# Health Stream

INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

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## *In this Issue:*




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## MTBE Debate For Australia

The fuel additive MTBE (methyl tertiary butyl ether) recently emerged as an issue of concern for the Australian water industry, a few months after the approval of the Fuel Standards Act in December 2000. The Act specifies new requirements for petrol and diesel fuels to be phased in over a four year period beginning in January 2002. These changes are designed to reduce air pollution levels in urban areas, and will bring Australian standards for fuel quality into line with changes in international standards. This is expected to result in a reduction in rates of respiratory illnesses and lower cancer risks, with an estimated saving of up to $3 billion in health costs in Australia over the next 20 years.

Attainment of the new standards will require changes in petrol formulation to reduce emission levels. Internationally, this has generally been achieved by adding oxygenate compounds to petrol. MTBE is one of several compounds that can be used for this purpose, and has achieved market domination because of its low cost. However MTBE from petrol has been associated with significant water pollution problems in the United States since use of this agent escalated in the 1990s, resulting in calls from some water authorities for a complete ban (1).

During the period leading to formulation of specific standards for fuel components, some independent petrol retailers in Australia submitted that continued importation of MTBE-containing fuel from Asia was necessary to maintain viability in the competitive market with locally refined petrol (2). This was strongly opposed by representatives of the Australian water industry and a number of environmental groups on the grounds that MTBE posed an unacceptable threat to water supplies.

After several months of debate, the Australian Federal Environment Minister announced on 15 July that MTBE levels in petrol sold in Australia would be limited to 1% v/v from January 2004. The states of Queensland, South Australia and Western Australia have already put in place bans on MTBE in petrol in response to perceived environmental risks.

MTBE emerged as a significant issue for water utilities in the US in 1996 when it was detected in groundwater supplies for the city of Santa Monica only two years after it was introduced into fuel supplies in California. Testing revealed MTBE to be present in 7 of 11 wells, with concentrations reaching as high as 600 micrograms/L (ppb), resulting in closure of the affected wells. The contamination was traced to leaking underground fuel storage tanks.

MTBE possesses several properties that enable it to rapidly spread to groundwater supplies. It does not bind well to soil particles, is highly water soluble and poorly biodegradable. As a result it moves more rapidly through soil than other petrol components, with travel distances of up to 4.8 km (3 miles) being documented. There have been a number of recorded incidents where small fuel spills have caused detectable water contamination problems, including one spill of 30-38 litres (8 to 10 gallons) from an automobile accident which affected 24 private wells. Conventional water treatment methods are not very effective for removal of MTBE, and techniques such as air stripping, advanced oxidation processes, and granular activated carbon must be used.

Taste and odour thresholds for MTBE in drinking water are low, with one study of four people trained in water tasting reporting a taste threshold as low as 2-5 micrograms /L, although the taste was not considered objectionable until levels of 50 micrograms/L had been reached. Studies in less highly selected groups of people have suggested average odour thresholds ranging from 15 to 180 micrograms/L in water.

The taste and odour have been described in various studies as being bitter, solvent-like or plastic-like. The US EPA has set an advisory level of 20-40 micrograms/L in drinking water based on taste and odour, but some states such as California have set an aesthetic level of 5 micrograms/L in recognition of the fact that some individuals may be more sensitive to the compound than others.

The human health effects of MTBE exposure have prompted much debate. There have been many anecdotal reports of adverse effects such as headache, dizziness, eye and nose irritation and nausea attributed to inhalation exposure to fuel containing MTBE or other oxygenates, however studies under controlled conditions have failed to demonstrate consistent associations. Some studies have suggested that adverse publicity about the introduction of fuel additives may have influenced people's perception of health effects, and that common symptoms of respiratory infections or other illnesses may have been attributed to fuel exposure in some instances. However the possibility that some individuals in the population are more sensitive to MTBE than others can not be ruled out.

Animal toxicity data from chronic inhalation exposure suggests that even under worst case scenarios, people with occupational exposure are unlikely to suffer non-cancer health effects, and risks for the general public are much lower. However, as aptly expressed by one reviewer, *"rats don't retch"* and animal studies can not provide evidence on the aesthetic aspects of exposure in humans.

Assessments of the potential cancer risks posed by MTBE are also a source of controversy. In its *9th Report on Carcinogens* published in 1999, the US National Toxicology Program reviewed the evidence on MTBE and concluded that the available rodent cancer data *"were not sufficient for listing in the Report as reasonably anticipated to be a human carcinogen"*. The same conclusion was reached by the International Agency for Research on Cancer, however some critics have charged that both bodies have acted unreasonably, and in contravention of their own criteria, in discounting some of the data from animal studies when making their decisions (3). A number of other bodies including the US EPA have concluded that MTBE is an animal carcinogen and may potentially be carcinogenic to humans.

