Health Stream

INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

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WHO Drinking-water Guidelines Released

The World Health Organisation has released the first volume of the third edition of its *Guidelines for Drinking-water Quality*. The Guidelines were launched at the 4th International Water Association Congress in Marrakech, Morocco on 21 September. This edition incorporates a catchment to tap preventive risk management approach for the provision of safe drinking water, in keeping with recent international trends in water quality management. *Volume 1 - Recommendations* describes the development of comprehensive system-specific Water Safety Plans to ensure microbial safety of drinking water supplies. It also includes updated information on chemical hazards, and discusses the role and responsibilities of the various stakeholders including regulators, suppliers, communities and surveillance agencies.

The document emphasises the paramount importance of microbial safety and the need to implement multiple barriers to prevent and reduce contamination of water supplies. As for previous editions, these guidelines are designed to be used by both developed and developing countries as a basis for national regulations. The scope of the Guidelines has also been expanded to include water safety on ships and aircraft, and in large buildings. There is also advice on packaged and bottled water, water for food production and processing, travellers, desalination systems, and dealing with emergencies and disasters.

The Guidelines may be downloaded from the WHO website or purchased in the print version:
www.who.int/water_sanitation_health/dwq/gdwq3/en/

Ranger Uranium Mine Incident

The Supervising Scientist Division (SSD) has released a report on the drinking water contamination incident at the Ranger uranium mine in March this year. The SSD is the Australian federal government agency charged with monitoring environmental protection measures for uranium mines in the Alligator Rivers region in the Northern Territory. Only the Ranger mine, operated by Energy Resources of Australia (ERA), is currently mining uranium in the area. The mine is located within the World Heritage listed Kakadu National Park.

The incident was caused when production water from the mining process was cross-connected to the drinking water supply in the processing plant, allowing process water containing uranium and other contaminants to enter the drinking water supply. Workers at the mine were exposed through drinking and showering in the contaminated water, and some water also entered the drinking water supply to the nearby town of Jabiru East. The report, tabled in Parliament on 30 August, detailed the investigation into the circumstances leading to the incident, remedial actions to decontaminate the potable water supply, an assessment of the impact of the incident on the health of mine staff, and the environmental impact of the incident.

The Ranger mine has three water supplies which are intended for different purposes:

- Potable water is piped from a bore water supply for drinking, showering, flushing toilets, and for supplying safety showers and eyewash stations throughout the mine buildings. The potable water pipeline from the bore field continues 4 km past the mine to Jabiru East, where it serves businesses located at the Jabiru airport, an SSD field station and the Gagadju Workshop (which provides technical services to remote communities in the area). The pipeline also feeds water to a 1.2 megalitre storage tank at Jabiru East which serves an emergency supply in the event that the pipeline from the bore field should fail. The town of Jabiru, a stop off point for tourists visiting Kakadu National Park, has an entirely separate potable water supply and was not affected by this incident.
- Process water is highly contaminated water used in the uranium extraction process. It is recirculated on site for use in the mill and process plant. Process water is not permitted to be released to the environment unless it is first treated to reduce contaminant levels.
- A pond water system at the mine manages rainfall runoff and seepage from ore stockpiles. This water has been in contact with uranium ore but is not as highly contaminated as process water. In the event that the process water system fails, pond water is used as an alternative supply source for processing equipment.

The cross-connection between the process water supply and potable water supply was discovered at about 7.30am on Wednesday 24 March, shortly after commencement of the day shift at the mine. The shift supervisor noticed a strong bitter taste when he drank from a water cooler in the Grinding building and immediately suspected that the water was contaminated with process water. Inspection of the processing equipment revealed a hosepipe connected between a potable water tap on the ground floor and the water manifold on the Fine Ore Bin (FOB) scrubber on the second level, with the valves open at both ends of the hosepipe. The valves were then closed off and a sample from the water cooler was taken to the on-site laboratory for analysis.

By 8.00am the contamination was confirmed by detection of a very low pH, high electrical conductivity and a uranium concentration of about 8,000 parts per billion (ppb) in the water sample. A warning was broadcast to workers not to drink from the potable water supply, and procedures to shut down the plant and send workers home were commenced. It was later determined that some night shift workers reported that they had felt itchy after showering or that the water had left an oily film on skin and hair at the end of their shift at 7.00am that morning. One employee had also reported that the water tasted unpleasant but his supervisor had apparently interpreted this to refer to a possible problem with chlorination levels which had caused complaints in the previous week.

The subsequent investigation determined that a hydraulic connection between the potable water system and the process water had been established at about 9.40pm on the evening of 23 March, when an operator opened the valve on the FOB scrubber manifold inlet which was already connected to a hosepipe originating from the ground floor. The operator stated that his intention was to provide more process water to the FOB scrubber, and he had assumed the other end of the hosepipe was connected to a process water tap on the ground floor, although he had not checked the connection. In fact the other end of the hosepipe was connected to a potable water tap on the ground floor, and the valve at the ground floor end was open.

The low water flow alarm on the FOB scrubber had been triggering repeatedly during the day, sounding an audible buzzer that required the operator to silence it by pushing a button on the control panel. After the valve was opened the audible buzzer ceased, causing the operator to believe that the hosepipe was supplying additional water to the processing equipment. In fact, the higher pressure in the FOB scrubber was forcing process water into the potable water system, causing the alarm to remain constantly in the active (low flow) state without retriggering the buzzer. Conflicting statements were given by the operators and supervisors about when the lower end of the hosepipe was connected to the potable tap, and whether or not it was common practice for a hose to be connected to this tap. All workers denied having opened the valve at the potable water end of the hosepipe prior to the cross-connection being established, and all stated that they knew the potable supply should never be used for supplementing the process water supply to the FOB scrubbers.

However the SSD report noted that while four workers had stated they had seen the hosepipe connecting the potable water tap to the FOB scrubber earlier on the day of the incident before the hydraulic cross-connection was established, none reported taking action to disconnect the hosepipe or report it to management, as might have been expected if this was an usual situation which they recognised as being hazardous. The SSD concluded that contrary to ERA policy, it was likely that the potable water had been used to supply the FOB scrubbers in the past. Two scenarios might be envisaged; the first being the same configuration as the contamination incident where both potable and process water systems were connected to the FOB scrubber, the second being where potable water alone might have been used if the process water system had failed. Given that records for monthly monitoring of the potable water supply since 1980 showed no indication of changes in electrical conductivity or sulphate levels (which would be expected if process water had entered the potable supply), the first scenario was deemed unlikely. For the second scenario, cross contamination of the potable supply would not be expected, as only potable water would be present in the scrubbers, and the SSD report concluded this may have occurred in the past.

The investigators noted that the process water system was in poor condition with 20 to 30 entries in the Control Room Log relating to failures or repairs during the period 1 March to 24 March alone. Leaking pipes, broken and corroded valve handles, and colour coding on pipes obscured by dirt and rust were noted during the site inspection following the incident. The investigators concluded that it was evident that operators and supervisors were routinely implementing "work around" procedures to keep the plant operating when the process water system failed, that proper change management procedures to assess risks before deviating from normal operating practice were not being followed. ERA had already begun a program to replace the entire process water system prior to the incident, but this work was not scheduled for completion until September 2004.

On the morning the contamination incident was discovered, ERA staff had acted quickly to isolate the pipeline to Jabiru East, and the potable water storage tank serving the town. Potable water samples taken from storage tanks at the SSD field station and Gagadju workshop complied with Australian Drinking Water Guidelines for electrical conductivity, iron, manganese, sulphate and uranium, indicating that they had not been affected by contamination. Water samples could not be obtained from the airport as it had no storage tanks, however modeling of overnight water use for this section of

the pipeline (comprising irrigation at the field station and preparation of small amounts of tea and coffee at the airport) showed the contaminated water would only have travelled about halfway along the branch pipe and not reached the first offtake (the SSD field station) before the system was closed down.

