurred in the two week period covered by the questionnaire. Nevertheless they conclude that the strong association indicates that the result is unlikely to be an artifact. They suggest that if this finding is repeatable it would indicate that a substantial proportion of gastroenteritis cases are due to burst mains or other low pressure events allowing contamination to enter the distribution system.

*Comment* The paper has been published as a brief report and is therefore frustrating lacking in detail, considering the potential implications of the findings for waterborne disease risks. No information is given about whether the controls with diarrhoea differed from controls without diarrhoea in terms of age and gender distribution, or geographic or time distribution. This is important as it might indicate whether some kind of bias is operating to affect the result. It does not appear that low pressure episodes or supply disruptions reported by participants were verified against water company records to determine whether these events really did reflect water distribution system problems. Only Adjusted Odds Ratios are presented and the factors adjusted for in the final multivariate analysis are not stated. Knowledge of the temporal relationship between illness and low pressure events is critical to support the cause and effect link that is being inferred by the authors. If some of the disease events occurred before the water supply problem, then clearly a cause and effect relationship could not exist for these events. Exclusion of such events from the analysis may well have the effect of abolishing the observed statistical association.

Immunocompromised Hosts**Provision of safe potable water for immunocompromised patients in hospital**

Hall J, Hodgson G, Kerr KG (2004) *Journal of Hospital Infection*, **58**(2); 155-8.

In the UK, guidelines on the provision of safe drinking water for immunocompromised individuals have focused almost exclusively on *Cryptosporidium*

*parvum* with little if any attention paid to other infection risks. Opportunistic gram-negative bacterial pathogens or fungi such as *Aspergillus* species may be a significant risk for immunocompromised patients, and these pathogens might be acquired through potable water. The authors assessed acute hospital Trust in the north of England to identify current practices in the provision of potable water for immunocompromised patients, and assess alternative methods for supplying water in these settings.

A postal survey was conducted for units in acute hospital Trusts which treated patients with severe immunocompromising conditions (cancer and AIDS). Of 15 Trusts approached, 10 replied and reported data for 14 separate treatment units. The majority of facilities (9) provided tap water to all patients, irrespective of their condition. This is despite current UK guidelines which state that 'all water, from whatever source, that might be consumed by immunocompromised persons should be brought to the boil and allowed to cool before use'.

Two units reported using iced water, with ice from commercially-available makers. Ice from these sources is frequently contaminated with potentially pathogenic bacteria, and it is a well-recognised source of hospital-acquired infection. Five units distinguished between neutropenic and non-neutropenic patients, with the former receiving cooled, boiled water (3 units), sterile water (1 unit) and sterile water or carbonated water (1 unit). This suggests a potential breach of patient confidentiality whereby patients (such as HIV positive patients) could be identified because their water was treated differently to that of other patients. None of the units surveyed provided filtered water. Water in jugs was changed daily (7 units), twice daily (3 units) or only when empty (4 units). Jugs were dishwasher-dried in seven units, air-dried in four, and by paper (2 units) or cloth towels (1 unit). In 10 units, patients were allowed to provide their own potable water, but none of the units provided written advice to patients on potable water.

Five options for the provision of potable water for immunocompromised patients were considered: untreated tap water; cooled, boiled tap water; sterile

bottled water; commercially available bottled water and filtered tap water. Tap water is clearly the lowest cost option but it does not meet with UK national guidelines for the prevention of cryptosporidiosis in these individuals. Cooled, boiled water would satisfy the guidelines, but there are safety implications for healthcare workers, as well as significant time demands, additional energy costs. Sterile bottled water has poor organoleptic quality, as well as the various logistical problems involved such as delivery of water to the site, storage of bottles on wards, and collection of empty bottles. Commercially-available non-carbonated water can contain high counts of Gram-negative bacteria. Carbonated water has lower microbiological content due to the low pH, but this type of water may be unacceptable to cancer patients who may have inflamed mucous membranes due to chemotherapy. Filters in self-contained cartridges are readily available, but a number of concerns exist concerning cost, potential for contamination and acceptability of filtered water to patients.

The authors conducted a one month trial of end-line commercially-available water filters in two cancer treatment wards. Filters were fitted to kitchen taps and filters were changed twice a week by designated staff. Contamination was assessed by swabbing internal and external surfaces of 11 used cartridges after removal from the tap and plating on blood agar at 30 and 37C. Only 2 of 22 (8%) of swabs obtained from time-expired cartridges yielded bacterial growth on culture. Protocols for the regular changing of filter cartridges were adhered to using a proforma completed by those designated to change the filters. Practices were reviewed by a study investigator, and a count of the number of filters used was also undertaken. Informal interview with patients indicated the water was acceptable to the majority.

Using the criteria of cost, microbiological quality, staff safety, patient acceptability and confidentiality, the authors concluded that end-line filtration represents the best option provided that there are robust protocols to ensure that filter cartridges are changed at the appropriate times. This was calculated to be cheaper than sterile or commercially-available bottled water, even taking into account costs associated with the potential need to modify taps.