In response to mounting concerns over water and environmental contamination, the US EPA began moves in March 2000 to reduce or eliminate MTBE in petrol under the Toxic Substances Control Act, a process that may take several years to complete (4). Many in the US water industry have urged more urgent action, citing accumulating evidence of widespread contamination of water supplies across the nation.

While initial concerns focused in groundwater supplies because of their vulnerability to contamination from spills and leaking underground tanks, surface water supplies may perhaps be more frequently affected by MTBE. The preliminary results of a random survey of 954 US water systems indicated that detectable levels of MTBE were present in 8.7% of all supplies, comprising 14% of surface waters and 5% of groundwaters sampled. Contamination was five times more common in areas where gasoline containing MTBE was used.

The contribution of different MTBE sources to surface water contamination has not been well established, however studies have shown that two-stroke motors in small water craft burn fuel very inefficiently, and that up to 30% of fuel is released unburnt into the environment. Thus recreational boating may be a significant source of MTBE in some surface waters. While airborne MTBE may potentially enter surface waters, evidence suggests that this is not a significant source, and that most airborne MTBE from release of tank vapours and evaporation remains in the air and is decomposed by photochemical reactions with a half-life of about three to seven days.

The pervasive nature of the additive was underlined by a recent study of petrol supplies in the states of Indiana, Illinois and Michigan, which found that MTBE could be detected in more than 70% of samples despite the fact that ethanol is the predominant fuel oxygenate used in these three states. Researchers attribute the contamination to residual amounts in storage tanks and fuel transport vehicles from other areas.

While advocating urgent action to eliminate MTBE use in fuel, US water authorities have also called for a more thorough evaluation of the potential environmental effects of alternative fuel additives to ensure that similar problems will be avoided in future. They have also called for a re-examination of mandatory requirements to add oxygenates to fuel in the US, given the outcomes of research undertaken at the University of California suggesting that modern automobile engines are capable of meeting US clean air standards without the use of such additives. However, the feasibility of completely banning MTBE has been questioned by many in the petroleum industry, and the need to retain the substantial health benefits achieved through improved air quality has been emphasised by the public health community.

The controversy over MTBE in the US is in contrast with the situation in Europe where MTBE is also used as a fuel additive, but is not presently perceived as a significant threat to water supplies. Several important differences exist, however, in the use of the additive in Europe. Firstly, in most European countries MTBE is added to petrol only as an octane booster at a level of about 1.6% v/v, in contrast to the 11-15% v/v used in the US for air pollution control. Secondly, European regulations governing underground fuel storage tanks have been more stringent and more strictly enforced than in the US. Thirdly, in Europe petrol is mainly dispensed under suction rather than under pressure, considerably lessening the likelihood of spills.

The relatively high cost of petrol in Europe also means that diesel fuel (which does not contain MTBE) is a competitive alternative to petrol for passenger vehicles, reducing the volume of petrol used. Higher costs and a different taxation structure have also been cited as providing more incentive for European petrol producers to avoid spills and wastage than in the US market. To date there have been few reports of MTBE groundwater contamination in Europe, although some researchers have warned that anticipated increases in MTBE levels in fuel to meet new European emission standards may bring with them similar problems to those that have occurred in the US.

(1) In the 1970s, MTBE was used in the US as an octane booster at 1-3% v/v. Use increased in the 1990s when the Clean Air Act required minimum oxygen levels for petrol sold in some metropolitan areas. MTBE is now used at 11% to reduce ozone production or 15% to control carbon monoxide emissions. MTBE-containing petrol constitutes about 27% of all petrol sales in the US.

(2) At present about 70% of liquid fuel used in Australia is locally refined, and MTBE is not added to locally produced petrol. Some petrol imports contain MTBE at levels of 3 to 7% v/v.

(3) Methly-tertiary-butyl-ether (MTBE) misclassified. Mehlman MA (2001) *American Journal of Industrial Medicine* **39**:505-508.

(4) Advance Notice of Intent to Initiate Rulemaking under the Toxic Substances Control Act to Eliminate or Limit the use of MTBE as a Fuel Additive in Gasoline, Federal Register Vol 65 No 58 p16093-16109, 24 March 2000.

## New Approaches For Water Quality Testing

The American Academy of Microbiology recently released a report advocating a radical overhaul of current approaches for measuring microbial water quality. The report *Reevaluation of Microbial Water Quality: Powerful New Tools for Detection and Risk Assessment*, was the outcome of a meeting of twenty-two international experts which took place in Florida during March 2000.

The report calls for the adoption of new technologies, particularly those based on molecular biology techniques, to provide more reliable methods of assessing human health risks, better early warning systems for hazardous events threatening water supplies, and improved ways of identifying and tracing contamination sources.