At the time of the incident, the overflow valve at the Jabiru East storage tank was faulty and was allowing water to discharge from the tank at an estimated rate of up to 18 litres per second. This leakage had the effect of drawing contaminated water along the pipeline from the mine's potable water supply into the tank. The exact degree of contamination of the water entering the tank is uncertain as the only samples taken in this vicinity before clean up operations commenced were obtained from a fire hydrant some 10 metres off the main pipeline and were probably not representative of water in the pipeline. Samples taken from the pipeline on 25 March contained up to 460 ppb uranium.

Modeling of a worst case scenario indicated that contaminated water would have reached the tank about 2 hours after the cross-connection was established. Water entering the tank may have had a uranium concentration as high as 3,000 ppb, while the overflow water may have contained up to 1,070 ppb. The overflow drained overland about 600 metres to a nearby creek. The SSD report noted that the valve had probably been leaking since January 2004 when ERA flow meter records showed a sudden and sustained increase in water usage on the Jabiru East line. This sudden change apparently did not trigger any action or investigation on the part of ERA and the leak remained unnoticed until the incident.

Two independent assessments of the risk to the health of exposed workers were conducted by the Australian Centre for Human Health Risk Assessment, and an ERA occupational physician. These assessments considered the estimated exposures calculated from the levels of water contamination and reported water ingestion by workers, and also the results of blood and urine samples from some workers. In addition to uranium, the potential acute and chronic health effects of exposure to other metals and dissolved salts were also considered including aluminium, ammonium ion, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, magnesium, nickel, strontium, sulfate, and zinc. Both assessments came to similar conclusions about health risks.

Water samples taken from the potable water system within the processing plant showed differing levels of contamination, reflecting the uneven distribution of the contaminated water. The two samples with the highest contamination levels were used in risk assessments to provide worst case estimates. The most heavily contaminated sample came from a toilet cistern in the ground floor grinding area and contained 7,100 ppb uranium, the second sample came from the engineering shower block and contained 370 ppb uranium. The undiluted process water contained 18,900 ppb uranium.

Of the 306 workers interviewed by ERA, about half reported they had not consumed any water from the potable water system during the 12 hour period when the cross-connection existed (not all interviewed workers were on-site during that period). Of the 143 workers who did report water consumption, 50% drank less than 500ml, 31% drank between 500 ml and 2 litres, and 27 drank more than 2 litres. The highest reported intake was 5 litres. Some workers reported that the water tasted bad, while others noticed no difference from normal. Two individuals reported vomiting shortly after drinking and a number experienced diarrhoea or abdominal discomfort in the days following the incident. These effects were most likely due to the high levels of sulfate and copper in the water (8,370 mg /L and 11.7 mg/L respectively in the most contaminated sample). Some workers also reported headaches. Overall 21 workers reported some symptoms of illness.

While press reports of the incident concentrated largely on potential dangers from radiation exposure, the health risk assessments concluded that radiological exposure as a result of the incident was very minor and not likely to be associated with any short or long term health risk. The estimated dose for the worst case scenario of ingesting 5 litres of the most heavily contaminated water would have resulted in a dose of 430 microSieverts. The work-related dose limit for a radiation worker is 20,000

microSieverts per year, and for a member of the general public 1,000 microSieverts per year. Given that the taste of the water would have been very unpleasant, it is unlikely that people who ingested large amounts were actually consuming the most heavily contaminated water. The "worst case" scenario therefore was a very conservative (high) estimate of risk compared to the levels of exposure that are likely to have occurred.

The contaminated water contained a number of substances of potential concern due to their chemical toxicity. The most heavily contaminated sample exceeded the Australian Drinking Water Guidelines (ADWG) health values for arsenic (by a factor of 4.6x the health guideline value), cadmium (5.5x), chromium (1.4x), copper (5.9x), lead (128x), manganese (1214x), nickel (85x), selenium (15x), sulfate (16.7x), and uranium (355x). The ADWG health guideline values represent a safe level of exposure for contaminants in water consumed daily over a lifetime, and are not readily applicable to this situation where high level exposure occurred over a short period of time. However the degree by which the concentration exceeded the health guideline value was used to prioritise those exposures with most potential for adverse health effects.

Regarding short term health effects, the health risk assessments concluded that ingestion of sulfate in combination with the associated anions copper and magnesium may have lead to gastrointestinal symptoms such as vomiting and diarrhoea. A number of metals and the acidity of the contaminated water could have contributed to skin itching and eye irritation due to showering, but these symptoms would not persist after exposure had ceased. Inhalation and dermal exposure were considered to have made a very minor contribution to the absorbed dose compared to ingestion.

For long term health effects, the health risk assessments found that the exposures occurring as a result of the incident were probably too low and too short term to cause systemic effects on target organs. Blood and urine samples taken from exposed and unexposed workers within 10 days of the incident generally did not show indications of toxicity among the exposed group, although three workers had relatively high levels of urinary N-acetyl-glucosaminidase (NAG) excretion. This is a possible marker of damage to the proximal tubules in the kidney, a known target for uranium toxicity. However these workers had normal levels of beta-2-microglobulin in the blood, whereas elevated levels are associated with uranium toxicity. Interpretation of the clinical results was hampered by a lack baseline data for the workers, and no accepted reference range for urinary NAG excretion in the general population. Thus it was not possible to determine whether the elevated results represented an effect of exposure during the incident, an effect of usual workplace exposure in the uranium industry, factors unrelated to uranium exposure., or indeed normal values

The SSD report made several recommendations as a result of the investigation:

- changing the fittings on the potable water system to ensure they are incompatible with other water systems on site.
- installation of a probe measuring electrical conductivity and pH in the potable water system with an alarm to notify operators of any significant changes.
- installation of non-return valves on the potable system.
- an independent audit of the process water system by the end of 2004 to ensure the replacement of the system has been completed and identify if any further deficiencies exist.
- introduction of a permit system by ERA for changes to water systems, and implementation of an improved housekeeping system on site.
- definition of minimum competency standard for operators by ERA and implementation of appropriate training.
- implementation by ERA of a Workplace Safety System such as Australian Standard 4801.
- provision of copies of the two health risk assessments to affected workers, and facilitation by ERA of a voluntary program to monitor possible long term health effects.
- consideration by the relevant Commonwealth government minister of action against ERA for breach of the environmental requirements relating to its operations.

- the relevant Commonwealth government minister should seek advice from the Northern Territory government on the audit and inspection regime at the ranger mine, and any concerns regarding the condition of the process plant and occupational health and safety issues.

Following the incident, the mine remained closed until 31 March, when uranium mining and stockpiling operations recommenced. Ore milling and processing operations were not resumed until 6 April when the SSD determined that adequate measures had been taken to prevent a recurrence of the incident. The potable water supply to Jabiru East was restored on 9 June after SSD endorsement of decontamination work by ERA.

The DSS report to Parliament on the water contamination incident was accompanied by a second report related to radiation clearance procedures for vehicles, and instances where earthmoving vehicles were allowed to leave the mine site while still contaminated with uranium ore. Following the delivery of the reports the Ranger mine closed voluntarily on 31 August to address immediate concerns raised in the reports, and reopened again on 3 September. The Northern Territory government is considering the SSD reports together with it's own investigation of the incident before deciding whether legal action will be taken against ERA.

Arsenic Removal Plants Failing

A survey of arsenic removal plants in West Bengal has found that most are not operating or are not being used by villagers. The 2-stage survey was carried out by researchers at Jadavpur University led by Dr Dipankar Chakraborti. Dr Chakraborti conducted some of the earliest research on arsenic toxicity from groundwater in the region, and is credited with first bringing this huge public health problem to the attention of the international community. Over the last four years his research group has carried out several surveys to determine whether arsenic treatment plants installed in an effort to provide safe drinking water have fulfilled their purpose, and what factors may affect their reliability and acceptability to the community.

