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Bangladesh Arsenic Case To Proceed

A judgement by the British High Court has cleared the way for a test case to proceed against the Natural Environment Research Council (NERC) over alleged negligence in failing to test Bangladesh groundwater supplies for arsenic during a 1992 survey. The survey was carried out by the British Geological Survey (BGS), a unit of NERC. It was funded by the UK Overseas Development Administration as part of a project to increase Bangladesh's agricultural production through extension of irrigation schemes.

The High Court action began in August last year when lawyers lodged a sample case on behalf of a Bangladesh resident who was alleged to have suffered arsenical poisoning from drinking contaminated groundwater. The action claimed that the BGS had a duty to test for arsenic during their survey, and the report summarising the findings gave the impression that there was no arsenic in the water and that it was safe to drink. As a consequence, no action was taken by Bangladeshi authorities to prevent consumption of the water until the late 1990s when the problem came to international prominence.

The claimant, a 43 year-old man, has been diagnosed with arsenic-related ulcers on his hands and feet which restrict his ability to work, and he may be at risk of developing cancers in the future as a result of arsenic exposure. It is alleged that if he had consumed arsenic-contaminated water for a shorter period of time, he may not have suffered the illness or may have had less severe illness. A second sample case on behalf of another Bangladesh resident was lodged in February 2003, and the firm of lawyers handling these cases are believed to also represent several hundred other people from Bangladesh.

In response to the action, NERC made an application to the High Court in October 2002 to strike out the claim; in effect asking the court to rule that there were no reasonable grounds for bringing the claim. Alternatively, NERC asked for a summary judgement to be made rather than allowing the case to proceed to trial, on the basis that the claimant had no real prospects of succeeding in the claim. A press release from NERC cited several grounds for its application:

- that it had no duty to test for arsenic as the purpose of the 1992 BGS survey was to identify water supplies suitable for irrigation not for potable use,
- that it was clear from the BGS report that arsenic had not been tested, and the report did not suggest that arsenic was absent from the water or that it was safe to drink,
- that the relationship between the claimants and BGS was too remote for any duty of care to arise between them, and
- even if a duty of care had existed, given the state of knowledge about alluvial deltaic groundwaters in 1992, no reasonably experienced researcher would have tested for arsenic without some special reason to do so.

After hearing arguments from both sides and considering legal precedents, Mr Justice Simon dismissed the NERC application on 8 May, clearing the way for the claimants case to proceed to trial. The claimants lawyers are expected to present evidence that arsenic poisoning cases from consumption of contaminated groundwater had been recognised in neighbouring West Bengal, India as early as 1983, and the presence of arsenic in shallow groundwaters in Bangladesh had been identified in 1988.

The WHO estimates that between 35 and 77 million people in Bangladesh are exposed to high levels of arsenic in drinking water (above the 1984 WHO guideline value of 0.05mg/litre or 50 parts per billion) (1). There are up to 12 million shallow tubewells in Bangladesh and about 27% are believed to be contaminated with arsenic, many with levels several-fold higher than the 1984 guideline value.

1) The WHO guideline value for arsenic was revised to 0.01mg/litre in 1993.

Milwaukee - 10 Years Later

The 10th anniversary of the 1993 Milwaukee cryptosporidiosis outbreak has been marked by a number of newspaper articles reviewing the event, and publication of two scientific papers on the economic impact and the vulnerability of the elderly population. The outbreak occurred in April 1993 and was estimated to have caused about 403,000 people to become ill with gastroenteritis among a population of 1.6 million in the greater Milwaukee area (1). About 4,400 people were hospitalised and about 100 people died as a result of the outbreak.

The Milwaukee outbreak is the largest ever recorded in the developed world, and was attributed to failure of filtration processes at one of the two water treatment plants serving the city. A number of deficiencies were found at the plant, including problems relating to a change in the type of water treatment chemicals used for coagulation of contaminants prior to the filtration step. Weather conditions at the time were unusual with a heavy spring snowmelt leading to high source water turbidity, and wind patterns that may have changed normal flow patterns in Lake Michigan, the raw water source for the city.

The Milwaukee outbreak and several smaller outbreaks attributed to *Cryptosporidium* or *Giardia* brought hazards from protozoal pathogens into prominence for drinking water supplies and led to major changes in water quality regulations in the US and other countries. Legal action over the outbreak extended over several years, however the eventual settlements were relatively small, with the City of Milwaukee paying out \$100,000 and General Chemical Corporation \$1.5 million for a class action lawsuit involving about 540 people. The largest individual settlements, associated with deaths attributed to the outbreak, amounted to only \$13,500 per claimant after lawyer's fees were deducted. Improvements to water treatment plants, including enhancement of filtration, installation of ozone treatment, better process monitoring and extension of the water intake pipe by 4,200 feet into Lake Michigan are estimated to have cost \$90 million.

The direct medical costs and productivity losses from diarrhoeal illness were assessed in a recent paper that estimated the total cost of illness and the average cost per person during the outbreak (2). Illness was categorised as being mild, moderate or severe according to the type of medical care required during the outbreak and in the following 2 months (mild = no medical care sought, moderate = visit to doctor or emergency department but not hospitalised, severe = hospitalised). The number of people in each category was derived from the results a telephone survey carried out one month after the outbreak (88% mild, 11% moderate, 1% severe) (1).

Medical costs were assessed by examining inpatient and emergency department healthcare costs, outpatient healthcare costs, ambulance transport costs, self-medication and prescribed medication costs. Productivity losses were also estimated and included time lost by infected people because of illness and time lost by those who cared for an ill person. Costs were converted to 1993 US\$ values.

The average costs of illness for persons with mild, moderate and severe illness were \$116, \$475, \$7,808 respectively. The average cost of illness for all people who had diarrhoeal illness, weighted by the proportion in each illness category, was \$239 per person: \$79 in medical costs and \$160 in productivity losses. Sixty-six percent of people hospitalised had pre-existing conditions affecting the immune system. Hospitalisation costs for people with AIDS were five times higher than for people hospitalised without any pre-existing condition. The total cost of illness associated with the Milwaukee outbreak was estimated at \$96,244,000, comprising \$31,655,000 in direct medical costs (33%) and \$64,589,000 in productivity losses (67%).

This analysis shows the substantial cost of this waterborne disease outbreak in terms of medical and productivity costs, and the authors note that where actual data were not available the assumptions used in their estimate were conservative. The estimate did not include non-medical costs, costs to businesses affected by the outbreak, or the costs of the public health investigation and outbreak control efforts.

The second paper published on the 10th anniversary of the outbreak examined the association between gastroenteritis-related emergency room visits and hospitalisations in the elderly and drinking water turbidity before and during the outbreak (3). A positive association was found between age and emergency room visits and hospitalisation due to acute gastroenteritis in the elderly. When compared to the pre-outbreak period, this association was significant by age category before the outbreak ($p=0.001$) and also during the outbreak ($p=0.002$). The increases seen here suggest age-related susceptibility to gastrointestinal infections within the elderly group (65 years and over).

There was a statistically significant association between high drinking water turbidity (above 0.5 NTU) and increased rate of acute gastroenteritis in the elderly at time lags of 5, 6, 7 and 13 days during the outbreak but not in the pre-outbreak period. When compared to all adults, a shorter median incubation period for cryptosporidiosis was seen in the elderly. A second peak in gastrointestinal illness occurred at 13 days postexposure and may reflect secondary person-to-person transmission of cryptosporidiosis from the primary cases to the elderly. These findings suggest the elderly may have a relatively higher risk of secondary transmission.

1) MacKenzie, W.R. *et al.* A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply., *N Engl J Med*, **331** (1994) 161-7.

The estimate of the size of the outbreak by the original investigators has been challenged (see paper by Hunter and Syed reviewed in Health Stream Issue 23) although a study of antibodies in children suggested widespread exposure had occurred (see paper by McDonald *et al.* reviewed in Health Stream Issue 22).