It makes a number of recommendations in the areas of microbial risk assessment, development of reliable molecular fingerprinting tools and databases to characterise pathogen characteristics and occurrence, improved education and communication to overcome barriers to acceptance of new methodologies, and consensus mechanisms for the assessment and development of standard techniques.

While acknowledging the contribution of traditional water quality measurements based on coliform bacteria to the protection of public health over the last century, the report underlines the inadequacy of this approach to assessing risks from pathogens other than faecal bacterial species. The traditional indicators are unreliable for assessing contamination risks for faecal viruses and protozoa, or for non-faecal pathogens such as *Legionella*. The chlorine sensitive nature of the coliform group also means that such measurements may provide a misleading assurance of safety for chlorinated supplies that are prone to contamination by more resistant organisms.

Citing recent instances of severe public health and economic impacts from contamination of drinking water, recreational water and shellfish supplies, the report notes several factors likely to lead to increases in risks of foodborne and waterborne diseases. International travel allows the rapid spread of pathogens from one continent to another via human carriers, and likewise the global nature of the food trade makes all countries vulnerable to imported pathogens. Ever increasing reliance on aquaculture to replace declining natural shellfish and fish catches means that coastal sewage pollution will pose a health risk to greater numbers of people.

Over the last few decades, advances in microbiology and molecular biology have had a huge impact in medicine, agriculture, bioremediation and many other areas, however these technologies have been very slow to penetrate the field of water quality measurement. Since water supplies are often prone to contamination from multiple point and non-point sources, identification and tracing of pollution sources is needed to implement effective management measures. Molecular techniques are seen to hold great promise in this area, and it is anticipated that direct detection of a range of microorganisms in environmental samples will soon be possible.

The report notes that there are both practical and behavioural barriers to the adoption of new methods. Concerns exist over the reliability of different technologies, and the potential for misinterpretation and misuse of results. In order to foster the development of new methods and their adaptation to routine use, it is essential that mechanisms are developed to enable reporting of results in a manner that does not expose innovative water utilities to bad publicity or recrimination.

Better education of policy makers is also needed, and scientists should ensure that their findings are presented in the context of the issue and with adequate explanation of the uncertainties involved in risk assessment.

The report urges more concerted attempts to document waterborne outbreaks and collect relevant information on their causes, and international collaborative approaches to developing, refining and standardising new methods for microbial water quality testing. While acknowledging that the practicality of advanced detection techniques such as gene chip technology have not yet been fully proven, it concludes that adoption of the new methodologies is essential to advance microbial risk assessment and provide more effective risk management for water supplies in the future.

The report is available from the web site of the Academy of Microbiology:
www.asmusa.org/acasrc/aca1.htm

## Value of Cyanobacterial Control

In the field of environmental regulation, as in other regulatory activities, there is an increasing need to provide evidence that the costs of compliance are justified by the benefits delivered to the community. In many areas the estimation of benefits in economic terms is not straightforward, as the benefits are "non-market goods" such as enjoyment of amenity which are not directly paid for by users. However, a number of techniques have been developed to estimate the equivalent monetary value of such benefits.

British researchers have carried out an assessment of the value of recreational and amenity values of a large water reservoir in Leicestershire which has been affected by cyanobacterial blooms in the past. The study estimated the annual value of the reservoir to users, and compared this to the costs incurred by the National Rivers Authority (NRA) in combating cyanobacterial blooms.

The Rutland Water reservoir is situated in a park some 1,260 hectares in area, and provides a range of recreational activities including sailing, fishing, windsurfing as well as walking and picnicking facilities. The reservoir experienced a large bloom of *Microcystis aeruginosa* in the summer of 1989, which forced its closure for a period of 6 weeks. Several animal deaths were attributed to the bloom and the closure of the reservoir attracted national media attention. Many other water bodies in the UK also experienced cyanobacterial blooms in 1989, and the NRA initiated a large program of data collection, analysis, modelling and remediation measures.

Three years after the reservoir closure, the researchers carried out a survey of visitors to determine patterns of usage, the activities undertaken and the value placed on the recreational and amenity benefits. The method used to estimate the economic value was the Contingent Valuation technique, whereby users were asked to state what amount of money they would be willing to pay each year to ensure continued access to the facilities. Visitors were shown a photoboard illustrating the current state of the reservoir (bloom-free), some basic information on cyanobacteria, and the condition of the reservoir during the 1989 bloom.

A total of 641 visitor parties were interviewed over a period of 18 days, representing 82.6% of those who were approached to take part. Participants were asked if they were willing to pay additional taxes to fund remedial water quality work to keep the reservoir free of cyanobacterial blooms. A total of 66.8% said they were willing to pay, 28.5% said they were unwilling and the remainder stated they did not know. Among those who did not wish to pay, the most common reasons given were that it was someone else's responsibility to pay, and that they paid too much tax already.