The most recent survey involved physical inspection of 182 arsenic treatment plants in March and April 2004, followed one to two months later by a more detailed inspection and water sampling for those plants which were operating satisfactorily and were being used as a drinking water supply by villagers. The first stage of the survey found that 63 of the 182 plants (35%) were not operating, and a further 67 (37%) were operating but were not being used as drinking water sources due to discolouration of the water, bad odours or mechanical problems such as water splattering or sand gushing. Only 20 plants (11%) were operating well and being used as drinking water sources without complaints from the users. The remaining 32 plants (18%) were operating but had periodic problems (with colour, odour etc) and were used for drinking only some of the time.

The second stage survey of the 20 operational wells found that 4 had become defunct in the short interval since the first visit. For one operational plant the arsenic concentration in raw water was less than 10 micrograms/L so the plant was unnecessary. Among the remaining 15 plants (which all had raw water with arsenic levels above 50 micrograms/L), only 7 were producing treated water with arsenic levels below the Indian drinking water standard of 50 micrograms/L. Only one plant out of these 7 produced treated water meeting the WHO 1993 guideline value of 10 micrograms/L. The plants also performed badly in terms of the iron content of the treated water, with 14 of the 16 plants tested producing water above the 300 micrograms/L aesthetic guideline value used by both WHO and the Indian regulations. High iron content in drinking water is not a health problem but causes objectionable taste, odour and discolouration which make the water unacceptable to users.

The researchers concluded that many of the problems with arsenic removal plants were due to lack of maintenance. There is also a lack of involvement and feeling of responsibility on the part of villagers, and practical difficulties with the design of some plants making them difficult to use. India has reportedly spent US$3 million on arsenic treatment plants, but it appears that this may have made little impact on the arsenic exposure levels of the population.

Fern Toxin Found In Water Supplies

A Danish scientist has reported the detection of a toxic and potentially carcinogenic chemical produced by the bracken fern in some rural well water sources in Europe. In a presentation at the Annual Meeting of the British Ecological Society on 9 September, Dr Lars Holm Rasmussen of the Royal Veterinary and Agricultural University reported that he had found the compound ptaquiloside (PTQ) in two wells in Sweden and Denmark. The issue was picked up by European newspapers with some reporting the story as if a causative relationship with PTQ contaminated water and human cancers had already been proven, whereas the scientific evidence for a significant role of PTQ in human cancers through any exposure route has not yet been adequately established.

Bracken fern (*Pteridium aquilinum*) is a widely distributed plant, occurring in all continents except Antarctica, with a fossil record extending back some 55 million years. The fern is known by a number of different common names and taxonomists are somewhat divided as to whether it comprises a single worldwide species or several closely related species. Bracken fern is a versatile plant that grows in most soil types, and requires less water than other fern species. It is often considered a nuisance species for agriculture as it readily colonises land cleared by fire, overgrazing or mechanical means. The species appears to have rapidly increased in abundance and geographic range in the last 5,000 years, probably due the expansion of agriculture and land clearing.

Bracken fern produces a wide array of toxic and bitter tasting chemicals which are believed to provide defences against disease, insect attack and grazing by herbivores. Some compounds may also play a role in inhibiting the growth of competing plant species. All parts of the plant are toxic to humans and a wide range of animals. Despite the presence of toxic chemicals, grazing animals will often consume bracken ferns, particularly the newly emerging coiled fronds (known as crosiers or by the common name of "fiddleheads"). A number of acute toxicity syndromes have been observed in different animal species in areas where bracken forms a significant proportion of the available fodder. Horses and pigs (which require thiamine in their diet) may develop thiamine deficiency and neurological symptoms due to the presence of a thiaminase enzyme in bracken fern, while cattle and sheep (which are able to synthesise their own thiamine) suffer instead from an acute haemorrhagic illness due to toxic effects on bone marrow and epithelial tissues. These conditions can be lethal after several weeks of feeding on bracken fern.

The effects of chronic consumption of smaller amounts of bracken fern include "bright blindness" in sheep (due to progressive damage to blood vessels in the retina), haemorrhages of the bladder wall leading to haematuria (blood in the urine), and cancers of the upper gastrointestinal tract and bladder in cattle. Bracken toxicity may cause immunosuppression, leading to increased vulnerability to infections, and there is some evidence that viral infections such as bovine papilloma virus may play a role in bracken carcinogenesis in animals. Bracken poisoning is believed to have a major economic impact in badly affected areas of the world due to animal mortality and loss of condition.

Bracken fern and various extracts have been shown experimentally to be carcinogenic in a number of animal species including rats, mice, guinea pigs, japanese quail and egyptian toads. The major carcinogenic substance appears to be ptaquiloside (PTQ), although other carcinogenic and/or mutagenic compounds may also be present. The plant also produces cyanide-containing compounds when damaged but these are believed to have a only minor role in toxicity to animals. Huge variations in PTQ content have been reported in various studies, ranging from undetectable amounts up to 15,000 micrograms per gram dry weight. The reasons for this are unclear and may include genetic variability between different fern populations and/or the influence of soil, nutrient, climatic conditions and physiological stress. The highest concentrations of PTQ generally occur in crosiers just after they emerge from the ground.

Bracken fern has been traditionally used in the human diet in many countries, either in the form of crosiers (consumed fresh, pickled or dried) or the

starchy underground rhizomes (roasted and eaten as a vegetable or ground into flour). The fern is currently grown commercially as a food or herbal remedy in Canada, the US, Siberia, China, Japan and Brazil, and is also harvested from the wild in many parts of the world. It has been suggested that toxins from bracken ferns may be a risk factor for some gastrointestinal cancers in regions where consumption is common, however epidemiological studies have produced inconsistent results and have been limited in their statistical power and ability to assess other risk factors.

Dairy products may represent another route of human exposure to bracken toxins. Experimental studies have shown PTQ is present in the milk of cows fed on a high bracken diet, and both the fresh milk and freeze-dried milk powder produced cancers of the small intestine and bladder when fed to rats. Therefore it has been hypothesised that milk may be a significant source of PTQ in the diet of farm workers and other consumers who drink milk from small local dairy operations in bracken affected areas. For larger population centres, any PTQ-containing milk would be greatly diluted by uncontaminated milk from other regions. Pasteurisation of milk has been reported to reduce PTQ content by 50% to 75%. Bracken fern produces large quantities of windborne spores in late summer to autumn, and these have also been suggested as a source of toxin exposure for local populations through inhalation or ingestion, however the PTQ content of spores appears to be very low. Nevertheless, fresh spores have been shown to be carcinogenic when fed to mice.

PTQ is water soluble, binds poorly to soil particles and moves at a variable rate through soil depending on pH and soil type. The rate of degradation depends on soil pH, carbon and clay content, and is slowest in acid soil with low carbon and low clay levels. Concentrations of up to 7 micrograms per litre of water extracted from soil 90 cm below the surface have been reported, however the recent conference report appears to be the first time PTQ has been detected in drinking water sources. According to information supplied to Health Stream by Dr Rasmussen, the two wells were tested at the request of the owners who had read a Danish newspaper article about his work on PTQ in soil which discussed the possibility of water contamination. Both wells were on former agricultural land now redeveloped for holiday homes. Both had bracken growing in the immediate vicinity of the well and drew water from shallow aquifers. One well had a PTQ concentration of 6 micrograms per litre while the other had 45 micrograms per litre. Two other wells which appeared not so highly vulnerable did not contain detectable levels of PTC.

Due to the lack of scientific evidence on human health effects, no regulatory agency has yet set a standard or guideline value for PTC in drinking water. Dr Rasmussen has carried out calculations using data from animal cancer studies together with a target risk level of 1 in a million cases of cancer for lifetime exposure, and produced an estimate of 1.4 nanograms per litre as the tolerable concentration, however another researcher has proposed a limit of 350 nanograms per litre based on some of the same data. It should be noted that the animal studies on which these estimates were based do not conform to accepted protocols used for standards setting - the dose levels of PTC were high enough to produce acute toxicity and lethality, and the duration of exposure was shorter than the animal lifespan. Accepted practice for chronic carcinogenicity testing requires that the daily dose (maximum tolerable dose) does not cause premature death or gross signs of toxicity, and that tests are run for the normal duration of the animals' lifetime.