2) Naumova E N, *et al.* *Emerg Infect Dis* (2003) **9**(4): 418-425. The elderly and waterborne *Cryptosporidium* infection: Gastroenteritis hospitalizations before and during the 1993 Milwaukee outbreak.

3) Corso P S, *et al.* Cost of illness in the 1993 waterborne *Cryptosporidium* outbreak, Milwaukee, Wisconsin. *Emerg Infect Dis* (2003) **9**(4):426-31.

Charges Over Walkerton Outbreak

Ontario Provincial Police have laid charges against the two operators of the Walkerton water supply system almost three years after the waterborne *E.coli* O157 outbreak that affected over 2,300 people and resulted in seven deaths (1). The former manager of the system faces four counts of public endangerment, one of knowingly making a false document, one of knowingly using a false document, and one of breach of trust. The foreman, who is the younger brother of the manager, faces two counts of public endangerment, one of knowingly making a false document, one of knowingly using a false document, and one of breach of trust. The charges carry maximum jail terms of two to ten years.

Reactions from Walkerton residents have been mixed, with some expressing disappointment that criminal charges of manslaughter had not been laid, while others felt that the operators had been made the scapegoats for the tragedy when the blame should have been shared by others. The judicial inquiry found that the operators had run the system in an incompetent manner, often falsifying test results, and the manager had lied to health officials when the outbreak occurred, however lack of adequate oversight by the provincial government had contributed to the tragedy by allowing the hazardous situation to continue unchecked for many years.

The police investigation that culminated in the charges being laid was conducted independently of the Walkerton Inquiry, as legal rules prevent prosecutors from using self-incriminating testimony given by witnesses at judicial inquiries. Police reportedly executed 44 search warrants and conducted 3,000 interviews to compile a one-million page brief for the Crown Prosecutors Office. The court case commenced on 10 June when the two brothers appeared in a Walkerton courtroom to hear the charges against them read. No pleas were entered, and the case was put over until September to allow the defendants lawyers time to examine the evidence brought by the prosecution and prepare their defence.

In the aftermath of the Walkerton outbreak, the Ontario government undertook to implement the

recommendations made by the judicial inquiry to improve the safety of drinking water supplies. To date, 76 of the 121 recommendations have been implemented. Among the most controversial have been attempts to regulate farming operations to protect surface and groundwater sources from pathogens in animal waste. Intensive farming operations are increasing in number in Ontario and the large amounts of animal manure produced by such operations are disposed of by spreading as fertiliser, generally without any treatment to reduce pathogen loads.

The Nutrient Management Act, passed late last year, gave the provincial government powers to override local municipality regulations regarding spreading of animal manure on agricultural land, however critics have charged that the government has weakened the proposed regulations in the face of strong opposition from farming lobby groups. When the first stage of the regulations take effect in July this year, only 1,000 of the largest farms out of an estimated 30,000 livestock operations in Ontario will be covered. Piggeries with less than 3,600 market hogs and beef cattle operations with fewer than 300 animals will be exempted, and there are no requirements for fencing of streams to prevent direct access by animals. No timetable has yet been set to extend subsequent stages of the regulations to smaller farms, or introduce promised legislation to strengthen watershed management.

The provincial government has also taken the first steps towards establishing a centre for water quality research and training in Walkerton. The Ontario Premier Ernie Eves visited the town on 19 June and announced the appointment of a Board of Directors for the Clean Water Legacy Trust. The Trust will administer the Clean Water Centre of Excellence in Walkerton. The government has provided \$50 million in initial funding for the trust. The role of the Centre will be to promote research and public education, and coordinate training programs for water system operators in Ontario.

1) Details of the Walkerton outbreak and subsequent judicial inquiry were reported in Health Stream Issues 18 - 21 and 25, 26.

Setback For Netherlands Dual Supplies

Dual water supply schemes in the Netherlands have suffered a setback following an outbreak of gastrointestinal illness attributed to an accidental cross-connection between the drinking water supply and a lower quality "grey water" supply. The incident has resulted in a reappraisal of risk assessments carried out prior to approval of dual reticulation schemes of this nature, with regulators concluding that risks for some enteric viruses had been underestimated in their initial calculations.

In the Netherlands the term "grey water" refers to surface waters which are partially treated but not to a potable standard. In Australia and some other countries this term is used to refer to effluent water from the laundry and bathroom of residences (excluding the toilet effluent). The water supply in this incident was drawn from the Rhine river and subjected to coagulation, flocculation, sedimentation and rapid sand filtration before distribution to households as grey water.

The outbreak took place in a new housing development that had dual water supply systems, with grey water being supplied for garden watering, toilet flushing and laundry use. No problems were detected for over a year after the estate was occupied, however in early December 2001 a number of householder complaints of disagreeable taste and odour of the potable water supply were received by the water supply company.

Investigations showed unusually high counts of total coliform bacteria in the potable water supply, with *E.coli* and *Enterococci* also detected, and an accidental cross-connection between the potable and grey water networks was discovered. The grey water system normally operated at a lower pressure than the potable supply as a safety measure to prevent potential cross-connections, however at the time of the incident it was operating at elevated pressure. This permitted grey water to enter the potable water reticulation system. The cross-connection had been in place for about one week before it was discovered. A boil water notice was issued and health authorities began an investigation to determine whether illness

had arisen in the community as a result of ingestion of potable water contaminated with grey water.

It was concluded that an outbreak of gastroenteritis affecting about 200 people had occurred as a result of the contamination incident. Testing of clinical specimens did not clearly identify the responsible pathogen(s), perhaps due to the time delay before faecal specimens were collected and the relatively small number of samples obtained. However, testing of the grey water revealed a high concentration of Norovirus particles. The viability of the virus was uncertain as there is no cell culture or animal model available to test the infectivity of Norovirus.

The Norovirus group (formerly called Norwalk-like viruses) are common causes of gastroenteritis around the world, and are probably the single most frequently occurring enteric pathogen in developed countries. The archetypal virus of this group was named after the town of Norwalk, Ohio, USA where an outbreak occurred in 1968. Noroviruses typically cause gastroenteritis of short duration (12 to 48 hours) with vomiting as the predominant symptom. Recovery is normally rapid and severe complications are very rare. The virus is present in large numbers in the faeces and vomitus of infected people, and the infectious dose is believed to be low. Viral particles may remain infectious for several months in the environment depending on the conditions (1).

As a result of this incident and examination of data on occurrence of Noroviruses and other viruses in contaminated source waters, Dutch regulators have decided that more treatment steps will be required in addition to the current water treatment train for grey water in order to adequately protect public health. This requirement will impact on the economic viability of grey water schemes, and it is expected water suppliers in the Netherlands will decide to abandon many planned schemes of this nature and terminate some existing operations.

1) See paper by Kukkula *et al.* in Health Stream Issue 17 *From the Literature* where a waterborne outbreak of Norovirus was attributed to sewage contamination travelling slowly downriver from an outbreak 4 months earlier in a town 70 km upstream.

EU Bathing Water Reforms Stalled

Proposed changes to the EU Bathing Water Directive have failed to win support at a meeting of European Union Environment Ministers held in Brussels during March this year. The current Directive was issued in 1976 and is considered to be outdated in several respects due to the progress of scientific and technical knowledge. The proposed changes to the Directive were largely based on the draft World Health Organisation Guidelines for Safe Recreational-water Environments released in 2001, which incorporated a risk management approach for bathing waters in addition to measurement of microbial water quality indicators.

The changes to the EU Directive would have reduced the number of parameters to be monitored from 17 to only two (*E.coli* and *Enterococci*) and changed the period over which compliance was assessed from one year to three years, thus reducing the impact of isolated pollution incidents and extreme weather events. The proposed mandatory standard for "good" bathing water was set at 200 intestinal *Enterococci* per 100ml at the 95th percentile and 500 *E.coli* per 100ml at the 95th percentile. More highly polluted waters would be classified as "poor", and a voluntary "excellent" rating would also be defined. Sites which had a poor rating for three consecutive years would be considered non-compliant and would have to be removed from the designated list of bathing waters. Sites with "good" ratings for three consecutive years would be able to reduce their monitoring frequency.