## NDMA

### **Detecting N-nitrosamines in drinking water at nanogram per liter levels using ammonia positive chemical ionization.**

Charrois JW, Arend MW, Froese KL and Hrudey SE (2004) *Environ Sci Technol.* **38**; 4835-4841.

The occurrence of N-nitrosamine compounds including N-nitrosodimethylamine (NDMA) in drinking water and wastewater has become an active area of research in the last few years due to the probable carcinogenic properties of these compounds. There are currently no standard analytical methods for detection of N-nitrosamines at the very low trace levels (nanogram/L) which occur in drinking water supplies. This paper describes the development of a sensitive new analytical method using solid phase extraction in conjunction with gas chromatography/mass spectroscopy ammonia positive chemical ionisation (PCI).

Method detection limits for eight tested N-nitrosamine species ranged from 0.4 to 1.6 nanogram/L. Application of the method to drinking water samples from two Canadian towns which used chloramination for disinfection resulted in the detection of three N-nitrosamine compounds. N-nitrosodimethylamine was detected at levels of 2-180 ng/L, N-nitrosopyrrolidine at levels of 2-4 ng/L, and N-nitrosomorpholine at 1 ng/L. The latter two compounds have not previously been reported in drinking water. The authors suggest that this methodology will overcome some of the cost and logistical limitations which currently hamper research into N-nitrosamine compounds.

## Water Quality

### **Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis**

Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM Jr (2005). *The Lancet Infectious Diseases* **5**(1); 42-52.

The authors conducted a search of medical literature databases to identify studies of interventions to

reduce illness through improvements in drinking water, sanitation facilities, and hygiene practices in less developed countries. Forty-six studies were identified and 38 of these contained evidence of the relative effectiveness of interventions. The studies were reviewed in detail, and where possible the data were extracted and pooled for meta-analysis to provide summary estimates of the effectiveness of each type of intervention. The analysis also assessed the likelihood of publication bias where studies showing small or absent effects of intervention may be less likely to be published

Hygiene-related interventions such as reducing contamination of hands, food, water, and fomites seem to be at least as effective as other interventions. These interventions were generally of two types; those concentrating on health and hygiene education, and those that actively promoted handwashing (usually alongside education messages). Meta-analysis of 11 studies produced a pooled estimate for relative risk (RR) of 0.63 (95% CI 0.52-0.77). Exclusion of poorer quality studies produced a stronger protective effect (RR= 0.55, 95% CI 0.4-0.75). Handwashing programs seemed to be somewhat more effective than education programs. There was some indication of publication bias.

For sanitation interventions such as the provision of communal or household latrines to reduce the incidence of diarrhoeal morbidity, the review identified four studies but only two were suitable for meta-analysis and only one was of good quality. The pooled RR was 0.68 (95%CI 0.53-0.87). The authors concluded that this is an area which requires further research. Methods of dry sanitation would be of particular relevance given the scarcity of water resources in many developing regions. No evidence of publication bias was noted for sanitation studies.

Water supply-related interventions refer to the introduction of a new water source, provision of a piped water supply or a household water connection. The review identified 9 studies, with 6 suitable for meta-analysis. The outcomes measured in these studies included cholera, typhoid and diarrhoea. The pooled RR was 0.75 (95% CI 0.62-0.91), and there was no evidence of publication bias. However when

only better quality studies of diarrhoea were analysed, no protective effect was seen (RR=1.03, 95% CI 0.73-1.46). Too few data were available to separately examine the role of community versus household connections and the health effects of water supply interventions. Interventions which aimed to improve the water source often did not consider methods of household storage and possible subsequent contamination. Furthermore, studies often did not record whether provision of an improved water supply substantially changed the amount of water use. These factors need to be addressed in any future research in this area.

Water quality interventions included water treatment at the point of use (eg chemical treatment, boiling, pasteurisation and solar disinfection). 15 studies were identified in this category, with 3 dealing with source water quality and 12 with household treatment only. Meta-analysis of 8 better quality household treatment studies produced an RR=0.61 (95%CI 0.46-0.81). Source treatment only was less effective (RR=0.89, 95% CI 0.42-1.90). There was some evidence of publication bias.

Multiple interventions refer to multiple concurrent activities such as the joint introduction of water, sanitation, and hygiene or health education measures. Nine studies were identified but only 5 could be used for meta-analysis. The pooled RR was 0.67 (95% CI 0.59-0.76).

In conclusion, the authors found that although the range of results derived from individual studies varied widely, overall estimates from meta-analysis appeared to suggest an important role for each type of intervention in the reduction of diarrhoeal disease. As previously reported in a 1991 review, multiple interventions did not appear to be more effective than single interventions. The results of meta-analyses also suggest that household water quality interventions may be more effective in preventing disease than previously thought.

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