When asked how much they would be willing to pay each year, individual answers ranged from 0 to 1,000 pounds, with a mean of 16.74 pounds and a median of 2.00 pounds. In order to assess the influence of extreme values on these estimates, the authors analysed a number of data subsets which excluded either high or low values or both. Two measures were then chosen to calculate the mean willingness to pay (WTP), the whole sample mean of 16.74 pounds (without trimming extreme data), and the lower bound confidence interval on the mean of 11.71 pounds from a dataset that excluded the highest bid.

The total number of visitors to the Rutland Water reservoir was not recorded in the year of the survey, however the estimate from the following year was 800,00 to 1,000,000 visitors. A figure of 900,000 visitors was therefore used in calculations, together with data on the number of visitors per party, number of visits per year and type of visitor from the survey.

This process yielded an estimate of the overall willingness to pay ranging from 364,608 to 521,225 pounds per year. Specific data on the costs of measures undertaken at Rutland Water reservoir after the 1989 blooms was not available, however the average annual cost of cyanobacterial works undertaken in England and Wales by the NRA during the period 1998 to 1993 was 295,000 pounds. Thus the amenity and recreational value to the community of preserving access to the reservoir is clearly greater than the cost of water quality management measures.

*Measuring the Recreational and Amenity Values Affected by Toxic Cyanobacteria: A contingent valuation study of Rutland Water, Leicestershire* (Chapter 3); Pearson MJ, Bateman IJ and Codd GA. *In* Economics of Coastal and Water Resources: Valuing Environmental Functions, Kluwer, Dordrecht, The Netherlands (2001).
ISBN: 0792365046

## Update On US Arsenic Rule

The US EPA has received three expert reports on arsenic commissioned early this year as part of the review of the Arsenic Rule. The incoming Bush administration ordered the EPA to review the newly promulgated Arsenic Rule which was legislated in the last days of the Clinton government (1).

The revised Rule would have lowered the arsenic standard for drinking water from 50 ppb (parts per billion or micrograms per litre) to 10 ppb. The development of the proposed Rule had been criticised from many quarters, with some environmental lobbyists saying it was not strict enough to protect public health, while representatives of the water industry voiced concerns over the interpretation of the scientific evidence on health risks, the validity of EPA assumptions, and lack of transparency of calculations on the economic impact.

After withdrawing the Rule, the EPA commissioned three expert reviews:

- An examination of water treatment cost issues by a working group of the National Drinking Water Advisory Council (NDWAC).
- A review of issues surrounding the estimates of benefits and the cost-benefit analysis by a panel under the Science Advisory Board of the EPA (SAB).
- An analysis of issues relating to health risks by a sub-committee of the National Academy of Sciences (NAS).

The Arsenic Cost Working Group delivered its report on 24 August, the SAB review of benefits was submitted on 30 August, while the NAS report on health risks was released on 11 September.

Cost Analysis

The report examined the methodology used by the EPA to estimate national compliance costs for the Arsenic Rule, and made a number of recommendations for revision of the cost estimates. In addition, the Working Group recommended the adoption of improved methodology for costing of future drinking water rules, noting that the resources allocated to such estimates should be commensurate with the expected economic impact of the change.

On the whole, the reviewers concluded that the EPA had produced a credible estimate of the cost of arsenic compliance given the constraints of present rulemaking, data gathering, and cost models. However they also felt that the cost estimates could be further improved using more recent information on treatment technologies, and reassessing a number of assumptions including those on administrative and training costs.

In the area of waste disposal, the reviewers recommended that the EPA reassess the effectiveness of the Toxic Characteristics Leaching Procedure (TCLP) test which is used to determine whether a substance is to be classified as hazardous. Recent research on arsenic waste suggests that the TCLP test may underestimate toxicity. The water industry had expressed concerns over the EPA assumption that arsenic waste would be regarded as non-hazardous, and that specialised disposal would not be required.

The report also recommended that the revised cost estimates should present more detailed breakdowns of capital and recurrent costs, and the number of water supply systems affected and the populations served. It also recommended that more detailed consideration should be given to point-of-use treatment systems for small supplies, including requirements for inspections of individual household systems. In considering the disproportionate compliance costs for small systems, the reviewers recommended that the NDWAC convene a working group to review EPA's methodology and assumptions for determining national affordability for drinking water regulations.

Benefits Analysis

This report addressed five questions relating to assessment of benefits of the Arsenic Rule, and made general comments on the benefits-cost analysis produced by the EPA.

*Treatment of latency of benefits* - the review found the EPA analysis was flawed in its treatment of the latency of benefits associated with reduction of arsenic exposure. It noted that the expression "cessation-lag" was more appropriate to describe the predicted gradual decrease in cancer risks if people currently exposed to arsenic at 50 ppb had their exposure reduced to a lower level (2). The primary EPA analysis assumed an immediate single step drop in cancer risks rather than a slow decline, while the alternative analyses assumed a single step drop at the end of the time period. Both approaches are erroneous.