The new Directive would also have required an assessment of the likely sources of pollution at each site, preparation of site-specific risk management plans, and issuing of warnings to the public when deterioration of water quality was expected due to poor weather conditions. Waters used for recreational activities other than bathing (eg surfing, windsurfing and water skiing) were specifically excluded.

While the general principles of the reforms had been previously endorsed by member states, the EU Environment Council meeting expressed concerns that the new level for mandatory microbiological compliance was more strict than the current

mandatory level, and would result in downgrading of the classification of many beaches. In the UK it was estimated that 15% of beaches meeting the current mandatory standard would be downgraded, while for Belgium the figure was 30%. Doubts were also expressed over the robustness of the epidemiological evidence on which the microbial classifications were based, and the magnitude of health benefits that might be achieved by the changes. Even if the predicted reduction in the incidence of gastrointestinal disease associated with bathing was achieved, the costs of implementation were likely to be several-fold greater than the benefits. In addition, there was criticism that the EU proposal failed to reflect the emphasis on human faecal pollution that was central to the WHO Guidelines, and lacked the promised flexibility of management options.

The draft WHO Guidelines classify water quality on a 5-category scale based on measurement of *Enterococci* (indicating faecal pollution from human and animal sources) and the degree of human faecal influence assessed from a sanitary survey (providing a differential weighting of risk that recognises the higher human infectivity of pathogens from human sources). Under the WHO scheme, beaches that experience periodic but predictable deteriorations in water quality (eg from stormwater drains that flow only after heavy rainfall) may manage the risk by warning the public and temporarily closing the beach. Provided the effectiveness of such measures in reducing public exposure can be demonstrated, the beach may retain a higher quality classification. The Guidelines do not set a pass/fail level suitable for bathing but advise that individual jurisdictions should consider bathing water quality in context with other public health priorities and resource availability.

Several EU states have suggested a number of revisions to the proposed Directive including the matching of microbiological cutoff levels to existing standards, expanding the number of ranking levels in a similar manner to the WHO Guidelines, providing the option of management by temporary beach closures, conducting further epidemiological studies to confirm health risk levels, and abolishing the current pass/fail concept for bathing waters in favour of a system of graded classifications.

News Items

Safe Drinking Water Act For Victoria

Victoria has become the first Australian state to introduce uniform mandatory requirements for potable water supplies. The Safe Drinking Water Act 2003 was enacted on 11 June. The Act requires:

- preparation and implementation of risk management plans by water suppliers and water storage managers
- auditing of such plans by approved auditors
- compliance with standards for a specified range of parameters
- disclosure of water quality information to the public
- reporting of known or suspected contamination to health authorities

Under the provisions of the Act water suppliers have the ability to vary aesthetic standards subject to community consultation. The Act will replace a number of different regulatory arrangements currently used in the state, and will come into force on 1 July 2004. Prior to that date, the regulations relating to the Act will be prepared and the new regulatory office will be established. A levy will be applied to water suppliers and water storage managers to cover the costs of administration. The Act is available from:

www.dms.dpc.voc.gov.au/sb/2003_Act/A01263.html

Arsenic Affects DNA Repair

Researchers from Dartmouth Medical School in New Hampshire USA have reported preliminary evidence that expression of DNA repair genes was reduced in blood samples from people with high arsenic exposure from drinking water, compared to people with low arsenic exposure. The researchers measured DNA repair enzymes in 16 people enrolled in a bladder cancer case-control study (6 cases and 10 controls) and estimated arsenic exposure from drinking water concentrations, toenail arsenic levels (a measure of long-term exposure) and calculated daily arsenic intake from water. Significantly reduced expression of 3 out of 6 DNA repair genes was found in the 5 people with toenail arsenic levels greater than or equal to 0.2 micrograms/gram, compared to 11 people with lower toenail arsenic levels. Expression of the genes was not related to bladder cancer status.

These findings support previous research pointing to inhibition of DNA repair mechanisms by arsenic as a possible mechanism for increasing cancer risks. In this small study arsenic levels in drinking water ranged up to 75 micrograms/L (75ppb). The researchers plan to repeat the study in a larger group of people and investigate the relationship with cancer status and smoking.

Andrew AS *et al.* *Int J Cancer* **104**, 263-268 (2003).

Study Supports 8 Glasses A Day

A number of articles have been published recently on the evidence (or lack of it) to support the conventional advice to drink 8 glasses of water a day to maintain health. A study of 10 college students, reported at the April meeting of the Society for Experimental Biology in San Diego, has supported this recommendation. Dr Wayne Askew of the University of Utah conducted a 12 week experiment where the students drank 4, 8 or 12 glasses of water per day for 4 days then had their state of hydration and well being assessed. When drinking only 4 glasses per day students had plasma volumes 5% below normal, while drinking 8 glasses they had normal plasma volume, and when drinking 12 glasses they had plasma volumes 10% above normal. When drinking 4 glasses per day students reported feeling less energetic and less focused than when drinking 8 or 10 glasses per day.

Water Terrorism Website

The WaterHealthConnection website has introduced a new section on water terrorism to provide information to healthcare providers, public health practitioners, and water utility professionals.

www.WaterHealthConnection.org

Canadian Water Guidelines For Viruses

The Canadian Federal- Provincial- Territorial Committee on Drinking Water has issued a document on *Virological Quality of Drinking Water* for public comment. The document reviews the characteristics of the major groups of human enteric viruses, their health effects, analytical methods, and water treatment technology. Methods of risk assessment for viruses are also discussed, and risk management based on treatment capability and operational monitoring is proposed as the most suitable approach.

The document is open for comment until 17 November 2003.

www.hc-sc.gc.ca/hecs-sesc/water/consult_intro.htm

Assessing The Outcomes Of Water Aid

The id21 Urban Poverty website has reported on a study to assess the impacts of water and sanitation projects in several developing countries. The assessment found that the projects had:

- reduced disease and mortality rates
- allowed people to devote more time to income generation, social obligations and school
- improved rates of school attendance and academic performance
- reduced differences in gender roles in some communities

The assessment found that communities were capable of developing their own management systems for sustainable operation of water and sanitation schemes, and that imposed systems were sometimes counterproductive.

www.id21.org/urban/s3bds1g1.html

SARS Sewage Theory

It has been speculated that spread of aerosols from contaminated sewage may have played a role in a SARS (severe acute respiratory syndrome) outbreak in a Hong Kong apartment complex. Investigations have raised the possibility that the virus has been transmitted from sewage, as the faulty design of U traps in floor drains, baths and showers may have allowed droplets of liquid from the sewage system to be drawn into bathrooms by negative pressure when extractor fans were used.

Preliminary tests have shown the virus may remain viable and infective for up to 4 days faeces at room temperature. However its susceptibility to disinfectants, solvents and heat inactivation appears to be similar to known human respiratory viruses. At this stage there is insufficient knowledge of human infective doses to determine whether the SARS virus may pose a risk for sewage treatment workers if it becomes established in populations. There does not appear to be any evidence to suggest a significant risk exists for treated drinking water supplies.

Circulation Report – Issue 30 June 2003

Circulation for the print version of this issue is 3286 copies, with readers in 59 countries. A further 372 readers are registered for email notification of new issues.