Bracken fern is presently classified as *possibly carcinogenic to humans* (Group 2B) by the International Agency for Research on Cancer (IARC). The last IARC review was conducted in 1987 and concluded there was *sufficient evidence* for carcinogenicity of bracken fern in experimental animals and *limited evidence* for the carcinogenicity of ptaquiloside derived from bracken fern in experimental animals. In February 2003 the Sixth Advisory Group of the IARC Monograph Program placed bracken fern in the high priority group of substances for re-evaluation due to accumulation of new data from animal carcinogenicity studies and human epidemiological studies.

Water Suspected In Ohio Outbreak

Faecal contamination of groundwater supplies is suspected as the source of a large gastroenteritis outbreak in Ohio, USA. Over 1,400 people have become ill with gastroenteritis after visiting South Bass Island on Lake Eyrie between July and September. The island is a popular weekend and holiday destination with up to 15,000 visitors per day in the summer peak season. Most illnesses have been of short duration, however about 4 percent of those interviewed by health officials reported they had visited a hospital emergency room for treatment. Few of the affected people have had faecal specimens examined to determine the cause of their illness. Several different pathogens have been found including Campylobacter (15 cases), Norovirus (9), Salmonella (1) and Giardia (1). Illness has occurred in all age groups, and visitors from 16 US states, Canada and Europe have been affected.

After initial investigations failed to reveal any common exposure (eg, a particular food venue, attendance at a particular event) among cases, the attention of health authorities turned to the local water supplies as a possible source of infection. Put-in-Bay, the main town on the island, is served by a municipal water treatment plant that draws water from Lake Eyrie. This supply meets USEPA water quality standards and has not shown signs of contamination. Some businesses and residences in the town use water from private wells for drinking. Businesses and residents outside the town are served by private wells. The town area is served by a central sewerage system, with the remainder of the island relying on septic tank systems.

Testing of 59 wells has revealed the presence of *E. coli* in 15 and total coliforms in at least a further 28 wells. There are estimated to be about 600 wells on the island, with only a few subject to regular microbiological monitoring. A number of businesses serving the public have been ordered to cease using wells. Residents who rely on well water have been advised to boil the water before drinking it, and visitors have been advised to use bottled water. An investigation is underway to determine whether the island's shallow aquifer has become contaminated.

Book Review

Safe Drinking Water: Lessons from Recent Outbreaks in Affluent Nations

By SE Hrudey and EJ Hrudey

ISBN: 1 84339 042 6 IWA Publishing

This book arose from the involvement of one of the authors (SE Hrudey) in the Walkerton Inquiry, which investigated the cause of a fatal waterborne outbreak in a small Canadian town in 2000. In addition to investigating the circumstances of the outbreak, the Inquiry was charged with making recommendations to improve the safety of water supplies in the province of Ontario and reduce the risk of future waterborne outbreaks. To assist this aim, information was compiled on waterborne outbreaks in comparable developed nations over the last three decades. The resultant compilation of knowledge gives insights into the human, organisational and technical factors that contribute to such outbreaks, and in the words of the authors, provide the means to learn from these events and "*convert hindsight into foresight"* to prevent future tragedies.

After a brief introductory chapter outlining the theme of the book, the authors describe the recognition of water as a route of disease transmission through the work of Dr John Snow and his contemporaries in the late 1800s, and the marked decline in waterborne disease in developed nations in the early 1900s as improvements in sanitation and drinking water treatment were implemented. The characteristics of the major classes of pathogenic microorganisms are then outlined, followed by more detailed descriptions of the ten pathogen species involved in the waterborne outbreaks compiled in the book.

The next chapter provides an overview of how water quality is defined and measured, and describes the characteristics of different water treatment methods and their effectiveness in removing or inactivating pathogens. The concepts of risk management and the multiple barrier approach to managing risks in water supplies are also briefly introduced. The bulk of the book is devoted to Chapter Four, which comprises detailed descriptions of 73 waterborne outbreaks occurring since 1974 in 14 developed nations. In at least 26 outbreaks some victims required

hospitalisation, and eight outbreaks involved fatalities. Also included are accounts of the Sydney, Australia 1998 water quality incidents, which were not associated with a disease outbreak, and a probable unrecognised waterborne outbreak in 1982 in Edmonton, Canada.

The final sections of the book examine the recurring themes revealed by the analysis of the outbreaks, and suggested approaches to preventing outbreaks and strengthening the provision of safe drinking water in developed nations. Most outbreaks are the result of multiple factors which erode safety over time, rather than a single catastrophic event which overwhelms a well designed and operated system. Pathogen contamination of any individual water source is intermittent, and therefore failure of water treatment processes or deviations from normal operating practices will not always lead to a detectable outbreak. For this reason a culture of complacency can become established among operators and regulators, allowing a gradual drift away from safe practices and leaving the system vulnerable when the next significant challenge arises. The authors discuss and endorse recent international initiatives to adopt preventive risk management approaches to drinking water safety as the most effective means to reduce the risk of outbreaks.

While drinking water outbreaks are rare events in developed nations and have relatively minor public health impacts, they undoubtedly undermine consumer confidence in public water supplies. As illustrated by this book, the vast majority of outbreaks are preventable by applying current scientific knowledge of drinking water treatment, and improving understanding of the fundamental importance of safe water supplies among water supply and public health professionals.

This well written and extensively referenced book is an excellent resource for those responsible for providing drinking water to the public, and for health professionals involved in the regulation of drinking water supplies.

Declaration of Interest: Health Stream's Editor provided comments to the authors on an early draft of this book.

News Items

WHO invites comment on nutrient minerals

The World Health Organisation is asking for comments on "*Nutrient minerals in drinking-water and the potential health consequences of consumption of demineralized and remineralized and altered mineral content drinking-water*". Draft papers from a workshop held in Rome in November 2003 have been posted on the WHO website, with comments requested by 30 November 2004. The main focus of the consultation is on desalination for drinking water production and the need for remineralization of water before distribution to consumers. Other topics include the role of drinking water as a source of trace minerals, the relationship between water hardness and cardiovascular disease risks, and the dental health impacts of fluoride.

www.who.int/water_sanitation_health/dwq/nutrients/

Australian Ministers Endorse Fluoridation

Health Ministers from Australian state, territory and federal governments have endorsed water fluoridation as an effective public health measure in a joint communique issued on 29 July. The Ministers met in Hobart, Tasmania to discuss the progress of the national Health Reform Agenda. Australia is currently developing a National Oral Health Plan which is due for public release in November 2004. The plan will address a number of health promotion goals including reducing the incidence of oral diseases such as tooth decay, periodontal disease, and oral cancers, and reducing the incidence of oral trauma injuries. Increased access to water fluoridation is expected to be an important component of the plan.

IBM To Pay For New Town Water Supply

The IBM Corporation has agreed to pay US$10 million to provide a new water supply for the town of Fishkill East, New York. IBM operates a large microchip and semiconductor production facility in the town. The groundwater in the area has been polluted with volatile organic compounds including tetrachloroethylene and trichloro-ethylene, from dumping of solvent waste in the 1970s and 1980s. The waste was dumped from a workshop which

cleaned computer microchips under contract to IBM. The pollution was discovered in 2000 and the contaminated site was placed on the US EPA's National Priorities List of most hazardous waste sites in June 2001.

While negotiating a long term solution with the EPA, IBM paid for the cost of installing and maintaining whole-of-house water treatment systems for 103 properties with wells affected by the groundwater pollution. The new water supply for East Fishkill (population 26,000) will be piped from a nearby town, with construction of the pipeline expected to take 2 ½ years. Some residents are unhappy with the deal, saying that IBM has escaped having to publicly accept responsibility and apologise for the pollution. The confidential settlement is contingent on withdrawal of litigation, and does not hold IBM responsible for damages. Residents have also expressed concern over the possible health effects of their exposure over the last 30 years, and the effects of airborne exposure in addition to water exposure.