*Treatment of health endpoints other than bladder and lung cancer* - the reviewers noted there was considerable evidence of non-cancer health effects of arsenic including ischaemic heart disease, hypertension, diabetes and skin cancers. They suggested that while present data may be insufficient to establish dose-response relationships, careful analysis of such studies might indicate whether these effects occurred at arsenic levels being considered for regulatory decision.

*Whether reduction/elimination of exposure should be evaluated as a separate benefits category* - the EPA estimate of benefits relates to the value of fatal or non-fatal cancers avoided, not to the societal benefits of lower exposure levels (ie the non-health value that people might attach to the risk reduction). The reviewers concluded this was the appropriate approach.

*Treatment of total benefits and costs and incremental benefits and costs for alternatives* - the reviewers applauded the EPA for presenting costs and benefits of a range of regulatory options (ie consideration of different arsenic levels), but recommended that these should be broken down into categories to illustrate the differing impacts on large and small water supplies. This would allow a better understanding of how rapidly costs escalate as systems decrease in size. They also recommended that the benefits should be presented in terms of morbidity and mortality avoided as well as in monetary equivalent terms.

*Treatment of uncertainties in the analysis* - the benefit-cost analysis contains uncertainties in measurement of exposure, measurement of dose-response, variation in health outcomes, and measurement of costs. The reviewers considered the applicability of sensitivity analysis and the Monte Carlo technique. They concluded that sensitivity analysis of a range of alternatives, with explicit statement of the assumptions for each was appropriate for most aspects of the analysis. For some aspects where a distribution can be specified a Monte Carlo simulation would be desirable.

*General comments* - the reviewers commended a number of aspects of the EPA analysis but noted a concerns about the calculation of costs and benefits, and presentation of the results, especially in the Executive Summary of the EPA report.

Health Risks Analysis

This review included evaluation of additional evidence from publications on epidemiology, toxicology and risk assessment published since the 1999 National Research Council report *Arsenic in Drinking Water.* The reviewers noted that the additional evidence supported the role of chronic arsenic exposure in hypertension and diabetes. There were also reports of associations with adverse reproductive effects and respiratory illness, however these required verification by further studies. Four additional epidemiological studies of arsenic exposure in drinking water and internal cancers had been published; two from Taiwan, one from Chile and one from the US. Of these, all but the US study had shown increased cancer risks associated with arsenic exposure. The specialised population in the US study was felt to limit its applicability to the general population, and exposure measurement in this study was considered unorthodox (3). The other three studies had some improvements in methodology over the older Taiwan studies, and supported the findings from the earlier studies.

Some advances have been made in understanding the metabolism of arsenic, but the mechanisms by which adverse health effects are produced remain unclear. Given the diverse impacts on different organ systems, it is believed that the effects of arsenic are probably exerted through several biological modes of action. These may operate independently and they may exhibit different dose-response relationships. In the absence of data to the contrary, the reviewers concluded that arsenic should be treated as a genotoxic carcinogen (ie assumed to act directly on DNA to cause cancer). Therefore, in keeping with EPA policy, the low dose extrapolation of the dose-response curve should pass through zero (ie assuming no threshold exists). Thus any exposure is considered to entail some risk of producing cancer. This assumption produces a higher estimate of risk than if a threshold model were assumed.

It appears that arsenic metabolism may be influenced by genetic factors, age, arsenic dose and micronutrient levels, resulting in considerable variability in the host response to exposure. It has not been established whether cancer risks relate to cumulative exposure, average lifetime exposure or peak exposure levels. The internal cancers most strongly associated with arsenic (bladder and lung cancer) are also strongly associated with smoking,

and some studies suggest a synergistic interaction between the two exposures. If this relationship exists, it would affect the accuracy of extrapolating risk levels from one population to another if smoking patterns differ between the populations.

The reviewers concluded that the dose-response data from the early Taiwanese studies still remained the most appropriate basis for risk estimates. By extrapolating from this data through the zero point, they calculated estimated lifetime excess risks of lung cancer and bladder cancer in the US population for exposure to different concentrations of arsenic.

Theoretical Maximum-Likelihood Estimates of Excess Lifetime Risk (Incidence per 10,000 people)

| Arsenic Level | Bladder Cancer | | Lung Cancer | |
|---|---|---|---|---|
| microg/L | Females | Males | Females | Males |
| 3 | 4 | 7 | 5 | 4 |
| 5 | 6 | 11 | 9 | 7 |
| 10 | 12 | 23 | 18 | 14 |
| 20 | 24 | 45 | 36 | 27 |

These risk estimates are somewhat higher than those estimated in the original EPA report prior to proposal of the 10ppb limit for arsenic. These differences are attributable to use of a different comparison population by the reviewers, different statistical methods and use of US background rates for cancer rather than Taiwanese rates. The reviewers note that even their highest estimated cancer risk (45 cases per 10,000 males exposed to 20ppb arsenic over a lifetime) would be extremely difficult to detect by epidemiological studies.