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| Australia | 2664 | Germany | 32 | Luxembourg | 1 | Russia | 2 |
| Algeria | 1 | Greece | 5 | Malaysia | 23 | Singapore | 6 |
| Argentina | 1 | Hong Kong | 24 | Mexico | 1 | Slovenia | 2 |
| Austria | 3 | Hungary | 1 | Morocco | 4 | South Africa | 10 |
| Belgium | 3 | India | 20 | Myanmar | 1 | Sri Lanka | 3 |
| Brazil | 2 | Indonesia | 3 | Nepal | 1 | Sweden | 3 |
| Cambodia | 1 | Iran | 1 | Netherlands | 13 | Switzerland | 4 |
| Canada | 42 | Israel | 10 | New Zealand | 22 | Thailand | 10 |
| Chile | 8 | Italy | 3 | Nigeria | 1 | Togo | 1 |
| Chinese Taipei | 18 | Ivory Coast | 1 | Norway | 3 | UAE | 1 |
| Cyprus | 1 | Japan | 67 | Pakistan | 1 | UK | 61 |
| Denmark | 1 | Jordan | 2 | Palestine | 3 | USA | 102 |
| Egypt | 2 | Korea | 1 | Papua New Guinea | 5 | Vietnam | 2 |
| Finland | 2 | Lebanon | 1 | Philippines | 7 | Yugoslavia | 1 |
| France | 25 | Lesotho | 1 | P.R. China | 1 | | |

From the Literature

New Feature ~ Web-bonus articles

Due to space constraints we can only include a limited number of articles in the print version of Health Stream. From this issue onwards, summaries of additional articles will be made available in the web page version of Health Stream and included in the searchable archive at:

www.waterquality.crc.org.au/pubs

A fatal waterborne disease epidemic in Walkerton, Ontario: comparison with other waterborne outbreaks in the developed world.

Hrudey S E, Payment P, Huck P M, Gillham R W, Hrudey E J. *Wat Sci Technol* (2003) **47**(3):7-14.

Groundwater arsenic contamination, its health impact and mitigation program in Nepal.

Shrestha R R, Shrestha M P, Upadhyay N P, et al. *J Environ Sci Health Part A-Toxic/Hazardous Substances & Environmental Engineering* (2003) **38**(1):185-200.

Effect of particles on the recovery of *Cryptosporidium* oocysts from source water samples of various turbidities.

Feng Y Y, Ong S L, Hu J Y, et al. *Appl Environ Microbiol* (2003) **69**(4):1898-1903.

How particles affect UV light in the UV disinfection of unfiltered drinking water.

Christensen J, Linden K G. *J AWWA* (2003) **95**(4):179-189.

Meta-analysis of studies on individual consumption of drinking water and bladder cancer.

Villaneuva CM, Fernandez F et al (2003) *J Epidemiol Community Health* **57**, 166-173.

Disinfection resistance of waterborne pathogens on the United States Environmental Protection Agency's Contaminant Candidate List (CCL).

Gerba C P, Nwachuku N, Riley K R. *J Wat Supply Res Technol-Aqua* (2003) **52**(2):81-94.

Fluoridation and social equity.

Burt B A. *J Public Health Dent* (2002) **62**(4):195-200.

Arsenic

Arsenic in drinking water and adverse pregnancy outcome in an arseniasis-endemic area in northeastern Taiwan.

Yang C Y, Chang C C, Tsai S S, et al. *Environ Res* (2003) **91**(1):29-34.

This study was conducted to compare the risk of adverse pregnancy outcomes between an area with historically high well water arsenic levels and an area with no historic evidence of arsenic water contamination. The study area included 18 villages in four townships in the Lanyang Basin on the northeastern coast of Taiwan and four reference townships. Residents in Lanyang use shallow well water, which has an arsenic concentration ranging from undetectable levels to 3.59 ppm.

Each of the townships studied was assigned an urbanisation level to take into account the possible confounding effect of socioeconomic differences. Each arsenic exposed (AE) township was matched with one reference non-arsenic exposed (NAE) township with the same urbanisation level. All residents in the NAEs obtained their drinking water from public drinking water supply systems served by the Taiwan Water Supply Corp, with arsenic levels below 0.0009 ppm.

Registration of births is required by law in Taiwan and data was collected on pregnancy outcomes from this computerised registration system. There were 18,259 (3,872 for AEs, 14,387 for NAEs) first-parity singleton live births included in the final analysis. On average babies born in AEs were 30g lighter than those born in NAEs. A higher prevalence rate of preterm delivery was found for the AEs than the NAEs (3.74% vs 3.43%), this difference was not statistically significant however. The adjusted odds ratio when comparing AEs with NAEs was 1.10 (95% CI, 0.91-1.33). When term birth weight was used as a continuous variable, and confounders were adjusted for, the estimated reduction in birth weight was 29.05g (95% CI, 13.55-44.55) ($p=0.002$).

This study suggests that arsenic exposure through well water plays a potential role in increasing the risk

of low birthweight babies, however further investigations should be conducted in defined populations with individual-level exposure data and including potential confounding variables.

Long-term arsenic exposure and ischemic heart disease in arseniasis-hyperendemic villages in Taiwan.

Tseng C H, Chong C K, Tseng C P, et al. *Toxicol Lett* (2003) **137**(1-2):15-21.

This study evaluated whether long-term exposure to arsenic could be associated with ischemic heart disease (IHD). The study area included three blackfoot disease arseniasis-hyperendemic villages located on the southwest coast of Taiwan. The arsenic concentration of the artesian well water in these villages ranged from 0.70 to 0.93 mg/l. The amount of arsenic ingested by residents in these villages was estimated to be as high as 1 mg/day during the 1960s.

A study of health hazards induced by long-term exposure to ingested inorganic arsenic was initiated in 1988, as part of this a health survey was carried out in 1993 and electrocardiograms were taken on a resting state. A total of 462 subjects (205 men and 257 women) had readable electrocardiograms and were analysed for this study.

The electrocardiograms were coded by a senior experienced physician and checked by a cardiologist. IHD was defined by Minnesota codes of coronary probable and coronary possible. Each study subject was interviewed using a structured questionnaire and arsenic content in artesian well water of the villages was obtained. Cumulative arsenic exposure (CAE) was calculated. Traditional risk factors for IHD were also obtained from each subject, which included: sex, body mass index, cigarette smoking, disease status of diabetes mellitus, hypertension and lipid profiles.

Of the subjects, 78 cases were diagnosed with IHD. As expected, the prevalence of IHD increased significantly with age. For CAE of 0, 0.1-14.9, and 15 and above mg/l-years, the prevalence rates for IHD were 5.2, 10.9 and 24.1% respectively (*P* less than 0.001). For those with a CAE of 0.1-14.9 and

15 and above mg/l-years, compared with those lacking drinking water exposure to arsenic, the odds ratios for IHD were 1.60 (95% CI, 0.48 - 5.34) and 3.60 (95% CI, 1.11 - 11.65), respectively after multivariate adjustment.

Comment Blackfoot disease is characterised by narrowing of the peripheral arteries, especially in the feet, resulting in ulceration and gangrene. This study found a dose response relationship between arsenic exposure and IHD in subjects living in arseniasis-hyperendemic villages, suggesting arsenic also affects the coronary arteries.

Campylobacter

Detection and typing of *Campylobacter jejuni* and *Campylobacter coli* and analysis of indicator organisms in three waterborne outbreaks in Finland.

Hanninen M L, Haajanen H, Pummi T, et al. *Appl Environ Microbiol* (2003) **69**(3):1391-6.

Three waterborne outbreaks of *Campylobacter jejuni* in Finland in 2000 and 2001 were studied. Intensive sampling was undertaken with both small and large water samples analysed for indicator organisms and *Campylobacter* species. In the first outbreak, water samples ranging from 100 to 1,000 ml from groundwater wells and tap water were examined for coliforms, *E. coli* and *C. jejuni*. In the second outbreak, water samples ranged from 10 to 5,000 ml from raw water, treated water and tap water and a lake and were examined for faecal coliforms. In the third outbreak, water samples were 2,000 ml initially and later 100 ml and 1 ml samples were used, and samples were taken from groundwater sources and tap water as well as from two dikes and a duck pond and examined for coliforms, *E. coli* and enterococci and *Campylobacter*.

Thermophilic *Campylobacter*s (*C. jejuni*, *C. coli* and *C. lari*) were tested in 4,000 to 10,000 ml samples of suspected water from each of the outbreaks. Human faecal samples were collected and cultured as were faecal sample from pigs and ducks. *Campylobacter* isolates from water, the environment and patients were compared by typing for heat-stable Penner

serotypes and by genotyping with pulsed-field gel electrophoresis (PFGE) to evaluate any association between exposure to contaminated drinking water and illness.