Spa Problems Highlighted

Analysis of 5,209 inspections of public spas in five US states has revealed a high rate of problems with disinfection, filtration systems and management. Data were compiled from Health departments in Florida (n=4,463 spa inspections), California (n=588), Minnesotta (n=74), Wyoming (n=49) and Pennsylvania (n=35) covering 4 months in 2002. It was found that 17.1% of spas violated state regulations on disinfectant residual, 14.6% on pH, and 17.3% on other aspects of water chemistry. Violations relating to filtration or recirculation systems were found at 27.3% of spas, and 23.3 % of operators lacked required training, while 12.7% had inadequate record keeping. Less than half (43.2%) of the inspections found no violations, and in 11% of cases the violations resulted in closure of the spa.

Incorrectly managed spas represent a potential risk for skin and/or respiratory infections by a number of opportunistic pathogens including *Pseudomonas spp.*, *Legionella spp,* and *Mycobacterium spp*. This survey highlights the need for improved training and maintenance of public spas in the US.

From the Literature

Web-bonus articles

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

www.waterquality.crc.org.au

Water fluoridation and the environment: Current perspectives in the United States
Pollick HF Int J Occup Envir Health (2004) **10**:343-350.

New data on ecological analysis of possible relationship between magnesium in drinking water and liver cancer.
Tukiendorf A, Rybak Z. Magnesium Res (2004) **17**(1):46-52.

Safe household water treatment and storage using ceramic drip filters: a randomised controlled trial in Bolivia.
Clasen T, Brown J, Suntura O, and Collin S. *Water Science and Technology* (200) **450**(1):111-115.

Wading pool water contaminated with both norovirus and astroviruses as the source of a gastroenteritis outbreak.
Maunula L, Kalso S, Von Bonsdorff CH and Ponka A. *Epidemiol. Infect.* (2004) **132**:737-743.

Potential ecological and human health risks associated with the presence of pharmaceutically active compounds in the aquatic environment.
Jones OAH, Voulvoulis N and Lester JN. *Critical Reviews in Toxicology* (2004) 34(**4**):335-350.

The need to decide if all estrogens are intrinsically similar.
Moggs JG AJ, Tinwell H, Lim FL, Moore DJ, Kimber I and Orphanides G. Environmental Health Perspectives (2004) **112**:1137-1142.

Potential ecological and human health risks associated with the presence of pharmaceutically active compounds in the aquatic environment.
Jones OAH, Voulvoulis N and Lester JN. *Critical Reviews in Toxicology* (2004) **34**(4):335-350.

Arsenic

The effect of arsenic mitigation interventions on disease burden.
Lokuge KM, Smith W, Caldwell B, Dear K and Milton AH. *Environmental Health Perspectives* (2004) **112**(11):1172-1177.

Concerns regarding the widespread exposure of the Bangladeshi population to arsenic from tube-well water has led to the advocacy of many interventions or alternative water sources to mitigate the problem. Mitigation may involve it's own risks, particularly with waterborne infectious disease, and as yet no meaningful assessment of the competing risks involved with these interventions have been performed. This article presents an evaluation of the possible change in overall burden of disease associated with arsenic mitigation interventions.

Disease associated with chronic arsenic exposure from drinking water has a relatively low incidence and long latency period for most end points appropriate for a burden of disease assessment. Mortality rates for arsenic related disease, however, are very high. Conversely, waterborne infectious diseases have a very high incidence and relatively low case fatality rate. Unlike arsenic-related disease which primarily affects older adults, approximately 90% of waterborne disease occurs in children aged less than five years. Mortality rates and disability-adjusted life years (DALYs) were calculated for disease end points related to disease from arsenic and infectious waterborne sources. DALYs are a measure of the loss of healthy lifeyears and can be used to compare predicted disease states. Relative risk estimates from past studies were used to determine disease-specific attributable risk fractions which were then applied to background estimates to determine the disease burden of the factors studied.

Arsenic exposure estimates were determined with available demographic data, the use of shallow tube-wells, and known concentrations of arsenic from these groundwater sources. Data on arsenic related disease endpoints were obtained from past studies, and Taiwanese data were used for dose-response calculations.

The burden of disease from waterborne infections in Bangladesh is overwhelmingly attributable to diarrhoeal illness. Tube wells were introduced to Bangladesh to provide microbiologically clean water, rather than contaminated surface water sources. If Bangladesh were to switch to surface water sources, it has been estimated that diarrhoeal diseases would increase by 20%.

The authors estimated that 58.8% of the Bangladeshi population are exposed to a drinking water arsenic concentration of below 11 micrograms per litre, 16.4% between 11 and 49 micrograms per litre, and 24.8% above 50 micrograms per litre. The total annual disease burden due to exposure to arsenic in drinking water above 50 micrograms per litre were calculated as 9,136 deaths and 174,174 undiscounted DALYs, which constitutes 0.3% of the total disease burden in Bangladesh. Reduction in the net disease burden could only be achieved when arsenic-related DALYs were reduced by 77% from interventions in those populations exposed to greater than 50 micrograms per litre of arsenic in drinking water. The authors suggest that interventions involving a return to use of surface water supplies would increase water-related diarrhoeal disease by an estimated 20% in those without adequate sanitation.

The authors maintain that although arsenic-related disease is a significant disease burden in those exposed, nationally it is of less importance than other risk factors. Arsenic interventions at the current time should only be undertaken in areas with high levels of exposure, and need to achieve significant reductions in arsenic exposure without causing substantial increases in other health problems such as waterborne disease.

Cryptosporidium

Risk factors for Sporadic Cryptosporidiosis among Immunocompetent Persons in the United States from 1999 to 2001.
Roy, S L, DeLong, S M, Stenzel, S A *et al. J Clin Microbiol* (2004) **42**(7):2977-2951.

It has been estimated that 90% of cases of cryptosporidiosis are not linked with known outbreaks. A case-control study of laboratory-

confirmed cryptosporidiosis was conducted to evaluate the risk factors of sporadic cryptosporidiosis and to determine the proportion of sporadic cases that may be attributable to those risk factors.

Seven state FoodNet sites across seven US states participated, enrolling immunocompetent cases with laboratory-confirmed cryptosporidiosis over a two year period. Cases were excluded if associated with a known outbreak. Controls were recruited by random or progressive digit dialling based on telephone numbers of cases. Cases and controls were matched by age-group and residential location within the same FoodNet catchment. One or two controls were matched to each case, and only one control was recruited per household. A questionnaire was administered to cases or guardians, to determine demographics, health status and exposures in the 14 days prior to disease onset. Statistically significant and biologically plausible risk factors were further analysed in a multivariate model.

Two-hundred and eighty two cases were recruited from a total of 983 total notifications. Reasons for exclusion included self-reported immuno-compromised condition (n=238), unable to be contacted (n=137), associated with an outbreak (n=83), no home telephone (64), refusal (39) and miscellaneous reasons (140). Excluded cases were predominantly male, African-American, aged over 25 years and lived in urban areas. The 282 enrolled cases were matched with 490 controls with similar demographics. Proportionally more cases than controls had an existing chronic medical condition (21 percent and 14 percent respectively).

Under univariate analysis, cryptosporidiosis was associated with contact with children less than two years of age with diarrhoea, contact with children aged between 2 – 11 years with diarrhoea, contact with cattle, international travel and swimming in freshwater, marine waters and private pools such as in hotels. Protective factors included swimming in home pools, filtering drinking water, and the consumption of raw vegetables, lettuce and salads, and cold protein-based salads. As half of the participants resided in Minnesota, risk factors for Minnesota compared to residence in the other states were analysed. When analysing by state, well water consumption, contact with ill children below 2 years of age and between 2 and 11 years of age were significant risk factors in Minnesota, but not outside Minnesota. Any swimming, swimming in freshwater, and any travel were significant outside of Minnesota. Drinking municipal water, well water or bottled water were not significantly associated with cryptosporidiosis risk in univariate analysis.