The EPA has extended the effective date for finalisation of the Arsenic Rule until 22 February 2002 in order to provide time for further public comment and discussion. Following the release of the National Academy of Sciences review of health risks, many environmental lobby groups have called for an even lower standard than the 10ppb previously proposed by the EPA.

(1) See Health Stream 21 for a report on withdrawal of the Arsenic Rule.

(2) The term "latency" is normally used to describe the time delay between exposure to a cancer causing agent and development of a detectable cancer.

(3) See Health Stream Issue 15 From the Literature for a review of this study (Lewis DR et al. 1999).

## Climate Change and Waterborne Disease

A study of waterborne disease outbreaks in the US has shown that more than half were associated with severe storm events. Researchers at the Johns Hopkins University in Baltimore compiled data from the US EPA database of waterborne outbreaks and meteorological records from the 2105 watershed regions covering the United States. Outbreaks attributed to cross connections or back siphonage of sewage were excluded from analysis as were chemically related drinking water outbreaks and recreational water outbreaks.

Outbreak locations were assigned to the relevant watershed area, and monthly precipitation readings from weather stations within each watershed were analysed. A total of 548 waterborne outbreaks between 1948 and 1994 were included in the analysis. Of these, 51% were associated with extreme rainfall events ( highest 10% of rainfall figures) prior to the outbreak. Consideration of the top 20% of storm events produced an association with 68% of outbreaks. These associations were statistically significant.

For surface water outbreaks the association was strongest for rainfall events during the same month as the outbreak, while for groundwater supplies the strongest association was seen with a two month delay period. These observations are consistent with the immediate effects of contaminated runoff on surface water supplies, as opposed to the slower and more complex routes by which surface water contaminants may reach underground water tables.

This study confirms the findings of smaller regional studies and anecdotal observations from many waterborne disease outbreaks. Given the increasing frequency of heavy rainfall events, attributed by some to global warming trends, it has been speculated that waterborne disease outbreaks attributable to weather events are likely to rise in the future. Effects on illness rates through increasing foodborne infections and insect-borne diseases have also been predicted.

The association between extreme precipitation and waterborne outbreaks in the United States, 1948-1994.
Currerio FC et al. Am J Public Health (2001) **91**(8) p1194-1199.

# News Items

**A Consumer's Guide to Drinking Water**

The CRC for Water Quality and Treatment has produced a consumer's guide to drinking water that outlines all aspects of drinking water - from the catchment to the tap. The guide provides an overview of water in Australia and around the world and discusses how water is collected, treated, distributed, used and regulated. It has been developed for the general public, community and environment groups, students and others seeking information on our water supply systems.

The guide is available on the Web page of the CRC: www.waterquality.crc.org.au/

**Rolling Revision of Australian Drinking Water Guidelines**

- Several revisions to the ADWG were released in September by the NHMRC. These comprised a revised Chapter 4 (Radiological Quality of Drinking Water), and revised or new Fact Sheets on Thermotolerant Coliforms and *E. Coli*, Coliforms, *Burkholderia pseudomallei*, Microcystins, Nodularin, Cylindrospermopsin, Radium-226 and Radium-228, Other beta and gamma emitting Radioisotopes, Aluminium, Boron, Copper, Monochloramine, and Atrazine.

These items can be downloaded from the NHMRC website: www.health.gov.au/hfs/nhmrc/publications/synopses/eh19syn.htm

- The Public Consultation period for the Framework for Drinking Water Quality Management closed on July 6. Modifications to the Framework, in response to comments received during the consultation process and integration into the ADWG are now in progress.
- A Discussion Paper on *Microbial Indicators of Water Quality* is scheduled for release shortly.

**Walkerton Inquiry**

Public hearings into the E. coli outbreak that killed 7 people and affected about 2,500 in the town of Walkerton, Ontario were scheduled for completion on 25 September. The Inquiry has examined a wide range of issues relating to drinking water quality management and regulation, in addition to the specific circumstances surrounding the outbreak.

Among the material submitted was a 400 page report from the Office of Ontario's Chief Coroner which focused on the systemic deficiencies which allowed the outbreak to occur. The report made 57 recommendations based on assessment of the outbreak including:

- clear delineation of the responsibilities of oversight agencies, and adequate resourcing of these activities
- annual inspections and spot checks on water treatment facilities, and follow up to ensure deficiencies are addressed
- an orientation program on drinking water risk, management and regulation for municipal politicians and elected public utility commissioners
- improved training of water supply operators including knowledge of health risks
- accreditation of private testing laboratories and mandatory requirements for reporting adverse monitoring results

The Inquiry is expected to complete its work later this year.