In outbreak 1, all *C. jejuni* isolates analysed from 10 patients and the *C. jejuni* isolate from tap water were the same serotype (Pen 12) and the same PFGE genotype. Only one tap water sample was positive for indicator organisms. Two separate samples from two different wells were found to be positive for *E. coli*. The cause of the outbreak was probably runoff of contaminated surface water into groundwater wells after heavy precipitation.

In outbreak 2, coliforms were found from several samples taken from raw water, treated outlet water and tap water. Five *E. coli* colonies were found in a 5000 ml tap water sample. *C. jejuni* isolates from five patients were all of the same serotype (Pen 12) and same PFGE genotype. The genotype of the isolate of *C. jejuni* from the lake water was different from that of the patients. The source of the outbreak was either a groundwater well contaminated with lake water or tap water contaminated in the distribution system.

In outbreak 3, coliforms were detected from groundwater wells, *E. coli* was found in one well and in the two dikes, enterococci was found in one well and also in the dikes. All 10 *C. jejuni* isolates from 10 patients were of the same serotype (Pen 12) and the same PFGE genotype. The *C. jejuni* isolate found in one well had a different serotype (Pen 55) and genotype to the patients' isolates. *C. coli* was found in water from one well and one dike but they were different genotypes. The *C. jejuni* isolate found in the duck pond was also unique. The cause of the outbreak was thought to be the same as outbreak 1.

The examination of these outbreaks showed that large volumes of water and multiple samples from several sources and sites improved the *Campylobacter* detection rates. The large volumes of water were required for detection of coliform bacteria and *E. coli* and helped to identify the route and source of contamination more definitely. The use of serotyping and PFGE typing of the patient and water isolates also confirmed the source of infection.

Cyanobacteria

Relationship between microcystin in drinking water and colorectal cancer.

Zhou, L. and Chen, K. *Biomed Environ Sci*, **15** (2002) 166-71.

Colorectal cancer is one of the most common types of cancer in developed countries, but occurs at lower rates in the developing world. In China the rate of colorectal cancer has been rapidly increasing for the last 30 years, and some studies have identified drinking from surface water sources as a risk factor. A retrospective cohort study was carried out in 8 townships within Haining City, China to assess whether there was an association between colorectal cancer and exposure to the cyanobacterial toxin microcystin in water supplies.

408 cases of primary colorectal cancer diagnosed in the towns between 1977 and 1996 were identified from a cancer registry. Information on drinking water sources was obtained from the patients (if still alive) or from relatives. One drinking water type was assigned to each patient as being their sole water source or source with longest duration of use during their lifetime. Information on the number of residents in each township and their drinking water sources was obtained from local civil and health authorities. In each township 10 water sources were sampled, with at least eight samples taken from each source over a 4 month period. A randomly selected subset (20%) of samples was analysed for microcystin. Samples were considered positive if they contained more than 50 picograms/ml.

The overall incidence of colorectal cancer was 8.37 cases /100,000 population /year. The rates differed markedly in populations with different types of water supplies; well water 3.61 /100,000 /yr, tap water 6.77 /100,000 /yr, river water 28.50 /100,000 /yr, and pond water 27.76 /100,000 /yr. The relative risks for tap, river and pond water were all significantly higher than for well water (P less than 0.01). Microcystin was not detected in any samples of well or tap water (12 and 17 samples examined respectively). For river water 36% of 69 samples were positive, with a mean value of 141.08 picograms/ml and maximum of

1,083.43 picograms/ml. For pond water 17% of 35 samples were positive, with a mean concentration of 106.19 picograms/ml and a maximum of 1,937.94 picograms/ml.

Each township used a mixture of water types, but in each town the proportion using river and pond water was similar (25%). A spearman correlation analysis was carried out for the relationship between the average microcystin concentration in river or pond water in each town and the incidence of colorectal cancer in each town. A strong correlation was observed, with a correlation coefficient of 0.881 (P less than 0.01). Relative risks for colorectal cancer were 1.88 for tap water, 7.4 for river water, and 7.70 for pond water compared to well water.

Comment The relative risks reported here are high but this study was of ecological design and did not assess exposures of individual people or factors such as diet, smoking and alcohol consumption that affect colorectal cancer risks. From the information presented, it is not possible to determine whether drinking water sources were the only potential difference in environmental exposure between the townships, or whether microcystin was the only contaminant of concern in water supplies. The latency period for colorectal cancer may be as long as 30 to 40 years, so the relevant exposures in this study may have occurred several decades before cancer diagnosis. Depending on changes in water nutrient levels or river flow during this time, microcystin levels measured now may not accurately reflect historical exposures.

Maximum microcystin levels detected here were in the range of 1,000-2,000 picograms/ml or 1-2 micrograms/litre - similar to the Australian Drinking Water Guideline value of 1 microgram/litre which was set on the basis of chronic liver toxicity. It has been reported that microcystin can enhance the growth of aberrant crypto foci (potentially pre-cancerous lesions) in the colon of mice, although the toxin alone did not induce crypt formation (Humpage AR et al. (2000) *J Toxicol and Environ Health Part A* 61:155-165). On current evidence, microcystins are not considered to be carcinogenic for humans.

Cryptosporidium

Is drinking water a risk factor for endemic cryptosporidiosis? A case-control study in the immunocompetent general population of the San Francisco Bay Area.

Khalakdina A, Vugia D J, Nadle J, Rothrock G A, Colford J M. *BMC Public Health* (2003) 3:11

A case-control study was undertaken in the San Francisco Bay Area to establish whether drinking water is the major route of transmission for endemic cryptosporidiosis in the immunocompetent general population. This study was part of the California active surveillance program sponsored by the Centers for Disease Control and Prevention (CDC).

Cases were identified through surveillance between July 1999 through July 2001 as having a positive stool test for *Cryptosporidium*. Of the 171 new cases of cryptosporidiosis reported, 26 were eligible for the study and were successfully recruited. Sixty-two controls were category age-matched to cases. The following types of controls were recruited: sexual/household, non-sexual/household, sexual/neighbourhood, non-sexual/neighbourhood, sexual/different water district, and non-sexual/different water district. Non-sexual contacts were recruited by sequential random digit dialling. Sexual contacts were sexual partners of cases who agreed to participate.

Case and controls were interviewed by telephone and administered a questionnaire. Questions were asked about: drinking water quality and quantity at home and outside the home, travel, recreational water exposure, person-to-person faecal exposures, consumption of risky food items, consumption of unpasteurised food and handling of raw foods, zoonotic contact and details on specific sexual practices. Demographic information was gathered and health status indicators. Most questions referred to two weeks prior to the development of cryptosporidiosis in cases. A univariate analysis was carried out with 102 variables evaluated. A multivariate analysis was also conducted with 13 composite variables created based on transmission route.

The main conclusion was that travel to another country was a very strong and significant risk factor for cryptosporidiosis transmission in a non-outbreak setting in the San Francisco Bay Area. Consumption of tap water without further treatment or processing was not associated with cryptosporidiosis transmission when compared to drinking boiled water. Exposures that would normally be considered risky such as contact with faecal matter, exposure to raw or uncooked food items, and animal contact did not have elevated risks.

The results did not show that drinking water was an independent risk factor for cryptosporidiosis among the immunocompetent population studied here. Larger studies are needed of endemic cryptosporidiosis to establish the exact mechanisms of transmission, whether they be waterborne, foodborne or person-to-person.

Comment This study had limited power due to the small number of cases and a relatively low participation rate with 46% of identified cases being ineligible due to immunocompromising condition, 15% unable to be contacted and 11% refusals.

Endemic cryptosporidiosis and exposure to municipal tap water in persons with acquired immunodeficiency syndrome (AIDS): a case-control study.

Aragon T J, Novotny S, Enanoria W, et al. BMC Public Health (2003) 3:2.