Under multivariate analysis, contact with ill children aged between 2 and 11 years was significant (OR = 3.0; C.I. = 1.5-6.2), as was contact with cattle (OR = 3.5; C.I. = 1.8-6.8), international travel (OR = 7.7; C.I. = 2.7-22.0), chronic medical conditions (OR = 2.2; C.I. = 1.2-4.0) and swimming in freshwater (OR = 1.9; C.I. = 1.0-3.5). These variables remained significant even when adjusting for international travel in the two weeks prior to the onset of diarrhoea. Drinking well water (OR=1.5, 95% CI 0.9-2.5) was not a significant risk, and filtering drinking water (OR=0.8, 95% CI 0.5-1.2) was not significantly protective in this analysis.

A seasonal pattern of cryptosporidiosis was noted with the enrolled cases, with the peak incidence (65% of cases) in the summer months between June and September. This pattern held for both children and adults. When adjusting for season, risk factors such as drinking well water (OR = 2.1; C.I. = 1.1-4.4), swimming in freshwater (OR = 2.1; C.I. = 1.1-4.0), and contact with children aged between 2-11 years with diarrhoea (OR = 2.8; C.I. = 1.1-7.3) were significant during summer, but not the other seasons. International travel and contact with cattle remained significant risk factors throughout the calendar year, and raw vegetable consumption remained protective.

Population attributable risks (PAR) were calculated from the multivariate model, indicating that majority of sporadic cryptosporidiosis in this population may be due to contact with cattle (PAR=16%), followed by international travel (11%), contact with children aged between 2 and 11 years with diarrhoea (10%) and fresh water swimming (10%).

No significant risk of transmission was found for persons aged over 11 years, suggesting that the risk

may be influenced by the age of the index case. Young age may be a surrogate for inadequate hygiene, faecal incontinence and the need for more assistance during illness. Contact with cattle is a known risk factor for cryptosporidiosis, and was statistically significant in this study. Interestingly, contact with other species such as dogs, cats, sheep and pigs did not show any significant associations. International travel and swimming in freshwater are known risk factor for cryptosporidiosis, and both were highly associated with disease in this study.

The protective effect of raw vegetables was also found by a recent Australian case-control study into sporadic cryptosporidiosis. The authors speculate that the protective effect may be due to regular exposure to *Cryptosporidium* oocysts from the vegetables, resulting in asymptomatic or mild infection and transient immunity, or that the intake of dietary fibre may interfere with the attachment of oocysts to the intestinal mucosa.

A limitation of this study was a likely recall bias caused by the time span involving the incubation period of the disease, delays in seeking diagnosis and the subsequent testing of the sample before interviews could take place. Cases were interviewed within 6 weeks of onset of diarrhea or 31 days of the stool specimen date. Both cases and controls were interviewed regarding the same time periods (2 weeks prior to the onset of disease in the case patient) so a differential bias should have been avoided. With over 100 exposure questions being asked in this study, a significant level of 0.05 would suggest that at least five variables be statistically significant due to chance. However, the significant variables from the multivariate analysis have all been previously associated with cryptosporidiosis. This study may not be immediately generalisable to other populations, as half of the participants were from a single state, and majority were white.

Disinfection Byproducts

Drinking water contaminants, gene polymorphisms, and fetal growth.
Infante-Rivard, C. *Environmental Health Perspectives* (2004) **112**:1213-1216.

This paper describes the findings of a case-control study into the association between drinking water disinfection byproducts (DBPs) and fetal growth. DBPs are formed from the reaction of chemical disinfectants and organic matter. Trihalomethanes (THMs) are the prevalent class of DBPs in treated drinking water, and include chloroform, bromoform, bromodichloromethane (BDCM) and chloro-dibromomethane. Recent reviews of literature have suggested that DBPs are associated with fetal growth restriction. Most previous studies have been based on birth records, and other information on risk factors for fetal growth and exposure factors for DBPs is usually highly limited. Chloroform has been shown to inhibit vitamin B-12-dependent methionine biosynthesis. A previous study has shown that polymorphism in the *CYP2E1* gene (encoding an enzyme involved in chloroform metabolism) can modify the effect of DBPs, but no study has considered the role of genetic polymorphisms on the relationship between DBPs and fetal growth. The study also examined polymorphisms in the 5,10-methylene-tetrahydrofolate reductase enzyme (MTHFR).

Cases were newborns with birthweight below the 10^{th} percentile for age and sex, born in the largest maternity hospital in Montreal, Canada, between May 1998 and June 2000. Multiple births and babies with congenital abnormalities were excluded. Controls were born at the same hospital, had the same inclusion criteria as cases except they were above the 10^{th} percentile for birthweight. Four-hundred and fifty one (451) cases and 451 controls were matched by gestational week, sex and race. The mothers of all cases and controls were interviewed within 2 days of delivery, and collected information regarding demographics, pregnancy history, medical history, and smoking history. Cord and maternal blood was obtained for genotype analysis. Drinking water exposure information was also collected, including residential history, source of drinking water, use of water filters, average daily glasses of water consumed, and showering behaviour. Average measurements of THM concentrations in drinking water were supplied by the Ministry of Environment for the 189 distribution systems identified by participant interviews.

Case mothers had a lower body mass index (BMI) before pregnancy and gained less weight during pregnancy than control mothers, and were more likely to be older, to have smoked while pregnant, to be primiparous, to have preeclampsia and to have had a previous pregnancy with intrauterine growth restriction (IUGR). When adjusted for potential confounders, there were no increased risks associated with any specific or total THMs between cases or controls. However when the infants genotype was taken into account the risk of developing IUGR was significantly associated with exposure to total THMs in newborns carriers of *CYP2E1* variant alleles (OR=13.2; C.I.=1.2-146.7). No effect was seen with variants in the MTHFR gene.

Although exposure to THMs and DBPs in drinking water were not found to be associated with overall risks of IUGR, these findings suggest that there may be genetic susceptibilities to THMs in the occurrence of IUGR associated with the *CYP2E1* gene. The mechanisms behind the association have not been determined, as past studies have been epidemiologic. The investigator was able to control for a large number of important potential confounders, such as age, sex, race, maternal smoking, BMI and preeclampsia in this study.

Does ozonation of drinking water reduce the risk of bladder cancer?

Chevier D, Junod B and Cordier S. *Epidemiology* (2004) **15**(5):605-614.

The carcinogenic potential of disinfection byproducts (DBPs) such as trihalomethanes (THM) has been examined by many epidemiological studies. Evidence suggests that the use of ozone with chlorination decreases THM levels in drinking water. Ozone is a strong oxidant, and can form potentially harmful byproducts, such as bromate and formaldehyde. As France has been using ozonation as an alternative to or in conjunction with chlorination for decades, the authors set out to assess the carcinogenic risk of ozonation byproducts, in addition to and independently of chlorination by analysing existing data from an earlier case-control study of bladder cancer.

The case-control study was conducted between 1985-87 in 7 hospitals, involving 765 cases and 765 matched controls (86% male). Case-control matching was based on age, sex and residence. The authors excluded subjects under 30 years of age and over 80, and patients with more than 2 years between diagnosis and interview, including their matched controls, leaving a final population for this study of 620 cases and 620 controls. Participants had been interviewed with a standard questionnaire, to collect demographic information, smoking and occupational history, and fluid intake. Detailed questions were administered regarding the consumption of a variety of fluids from the age of 18 years, including changes to consumption.

From the residential history spanning 1948 and 1987, the authors characterised the source and treatment of drinking water supplies of 557 large towns included in the 928 municipalities featured in the histories. These characterised supplies were responsible for over half of the person-years reported by the participants. Private well supplies were not able to be characterised.

THM levels were estimated for the majority of person-years using the Delphi method to assign a level of risk of 38 water utilities considered representative of the treatment strategies in use during the study period. Key factors in estimating THM levels were ground /surface water, presence/absence of prechlorination, and presence/absence of chlorination after filtration. Residences were assigned a THM level for each given year based on the average THM levels estimated for each water utility serving their municipality. No assessment of ozonation byproducts was possible. For groundwater supplies the estimated THM levels ranged from 0 to 10 microgram/L, while for surface waters the range was 27.4 to 78.3 micrograms/L. Odds-ratios for bladder cancer were calculated by logistic-regression, adjusting for sex, age, hospital, socioeconomic status, coffee consumption, occupation and tap water consumption.