**Update On Cryptosporidium Outbreaks**

As reported in our last issue, waterborne *Cryptosporidium* outbreaks recently occurred in Belfast, Northen Ireland, and North Battleford, Saskatchewan, Canada.

Initial investigations attributed the Belfast outbreak to overflow of untreated water from a blocked drain into the filtered water stream. According to information from the local public health unit, the water supply in question was not considered to be at risk of *Cryptosporidium* contamination and thus water leaving the plant was not subject to continuous monitoring under Drinking Water Inspectorate regulations. However continuous monitoring was being carried out on an aging aqueduct through which the water was delivered to part of the city. Monitoring at the plant was commenced only after the outbreak was recognised.

The boil water order on North Battleford was lifted on 25 July, three months after the outbreak was detected. The outbreak is believed to have affected at least 1300 people across several Canadian provinces. A number of changes have been made to the operation of the surface water treatment plant including provision to allow water to run to waste, and more stringent operating and monitoring guidelines. A UV treatment stage will be added to the plant before the end of the year. A Commission of Inquiry into the outbreak is currently underway.

# From the Literature

Arsenic

**Arsenic in Drinking Water and Pregnancy Outcomes.**
Ahmad SA, Sayed SU, Barua S, et al. Environ Health Perspect (2001) **109**(6) p629-31.

This study compared pregnancy outcomes in women who were chronically exposed to arsenic via drinking water and in nonexposed women.

A cross-sectional study was carried out in two villages in Bangladesh. An exposed group of residents from the village of Samta were compared to a nonexposed group of residents from the village of Katiarchar. Groundwater is primarily used as the water supply in Bangladesh and in large areas of the country supplies are contaminated with arsenic. The study subjects were married women of reproductive age (15-49 years) who previously had at least one pregnancy. The Katiarchar subjects used tube wells with an arsenic content of less than 0.02 mg/L whereas the Samta subjects used wells with an arsenic content above 0.05 mg/L for at least 5 years. The groups were matched for age, socioeconomic status, education and age at marriage.

Women who met the inclusion criteria were recruited through house-to-house visits. Information was collected on the subjects' lifetime pregnancy history. Arsenic concentrations in tube wells were obtained from the Department of Occupational and Environmental Health database. Rates of stillbirth, spontaneous abortions and preterm births were calculated and pregnancy outcome events were compared in the exposed and nonexposed groups.

There were 96 exposed and 96 unexposed women included in the study. Of the exposed group, 98% had been drinking water that contained more than 0.10 mg/L arsenic and 43.8% of these had been drinking this water for 5-10 years. Skin manifestations of arsenic toxicity were found in 22.9% of the exposed group. Among the exposed group adverse pregnancy outcome rates per 1,000 live births for spontaneous abortions, stillbirths and preterm birth were 68.8, 53.1 and 68.8 respectively as compared to 23.7, 23.7 and 27.1 for the same outcomes among the unexposed group. These differences were statistically significant (*p*-values of 0.008, 0.046 and 0.018 respectively). Adverse pregnancy outcomes were more common in women with longer duration of exposure to arsenic.

The authors conclude that adverse pregnancy outcomes were more likely among women who were chronically exposed to arsenic in drinking water.

*Comment In this study, pregnancy outcomes were self-reported by the participants as medical record systems in rural Bangladesh are rudimentary and pregnancy testing is rare. However the authors note that in rural areas, pregnancies are important events and it is believed that the number of pregnancies and outcomes are likely to be accurately reported.*

Copper

**Nausea Threshold in Apparently Healthy Individuals Who Drink Fluids Containing Graded Concentrations of Copper.**
Olivares M, Araya M, Pizarro F, Uauy R. Regul Toxicol Pharmacol (2001) **33** p271-5.

Consuming drinking water contaminated with copper has been associated with gastrointestinal effects such as nausea and vomiting and in rare cases diarrhoea and abdominal pain. The aim of this study was to evaluate the threshold copper concentration for the appearance of nausea in healthy individuals drinking fluids with graded concentrations of copper. As nausea represents the earliest response, it may be an adequate indicator to evaluate acute gastrointestinal effects. Data obtained from this study may provide a more scientific basis for guideline values for copper in drinking water.