A matched case-control study was conducted in San Francisco among persons with AIDS to test the hypothesis that drinking tap water is associated with the development of endemic cryptosporidiosis. *Cryptosporidium parvum* can cause prolonged and severe diarrhoeal illness in people with AIDS that can be life threatening and currently no treatment is available.

The study population comprised those with an AIDS-defining diagnosis living in San Francisco, California. Cases were residents of San Francisco with AIDS who were reported to the San Francisco department of Public Health having a laboratory confirmed positive stool test for *Cryptosporidium*

parvum from May 1996 to September 1998. Controls were any resident of San Francisco who reported with AIDS to the San Francisco Department of Public Health and did not have a laboratory-confirmed diagnosis of cryptosporidiosis. Information was collected from cases and controls on: date of birth, race/ethnicity, gender, month and year of diagnosis of cryptosporidiosis, all CD4⁺ T lymphocyte counts recorded and the date of each test. For cases the CD4⁺ count closest to the date of cryptosporidiosis diagnosis was determined.

A questionnaire was administered to cases and controls. Cases were asked about water exposures in the four-week period prior to diarrhoea onset. Controls were asked about water exposures in the four-week period prior to the interview. Questions were asked on sources of exposure to water, uses of tap water, type of drinking water consumed while travelling outside San Francisco, use of hot tubs, swimming in lakes or streams or any other recreational exposure in the period studied. Tap water and bottled water consumption were also examined. Other sources of cryptosporidiosis infection were assessed and recent travel outside San Francisco was detailed. The participant's residential address was used to determine whether, 4 weeks prior to cases illness their residence received municipal water that was filtered, mixed or unfiltered as the water distribution varies both geographically and temporally in San Francisco.

There were 72 cases identified as potentially suitable for inclusion, with 49 cases and 99 controls in the final analysis. A multivariable analysis with adjustment for confounders was conducted. Tap water consumption inside and outside the home at the highest exposure categories was associated with the occurrence of cryptosporidiosis. The odds ratio (OR) for inside the home was 6.76; (95% CI 1.37-33.5) and for outside the home OR 3.16; (95% CI 1.23-8.13). A strong negative association was found between always drinking bottled water at home and cryptosporidiosis (unadjusted matched odds ratio 0.09, 95% CI 0.03-0.37). Population attributable fractions (PAFs) were calculated. The proportion of cryptosporidiosis cases in San Francisco AIDS patients attributable to tap water consumption was up to 85%. The PAF from other potential risk factors

such as exposure to faeces, or living in a residence supplied with unfiltered water was less than 1%.

Based on the results of this study, people with AIDS in the San Francisco area, especially those that are immunocompromised, should consider not drinking tap water. Whether it is better to drink boiled water or bottled water is not clear, however from these results drinking appropriately bottled water may prevent infection.

Comment Water consumption in this study was assessed by frequency (never, sometimes, always) rather than volume consumed. Also the analysis did not take into account whether the tap water was filtered or boiled in the home prior to consumption. The authors note that in San Francisco the incidence of cryptosporidiosis among people with AIDs has dropped dramatically since the mid-1990s. This has also occurred in other developed nations and has been attributed to improved anti-HIV therapy which improves immune status. The first effective drug for treatment of cryptosporidiosis in children was recently approved and trials are underway in AIDs patients (see Health Stream Issue 28 News Items).

Disinfection Byproducts

Effect of trihalomethane exposure on fetal development.

Wright J M, Schwartz J, Dockery D W. Occup Environ Med (2003) 60(3):173-80.

A cross sectional study was conducted to examine the relationship between total trihalomethane exposure (TTHM) in Massachusetts drinking water and adverse birth outcomes. The study population included singleton infants born to residents of communities that routinely monitored THMs. Data was extracted from birth records and hospital worksheets during 1990 and provided by the Massachusetts Department of Public Health. The analysis was restricted to 56,513 infants between 22 and 45 gestational weeks weighing more than 200g at birth. Infant birth weight and gestational age were obtained from birth records. Prematurity was classed as less than 37 gestational weeks and low birth weight at less than 2500g. Small for gestational age

(SGA) infants were those in the lowest 10th centile of birth weight for each gestational week stratified by infant gender and maternal race.

Trihalomethane data were obtained (1987-93) from the Massachusetts Department of Environmental Protection records and data from 96 communities were included. Maternal exposure was estimated from average TTHM concentration for the town of residence. Based on month of birth, trimester specific and pregnancy average exposures were assigned. Individual maternal information on some potential confounders was included in the analysis.

The study population included: 1325 low birth weight, 5310 SGA and 3173 premature infants. Associations were found between pregnancy average and trimester specific TTHM exposures and birth weight among term infants. Adjustment for gestation age and other covariates was performed and reductions of 2.8g for each 20 microgram/l increase in pregnancy average TTHM concentration and 2.6g for each 20 microgram/l increase in second trimester TTHM concentration were found. Maternal exposure to increased TTHMs (above 80 microgram/l) was associated with lower birth weight when compared to the reference group (less than or equal to 60 microgram/l). The differences were statistically significant at the 0.05 level only for the second trimester and pregnancy average intervals.

No consistent associations were found for TTHM exposure and low birth weight among term births. Statistically significant increased risks of SGA births were found for mothers in the highest TTHM exposure group during the second trimester and over the entire pregnancy. There was no evidence of an association between TTHM exposure and preterm delivery - rather women with higher TTHM exposure during the second trimester and pregnancy average were less likely to have preterm deliveries.

Overall this study showed that maternal exposure to THMs may be associated with foetal growth retardation. Weaker associations between TTHMs and adverse developmental outcomes were found than reported in earlier studies and most associations were not statistically significant.

Chlorination by-products in drinking water and menstrual cycle function.

Windham, G.C., Waller, K., Anderson, M. et al. *Environ Health Perspect*, **111** (2003) 935-41.

This paper reports on one component of a prospective study being undertaken in northern California examining the effect of environmental exposures including tap water intake, smoking and exposure to solvents on aspects of female reproduction. The study group were premenopausal women aged 18 -39 years, who were not using hormonal contraception or intrauterine devices, and were members of a large private healthcare organisation. Of 1092 women identified as eligible for the study by telephone interview, 553 agreed to participate, and 403 eventually took part in the study.

Participants were asked to collect and freeze first morning urine samples each day for hormone analysis. Questionnaires were administered covering age, race, height, weight, education, income level, employment status, pregnancy history, smoking, alcohol and caffeine intake, hot and cold tap water intake, bottled water intake, duration of showering, and physical activity. Women also recorded details of menstruation during the study. Urine samples were analysed for metabolites of oestrogen and progesterone, with results adjusted for creatinine levels. Menstrual cycles were defined by bleeding patterns, and the day of ovulation was defined using an algorithm based on oestrogen-progesterone ratios.

Each of the women participated for 2 to 9 menstrual cycles (average 5.6), producing a data set for analysis with 1624 complete menstrual cycles; 1514 for follicular phase (first day of menses to day of ovulation), 1424 for luteal phase (day after ovulation to day before next menses), and 1714 for menses (duration of bleeding). Exposure to THMs was calculated from routine quarterly monitoring data from the 10 water utilities in the study area. THM exposure for each menstrual cycle for each woman was calculated as an average of THM readings taken from 60 days before to 30 days after the first day of the cycle. If no water samples were taken during this interval, the readings from samples closest to each end of the interval were averaged.

THM exposure was estimated based on THM levels in water and on estimated THM intake per day from reported water consumption volumes. Examination of baseline characteristics showed that women living in areas with higher TTHM levels were significantly more likely to have higher incomes, and also had higher intakes of alcohol and caffeine, and smoked more. In the final statistical analysis adjustment was made for income, age, pregnancy history, body mass index, caffeine, alcohol, race and smoking.