The risk of bladder cancer decreased significantly as duration of exposure to ozonated water increased.

There was a non-significant trend to increased risk of bladder cancer as average and cumulative exposure to THM increased. The risk of bladder cancer significantly decreased with duration of residence in areas with ozonated ground water (OR=0.91, 95% CI 0.84-0.99) and in areas with simultaneously chlorinated and ozonated surface water (OR=0.97, 95% CI 0.93-1.01), relative to areas with non-ozonated groundwater. The authors suggest that ozonation may have an independent protective effect against bladder cancer risk, and in conjunction with chlorination may negate the risks of bladder cancer from DBPs.

The authors cite that the major weakness of this study is the high percentage of exclusion from the original sample due to missing data. 619 subjects were excluded due to inadequate residential histories, and only people living in large towns and cities were included. There may have been an underestimation of the risk in the dose-response analysis due to the THM modelling not including the interaction between THM and ozone. Possible reasons for the protective effects found in this study include the reduction of THM concentration by the pre-ozonation of water, followed by filtration and then chlorination.

Comment The implication that ozonation per se reduces bladder cancer risk regardless of whether water is also being chlorinated would seem to suggest that factors other than chlorination DBPs are the cause of the risk (eg organic material that is broken down by ozonation).

Fluoride

Fluoride in the drinking water and the geographical variation of coronary heart disease in Finland.

Kaipio J, Nayha S and Valtonen V. *European Journal of Cardiovascular Prevention and Rehabilitation* (2004) **11**:56-62.

Fluoride in drinking water is protective against dental disease. Dental disease has been identified as a risk factor of coronary heart disease (CHD). CHD in Finland shows distinct geographical variation, with mortality in the north-east twice as high as in the south-west. The north-east region also has substantially lower fluoride in the drinking water than the south-west. This study examines whether the low intake of fluoride in the north-east may have contributed to poorer dental health and thus to the higher occurrence of CHD.

Mortality rates of CHD in small geographical areas during 1961- 1995 were examined in relation to drinking water measurements in the same areas in 1958. The degree of water hardness and mean income were also considered as potential confounders.

CHD mortality was markedly higher in the north-east than the south-west regions. Fluoride concentrations followed an inverse pattern, with lower concentrations in the north-east than the south-west. CHD mortality has declined since the 1970s in both the north-east and south-east regions. With negative binomial regression, the adjusted mortality from CHD was 2.57 times higher in males than females, and increased with age. The association of CHD with mean income was almost linear, with CHD declining with rising income.

Past studies into the association between fluoride in drinking water and cardiovascular diseases have given conflicting results. A case-control study in south-eastern Finland found risk-ratios of 3.0-4.4 for experiencing a myocardial infarction in patients whose drinking water had fluoride levels less than 0.1mg/l. A study in the USA found no difference in CHD mortality between cities with different levels of drinking water fluoride, but none of these samples had fluoride levels less than 0.1 mg/l. This study was based on national population data, and covered a relatively long period. Inability to assess other confounding factors in CHD mortality, such as smoking, means that a causal link between fluoride and CHD cannot be asserted, however the consistency of the association is promising. Therefore, this study has shown an ecological association between drinking water fluoride and CHD mortality in Finland.

Comment Fluoride may have an indirect effect on CHD risk by reducing the incidence of periodontal disease. Periodontal disease is associated with increased risks of CHD although the mechanism for this is unclear. In this study maximum reduction in CHD risk was seen for water fluoride concentrations in the range of 0.15 to 0.30 mg/L.

Nitrate

Dietary nitrites and nitrates, nitrosatable drugs, and neural tube defects.
Brender JD, Olive JM, Felkner M et al. Epidemiology (2004) **15**: 330-336.

Recent studies have suggested that use of certain over the counter or prescription medications during pregnancy may increase the risk of birth defects. These drugs include some antihistamines, antibiotics, and components of cold remedies. The hypothesised mode of action is via the formation of N-nitroso compounds by reaction of amine or amide functional groups on the drug molecule with nitrite in the body. The drugs capable of being transformed in this way have been termed "nitrosatable" drugs.

This case-control study assessed the relationship between intake of nitrosatable drugs, dietary nitrite and nitrate, and the risk of neural tube defects (NTDs) among the pregnancies of Mexican-American women in 14 counties of Texas near the Mexican border. Eligible women were defined as Mexican-Americans who delivered a live or stillborn infant with an NTD, or who had a spontaneous or induced abortion due to an NTD between June 1995 and May 2000. Controls were Mexican-American women who were resident in the same area and who had delivered normal live births during the same period.

Cases and controls were interviewed within 6 weeks of the delivery event. Information was collected on maternal health and reproductive history, medical history, use of medications and nutritional supplements and other potential risk factors. Dietary intake of nitrite and nitrate were estimated from a food frequency questionnaire, and information was collected on drinking water sources. Where possible, samples of drinking water were collected an analysed for nitrate. Exposure assessment focused on the period from 3 months before to 3 months after the estimated conception date as neural tube defects occur in the first trimester of pregnancy.

Interviews were completed by 184 of 225 identified cases (82%) and 225 of 378 (60%) of controls. Cases included 83 with anencephaly, 84 with spina bifida, and 17 with encephalocele. Case women tended to have lower income and education levels than control women, were more likely to be overweight or obese, and were more likely to report having a fever during the peri-conceptual period. Taking nitrosatable drugs during the periconceptual period was associated with a statistically significant increase in the risk of an NTD (OR=2.5, 95% CI 1.3-4.8). Adjustment for income level, body weight and folate intake produced a slight increase in estimated risk (OR=2.7, 95% CI 1.4-5.3). Adjustment for reported fever slightly reduced the risk estimate for nitrosatable drug exposure (OR= 2.4 95% CI=1.3-4.5).

Stratification of cases and controls by dietary nitrite and total nitrite intake showed increased risks of NTDs were associated with higher nitrite intake for those women who also used nitrosatable drugs. For those with a dietary intake of total nitrite in the highest tertile (more than 10.53 mg/day) who used nitrosatable drugs the OR was 6.1 (95% CI 1.4-39), compared to women with the same nitrite intake who did not use nitrosatable drugs (OR defined as 1.0).

Drinking water nitrate concentrations ranged from 0 to 28 mg/L with a median of 5.4 mg/L for cases and 3.5 mg/L for controls. Stratification by nitrate levels in drinking water (regardless of dietary nitrate or nitrite intake) showed an increased risk for NTDs for drinking water concentrations above 3.52 mg/L (OR=11, 95% CI 1.3-500) for women who used nitrosatable drugs. Only 43 case women (23%) and 67 controls (30%) provided drinking water samples for analysis, therefore the analysis of risks relative to drinking water nitrate was based on small numbers. This is reflected in the wide confidence interval for the OR estimate. The authors conclude that their results support the role of nitrosatable drugs in early pregnancy as risk factors for NTDs, and that levels of dietary nitrite and nitrate should also be assessed in studies of such drugs and pregnancy outcomes.

Comment Information of the volume of water consumed by the women participating in the study was not collected, so the classification of water nitrate exposure was based only on the nitrate concentration in water. The authors comment that the apparently strong influence of nitrate in drinking water is difficult to explain given that only 5% of ingested nitrate is believed to be converted to available nitrite in the body. The contribution of nitrite and nitrate from food to total nitrite exposure would have been greater than drinking water.

Drinking-water nitrate, methemoglobinemia, and Global Burden of Disease: A discussion.
Fewtrell L Envir Health Perspectives (2004) **112**: 1371-1374.

As part of the World Health Organisation Global Burden of Disease project the author has carried out literature reviews to derive an estimate of the impact of nitrate in drinking water on human health. This paper deals with the findings on methemoglobinemia, or blue baby syndrome. This condition occurs when nitrite in the bloodstream oxidises the ferrous ion in hemoglobin to the ferric form, thus changing the properties of the molecule so that it is unable to bind oxygen. If the percentage of abnormal hemoglobin (methemoglobin) rises above 10% clinical signs begin to appear, including blue or gray tinged skin colour, irritability, and lethargy. If levels of methemoglobin rise above 45% the infant may suffer coma, heart arrythmia, convulsions and eventually death.