An inverse relationship was found between TTHM concentration in tap water and average cycle length, with women exposed to TTHM greater than 60 micrograms/litre having a menstrual cycle 1.1 days shorter than those exposed to water with 40 micrograms/litre or less (95% CI -1.8 to -0.40 days). When individual consumption of unheated tap water was used to estimate exposure, a U-shaped response was seen with the shortest cycle length being observed in the middle category with women ingesting 40 to 60 micrograms TTHM per day having a 1 day decrease in cycle length, while those in the highest category (more than 60 micrograms/day) had a decrease of 0.4 days. When individual exposure was assessed on total tap water consumption (hot and cold) a more consistent trend to decreasing cycle length with increasing exposure was seen. Overall, the decrease in average cycle length was due to a shorter follicular phase with little change in luteal phase or duration of menstruation. The variability of cycle length was not affected by THM exposure.

Analysis on the basis of individual THMs showed that chloroform was only weakly associated with changes in cycle length, but each of the three brominated THMs showed a stronger relationship. The strongest association was seen with chlorodibromomethane where mean cycle length was 1.2 days shorter in the highest quartile of exposure. Length of time spent showering each week had little effect on cycle length.

The authors note that this is the first study to examine possible effects of THM exposure on the menstrual cycle, and further studies are needed to confirm these observations. The differential associations seen with chloroform and brominated THMs indicate that total

THM exposure is not a meaningful measure when comparing different water supplies as the ratio of chloroform to brominated compounds will vary. Also, the lack of effect of showering, and the stronger association seen with total tap water intake rather than cold tap water intake implies a non-volatile compound may be responsible for the observed effects rather than the volatile THMs.

Comment A number of exposures and behavioural factors have been associated with changes in menstrual cycle length including pesticides, some prescribed drugs and exercise. In this study smoking was associated with a larger decrease in cycle length (2.5 days) than THM exposure. Nutrition may have strong effects but was not assessed here, and the authors comment that variations in nutritional status among participants were unlikely to have coincided with variations in THM levels. Nevertheless the statistically significant association observed between income levels and THM exposure raises the possibility that a number of other important differences existed that may not have been sufficiently compensated for in the adjusted analysis. The biological impacts of changes in the length of the follicular phase are uncertain; this phase is normally the most variable component in overall cycle length in individual women.

Disinfection

Chlorination and safe storage of household drinking water in developing countries to reduce waterborne disease.

Sobsey M D, Handzel T, Venczel L. *Wat Sci Technol* (2003) **47**(3):221-8.

Two separate studies were conducted to evaluate point-of-use chlorination and storage of collected household water in special plastic containers with the aim of improving the microbial quality of water and reducing diarrhoeal illness of consumers living in poor sanitation and hygiene conditions.

One of the study sites included two peri-urban settlements near a city of 70,000 people in subtropical Bolivia where shallow groundwater was collected for household use. The other site was an informal urban settlement in Dhaka City, Bangladesh

where water was mainly collected from clandestine connections to the municipal water supply, which provided water of variable quality and for only a few hours per day. The populations in both of the sites were of low socioeconomic status and had poor sanitation. Families were recruited and assigned to a control and intervention group randomly. There were about 140 households in Bolivia and 275 in Bangladesh. Control households in both studies used their usual source of water and storage container.

The intervention households were given a plastic water storage container for disinfection of collected water and bottles of free chlorine solution weekly. Containers were designed to minimise potential for contamination, with small openings for filling and separate taps for dispensing water. Households were instructed to add stock chlorine to the water container to achieve a dose of around 1.25 mg/L free chlorine in Bangladesh and 5 mg/l free chlorine in Bolivia. Water samples from all households in Bangladesh were analysed for faecal coliforms and *Escherichia coli*, and in Bolivia water samples were analysed for *E. coli*, *Clostridium perfringens* and heterotrophic plate count (HPC) bacteria. Trained health workers visited study households weekly and information on household cases of diarrhoea was gathered.

Baseline studies showed that 87% of source water samples in Bangladesh were contaminated with faecal coliforms and *E. coli*. Household water storage containers had an even higher concentration of these bacteria, indicating further contamination occurred in the household during use.

During the 8-month study period the percentage of stored household water samples that were positive for *E. coli* and the geometric mean *E. coli* concentrations were significantly lower (P less than 0.01) in the interventions households than in the control households. In Bolivia baseline studies showed that 95% of household water samples were contaminated with *E. coli*. During the 6-month intervention period, the percentages of stored water samples positive for *E. coli*, *C. perfringens* and HPC bacteria as well as the median concentration of these bacteria in water, were significantly lower (P less than 0.0001) in intervention households than in control households.

In Bolivia, episodes of diarrhoeal illness per month were 1.25 in the intervention group and 2.2 in the control families. Therefore the intervention prevented 43% of community diarrhoea. In Bangladesh, mean episodes of child diarrhoeal illness/ 1,000 days were 19.6 and 24.8 in intervention and control groups respectively. Therefore about 24% of observed diarrhoea was prevented using the intervention.

These studies showed that using simple, accessible and low cost interventions to treat and safely store household water, significant improvements in microbial quality of drinking water and reductions in diarrhoeal illness and conceivably other diseases are possible.

Magnesium

Magnesium in drinking water and liver cancer morbidity--a possible relation?

Tukiendorf A. *Cent Eur J Public Health* (2002) **10(4):157-62.**

This study examined liver cancer prevalence in relation to magnesium exposure in drinking water in Opole province, Poland. Magnesium data from 80 administrative units of the province from 1980-1985 were included. During the analysis period, 60% of the population of the province drank from relatively shallow wells, while the other 40% drank mains water supplied from deeper aquifers. Weighted average magnesium concentrations in drinking water consumed by residents in each administrative district were calculated.

Data on cases of liver cancer disease from 1985-1994 came from the Regional Cancer Registry in Opole. In these 80 districts for the years studied there were 219 prevalent cancer cases in males and 273 in females out of a total population of 462,876 males and 485,403 females according to the National Census of 1988.

Logistic regression analysis using Bayesian techniques was performed and it was found that males and females showed very similar trends in liver cancer morbidity. An increase in magnesium content in drinking water was associated with reduced risk of

liver cancer. For the category with lowest magnesium concentration in drinking water (2.0-3.9 mg/L), the cancer risk was four times higher in males and three times higher in females than for the category with highest magnesium content (24-41 mg/L). The results suggest a possible relationship between deficiency of magnesium in drinking water and increased liver cancer morbidity in the population studied.

The authors note that this ecological study did not assess well known risk factors for liver cancer including alcohol consumption and hepatitis virus infections, but suggest the potential role of magnesium warrants further investigation.

Magnesium in drinking water and the risk of death from liver cancer.

Yang C Y, Chiu H F, Tsai S S, Chang C C, Chuang H Y. *Magnes Res* (2002) **15(3-4):223-8.**

The relationship between the level of magnesium in the drinking water and risk of death from liver cancer was examined in this study. In Taiwan, liver cancer is the leading cause of cancer mortality in males and the second most common cause of cancer mortality in females. 322 of the 361 municipalities in Taiwan were included in this study. Data was obtained from the Bureau of Vital Statistics of the Taiwan Provincial Department of Health on all deaths of Taiwan residents from 1994 through to 1998. There was detailed demographic information available for each death. Cases included all eligible liver cancer deaths that occurred in individuals between 50 and 69 years of age. The control group included all other deaths from other causes except causes previously associated with a negative relationship between hardness (magnesium or calcium) levels in drinking water. Control subjects were pair-matched to cases by year of birth and year of death and selected randomly. To be included in the study, all study subjects had residence and place of death in the same municipality.

The Taiwan Water Supply Corporation supplied information on the levels of magnesium in each municipality's treated drinking-water supply. Drinking water quality data suitable for the study

purposes was available from 252 municipalities. The municipality of all cancer cases and controls was assumed to be their source of exposure to magnesium via drinking water.

There were a total of 9166 liver cancer cases with complete records for the study period and the same number of controls. The mean magnesium levels in the drinking water were 12.0 (SD=7.7) mg/l for cancer cases and 11.6 mg/l (SD=7.6) for controls. A significantly higher percentage of cancer cases were found to live in metropolitan municipalities compared to controls. There was no apparent statistically significant association between magnesium levels and liver cancer risk found in this study. Possible confounding variables such as hepatitis B and C infection might contribute more to liver cancer risks in Taiwan than magnesium in diet or drinking water.