Early investigations of links between nitrate levels in drinking water (commonly well water) noted the relationship of nitrate content with poor sanitary conditions, and discussed the possible role of enteric infections as a cofactor for disease. By excluding cases where water nitrate levels were low, some studies created a self-fulfilling case definition of water-related disease. However over time, this aspect of the evidence was neglected and a simple cause and effect relationship for nitrate in drinking water came to be accepted by regulatory authorities. This review notes that there are very few reliable data on either nitrate exposure levels in populations or the incidence of methemoglobinemia in infants. Moreover, a number of scientific publications since 1980 have shown links between gastrointestinal illness and methemoglobinemia in the absence of excess exogenous nitrate exposure. Although ingested nitrate may play some role in the condition, the author concludes that it is not appropriate to estimate a global disease burden given the uncertainty of the the evidence and the lack of exposure and incidence data.

Comment See Health Stream Issue 25 for a review of the book Nitrate and Man by L'hirondel and L'hirondel, which addresses the evidence on nitrate and adverse health effects.

Outbreaks

Waterborne outbreak of gastroenteritis in a religious summer camp in Norway, 2002.
Nygard K, Vold L, Halvorsen E, Bringeland E, Rottingen JA and Aavitsland P. *Epidemiol. Infect.* (2004) **132**:223-229.

In July 2002, an outbreak of acute gastroenteritis occurred in a camp facility in Norway during a 10 day seminar. Between 250-300 people stayed overnight at the camp during this time, and there were many day attendees. On day five of the seminar, the local health authorities were notified that four attendees had experienced gastroenteritis (vomiting, diarrhoea, abdominal cramps) which had lasted for about one day. The camp consisted of a main building, a chapel and five residential cottages. Some visitors used the camp facilities but slept in private boats. Most meals were taken in the main building which was equipped with a large kitchen. Drinking water was supplied from a drilled well, and was not treated. An investigation was undertaken to determine the source and mode of the outbreak.

Questionnaires were mailed to all families entered in the booking list of the camp. Daytime visitors were not registered. Fifty-four families were included, and were asked about symptoms, food and water exposures, hygienic routines, and place and duration of stay at the camp. A case was defined as a person who visited the centre during the 10-day period and developed vomiting or diarrhoea within 3 days of the visit. Eleven stool samples were obtained from cases, including staff members and visitors, which were analysed for bacterial enteric pathogens and viral species. Drinking water samples were collected and tested for microbial contamination. A hygiene inspection was undertaken of the food preparation areas and food-handlers.

Of the families contacted, 134 of 205 respondents met the case definition (attack rate 65%). The majority of cases became ill in the last few days of the seminar period. There were no significant differences between attack rates by gender or age. The mean duration of illness was 2 days (range 1-14 days), with 3 cases requiring hospitalisation for their

illness. Several respondents had contact with a person with gastroenteritis immediately prior to attending the seminar, and 64 respondents reported knowing of a person who did not attend, but developed gastroenteritis after having contact with someone returning from the camp.

Under univariate analysis, drinking water, taking showers, eating shellfish, strawberries and unpeeled fruits were significantly associated with illness. Bringing one's own drinking water to the camp was protective (RR=0.7; C.I.=0.6-0.9). A dose-response relationship was found between the consumption of drinking water and the risk of illness. Under multivariate analysis, only drinking the water (RR=1.8; C.I.=1.1-2.8) and using the showers (RR=1.5; C.I.=1.2-1.9) remained significant. By calculating the population attributable fraction (PAF), the investigators concluded that 41% of the cases were due to drinking water, and 23% to using the showers. When analysis was restricted to index cases in each family (ie the first person to develop symptoms), the association between drinking water and using showers became stronger, giving a PAF of 69% and 28% respectively.

Of the 11 faecal samples, norovirus was found in 8, *Campylobacter spp* in 2, rotavirus in 2 and adenovirus in 1. The water samples were negative for norovirus, but showed coliforms, thermostable coliforms and faecal streptococci in a variety of locations.

The septic tank was located 50 metres from the well, and had been subject to past leaks and breaks. Water pipes and sewer pipes were laid in the same trench. Effluent was discharged through a pipeline to the sea, however some blockage of the sewage was suspected. No maintenance of the water supply or sewage system had occurred since the facility was built in the 1970s.

Investigators issued hygiene warnings to attendees via the telephone, and issued a boil water advisory. Recommendations were also made to thoroughly disinfect all bathroom and toilet facilities at least twice a day. A disinfection system was fitted to the drinking water supply while plans were made to shift the supply further away from the camp.

This outbreak was caused by faecally contaminated drinking water, which was further amplified by person-person transmission. Norovirus was the likely causative organism, as although it was not found in the drinking water samples, the presence of faecal contamination in the supply, the detection or the virus in most of the stools tested and the epidemiology of transmission suggests a norovirus aetiology. The standard recommendations during waterborne outbreaks include boil water advisories and hygiene precautions, however this study showed that showering was a significant risk factor, and thus the standard precautions may not be sufficient. This was a small outbreak with low morbidity, but the authors estimated it had direct costs of 15,000 Euros in terms of time lost from work and medical consultations.

Comment *Norovirus is believed to have a low infectious dose (less than 100 virus particles), therefore ingestion of a small amount of water while showering may be sufficient to cause infection. There has also been a report of airborne transmission where people sitting in a restaurant "downwind" of a Norovirus-infected person who vomited, had an increased rate of infection compared to those sitting "upwind" relative to the ventilation system.*

Recycled Water

Groundwater recharge with reclaimed municipal wastewater: health and regulatory considerations. Asano T, Cotruvo J A. *Water Research* (2004) **38**:1941-1951.

The artificial recharge of groundwater basins is growing in importance due to the increasing scarcity of high quality water and increasing demand on limited water resources. Artificial groundwater recharge has been primarily employed for three purposes: to maintain or increase groundwater levels; protect underground freshwater in coastal aquifers against seawater intrusion; and to store surplus surface water, such as stormwater, for future use. Recharging groundwater with municipal wastewater brings obvious health risk considerations.

The two main types of groundwater recharge used with municipal waste water are surface spreading (percolation) and direct aquifer injection. With surface spreading, municipal wastewaters percolate from spreading basin through unsaturated soil. This method offers additional treatment to the percolating water through the soil. Direct aquifer injection involves the pumping of highly treated reclaimed water into a well-confined aquifer.

The authors identify four primary water quality factors for groundwater recharge with reclaimed water: microbiological; total dissolved solids; heavy metals; and organic substances. The degree of necessary pre-treatment is dependent on the proposed use of groundwater, the source of the reclaimed wastewater, method of recharge, and the degree of public acceptance. For the direct injection of reclaimed wastewater to an aquifer used for domestic water supplies, extensive treatment including microfiltration, reverse osmosis and ultraviolet disinfection may be necessary.

A source control program should be implemented to limit the input of potentially harmful substances and organisms entering groundwater through artificial recharge with reclaimed wastewater. Once contaminated, it is very difficult to rehabilitate groundwater aquifers. In the United States, in the absence of federal policy in this field, each recharge project is overseen on a case-by-case basis by state agencies.

The major health concerns regarding aquifer recharge are the same for those involving drinking water drawn from polluted or potentially contaminated surface sources. In particular, infectious pathogens are considered the primary risk from wastewater recharge of aquifers, as they may be present even when the water meets microbiological standards for drinking water. Risk assessment for groundwater aquifer recharge is very similar to those undertaken for surface water sources – characterising hazards in the water and determining potential human exposures.

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.

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Both newsletters are available free of charge to the water industry, public health professionals and others with an interest in water quality issues. Electronic versions of the newsletters and a searchable archive of Health Stream articles are available on the Web page of the CRC.

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