Outbreaks

A waterborne outbreak of Norwalk-like virus among snowmobilers-Wyoming, 2001.

Anderson A D, Heryford A G, Sarisky J P, et al. *J Infect Dis* (2003) **187**(2):303-6.

Reports were received by the Wyoming Department of Health in early February 2001 of acute gastroenteritis from people who had recently visited a snowmobile vacation lodge (lodge A) in Wyoming. Guests at lodge A often visited other lodges (lodges B and C). A retrospective cohort study was conducted among guests from lodges A and B; lodge C did not participate in the epidemiological investigation.

Lodge guests were interviewed by telephone and a standardised questionnaire was administered. Questions included: symptoms, dates of illness, water and ice consumption and menu items consumed at the lodge A restaurant. Stool samples from 13 lodge guests were tested for Norwalk-like virus (NLV), *Salmonella*, *Shigella*, *Campylobacter*, and *Escherichia coli* 0157:H7. Water samples were taken from well water from lodge A and tested for the presence of NLVs and faecal coliforms. Well-water samples from lodges B and C were also tested for

faecal coliforms. Food handlers from the lodge A restaurant were asked about food preparation procedures and history of illness. An assessment was also carried out of the lodge's water supply and sewage disposal systems.

It was found that 41% of respondents from lodge A (22 of 54) and 48% of respondents from lodge B (13 of 27) developed acute gastroenteritis during or within 1 week of their visit. Guests were ill from 1 to 9 days (median, 2 days) and 7 guests sought medical care with one guest being hospitalised. There was a significant association found for illness and water consumption (relative risk, 3.3, 95% CI, 1.4-7.7) among guests from lodge A. The risk of illness increased with the number of glasses of water consumed. There were no associations found for food items. Water consumption at lodge B was not associated with illness among lodge B guests. Guests from lodge B who ate or drank at lodge A had a significantly greater risk of illness than guests who did not (relative risk 7.5; 95% CI, 1.1-49.2).

Eight of the 13 stool specimens collected from lodge guests who were ill, tested positive for NLV. A total of three distinct sequence types were detected in the outbreak. There were no bacterial pathogens found in stool samples. Of the well-water samples first collected from lodge A, 7 out of 8 tested positive for faecal coliforms. Well samples from lodge B and C showed no bacterial contamination.

All 3 wells that served lodge A were situated within 92-115 feet of a septic tank or outhouse. The geological conditions in the area and an overloaded sewage disposal system were implicated in the contamination of the water supply. The sewage system had been remodelled in November 2000 and new connections to the system increased the flow of wastewater. The system however was not designed or constructed to successfully treat the increased volume. Food safety training of food handlers and managerial controls were also inadequate. Some of the food handlers had gastrointestinal illness during the epidemic period. The finding of multiple strains of NLV suggests that incoming guests may have repeatedly contaminated the water supply.

Viruses**Incidence of enteric viruses in groundwater from household wells in Wisconsin.**

Borchardt M A, Bertz P D, Spencer S K, Battigelli D A. *Appl Environ Microbiol* (2003) **69**(2):1172-80.

This study estimated the incidence of human enteric viruses in household wells in Wisconsin located near high volume septage (untreated wastewater from septic tanks) land application sites or in subdivisions served by septic systems. The occurrence of enteric viruses among wells in different hydrogeologic settings was compared and the predictive value of water quality indicators for virus contamination was assessed. Wells were selected to represent seven of the nine major hydrologic districts in Wisconsin. The Wisconsin Department of Natural Resources records and reports were used to identify land application sites and these were ranked in each hydrogeologic district by the total volume of septage applied.

There were 50 wells sampled, half were sampled from January 1999 to November 1999 and the other half from November 1999 to June 2000. The wells were sampled four times, once per season. A laboratory technician collected samples from a household tap and where possible selected taps that bypassed water softening or home filtration units. Water samples were analysed for enteroviruses, rotavirus, hepatitis A (HAV) virus and Norwalk-like (NLV) viruses by reverse transcriptase PCR (RT-PCR) followed by Southern hybridisation. Cell culture was also used to detect culturable enteroviruses. Along with the collection of a water sample for virus analysis another sample was taken to test for water quality indicators. The microbial indicators included total coliforms, *Escherichia coli*, faecal enterococci and F-specific RNA (FRNA) coliphages and chemical indicators including chloride anion and nitrate.

Of the 50 wells sampled, 4 were virus positive (8%). Virus positive wells were located in three of the seven hydrogeologic districts included in this study. Three of the four positive wells were positive for HAV with intermittent virus occurrence, each well having only one positive sample found out of the four

collected. The other well was positive for enterovirus in the summer, negative in the autumn and then positive for rotavirus and Norwalk-like G2 virus in the winter. Viruses were only found in wells during the summer and winter sampling. None of the 194 samples tested by cell culture were positive for culturable viruses. Of the microbial indicators, total coliform bacteria were the most common and *E. coli* was only detected in one sample. FRNA coliphages were found in two wells. The US EPA maximum contaminant level for NO₃ was exceeded in four of the wells and 20 wells had a chloride level above 28mg per litre. The water quality indicators showed no statistical association with the occurrence of viruses; the highest positive predictive value was only 15% for chloride.

In the United States there are 15 million households using private wells as their main source of drinking water. If it is assumed that there is an 8% virus contamination rate as determined in this study, then 1.2 million households may be exposed to enteric viruses from their private wells. However the wells sampled in this study were selected as potentially having a high risk of contamination and may not be representative. The authors comment that the 4 wells positive for viruses by PCR were 3 to 22 years old and conformed with state regulations requiring a minimum 40 foot casing depth.

Water Quality**The quality of drinking water from private water supplies in Aberdeenshire, UK.**

Reid D C, Edwards A C, Cooper D, Wilson E, McGaw B A. *Wat Res* (2003) **37**(2):245-54.

The drinking water quality in private water supplies (PWS) in Scotland was examined in this study. Routine PWS data was analysed for separate supply categories located in the Aberdeenshire Council area in the North East of Scotland for the years 1992-1998. Data for the Central and South Divisions was available from 1992-1998 and for the North Division from 1996-1998.

In 1997 a separate and intensive monitoring program of PWS was undertaken. PWS in Category one F

(non-commercial supplies with 1 dwelling) were sampled for total coliforms (TC) and faecal coliforms (FC) and nitrate concentration. Sampling of 82 properties selected randomly from a sub-set of the register of PWS from the Central Division of Aberdeenshire Council was conducted. The majority of these PWS were sampled on three occasions but some were only sampled twice.

Of the approximately 1750 samples collected routinely by the Local Authority from PWS in Aberdeenshire for the 1992-1998 period, failure rates were 41% for TC, 30% for FC and 15% for nitrate. The combination of random sampling and higher frequency in the separate survey indicated that the overall failure rate might be greater, with approximately 80% of Category one F samples failing. The actual and expected number of PWS samples collected suggests that the Local Authority was not able to fulfil the statutory sampling requirements with only about a third of the statutory sampling frequency requirements being met.

Failure rates of samples collected directly from the source or at the kitchen cold-water tap were compared and failure rates for microbiological

parameters or nitrate were similar. This suggests that for the majority of cases, direct contamination of the groundwater source is occurring rather than contamination of the storage or supply line.

A different mechanism or source of contamination between coliforms and nitrate is suggested as a relatively small number of samples failed simultaneously for both. Failures of samples on microbiological grounds showed a seasonal trend with failures being greater in the latter half of the year. This can partly be explained by a significant positive relationship between failure and rainfall rate. For nitrate a greater number of failures occurred during spring and no relationship was found for rainfall. The authors suggest that as local authority resources are limited it might be more efficient to concentrate on the periods of greatest contamination risk and target them for sampling,

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