Healthy subjects aged 25 to 60 were recruited in Southeastern Santiago, Chile. In the first study, a range of copper concentrations from less than 0.01 to 12 mg elemental Cu/L were administered randomly in 200mL of purified water to asymptomatic subjects after an overnight fast. Subjects were asked to report symptoms 15 and 60 minutes after ingestion as well as complete a questionnaire on gastrointestinal and other symptoms. This same questionnaire was administered by phone the following morning. The concentration at which a subject first reported an outcome was defined as the apparent threshold and this was confirmed by repeat exposure. The second study aimed at evaluating whether and how concentrations defined as a confirmed threshold were

modified when copper was delivered in an orange flavoured drink. The same study design was used with subjects receiving the same copper concentrations, starting at the confirmed threshold concentration in water.

There were 61 subjects who took part in both studies. A dose-response relationship was found between copper ingestion and appearance of gastrointestinal symptoms with copper concentrations between 4 and 12 mg Cu/L. Mild nausea shortly after copper ingestion was reported by 5 of 48 subjects at 4 mg Cu/L in water, but no symptoms were reported by 51 subjects exposed to 2 mg/L. The no-observed-effect level (NOEL) for copper in purified water was 2 mg/L for nausea and 4 mg/L for vomiting. The NOEL increased to 6 mg Cu/L for nausea when copper was ingested with orange-flavoured drinking. There were no subjects who experienced vomiting with up to 12 mg Cu/L in orange-flavoured drink. The results suggest that for acute effects the tolerable copper intake is between 2 and 4 mg Cu/L in water, this depends on whether apparent or confirmed nausea thresholds are used as the standard.

**A review of the science behind drinking water standards for copper.**
Fewtrell L, Kay D, Macgill S. Int J Environ Health Res (2001) **11**(2) p161-7.

This paper examines the strength of the evidence used to derive the European Union drinking water directive for copper (2mg/L) and the US EPA action level (1.3 mg/L). The scientific evidence for each is reviewed relative to a quality audit framework which evaluates aspects of Observation, Method, Output, Peer review and Validity.

The quality of evidence for the EU level is rated at only 6.5 points out of a possible total of 36, while the US EPA level scores 10 points out of 36. The authors note that current standards for copper are based on scant data of unsatisfactory quality including a single reconstruction of an accidental human poisoning incident, and an unpublished sub-chronic exposure study in dogs that may not be a valid model for human effects.

They conclude that while there is little evidence that copper exposures of up to 3 mg/L are problematic, more robust and scientifically defensible data would be highly desirable for defining public health risks.

Disinfection Byproducts

**Relation between trihalomethane compounds and birth defects.**
Dodds L, King WD. Occup Environ Med (2001) **58** p443-6.

The aim of this study was to evaluate the risk of birth defects from exposure to two trihalomethanes, chloroform and bromodichloromethane (BDCM) in public water supplies. A retrospective cohort study was undertaken among 49,842 residents of Nova Scotia, Canada between 1988 and 1995 that included women who had singleton births who lived in an area with a municipal water supply. Perinatal information was obtained from the Nova Scotia Atlee perinatal database. The Nova Scotia Department of Environment provided information on exposure concentrations to trihalomethanes from the results of routine monitoring. The birth defects studied were neural tube defects, major cardiac defects, cleft defects and chromosomal abnormalities.

Maternal exposure to THMs during the relevant time window for each type of defect was estimated from routine water supply measurements in the area of residence. There was no information on drinking water consumption or other routes of exposure (dermal or inhalation) to THMs. Information on potential confounders such as maternal age, parity, smoking and family income was included in the statistical analysis.

For neural tube defects, excess risk was observed only at the highest level of exposure to BDCM and no dose-response pattern was evident. The adjusted relative risk (RR) at exposure to the highest concentration of BDCM (20 microgram/l or above) relative to exposure to concentrations less than 5 microgram/l was 2.5 (95% CI 1.2 to 5.1). There was no association between chloroform and neural tube defects. For cardiac defects, there was a significant reduction in risk associated with exposure to 20 microgram/l or higher of BDCM (RR=0.3, 95% CI 0.2 to 0.7) and a trend of decreasing risk associated with increasing level of exposure. A decreased risk associated with exposure to levels of 100 microgram/L chloroform or more (RR=0.7, 95% CI 0.5 to 1.0) was suggested. There were no significant associations or trends between concentrations of BDCM and chloroform and cleft defects. There was a stronger relationship between chloroform and

chromosomal abnormalities than between BDCM and chromosomal abnormalities.

*Comment This study included therapeutic pregnancy terminations for congenital abnormalities and thus provides a greater degree of coverage of possible pregnancy outcomes than most previous studies.*

**Use of routinely collected data on trihalomethanes in drinking water for epidemiological purposes.**
Keegan T, Whitaker H, Nieuwenhuijsen MJ, et al. Occup Environ Med (2001) **58** p447-52.

The aim of this study was to characterise routinely collected data on trihalomethanes (THM) in drinking water to determine the best measures for use in exposure assessment for epidemiological studies. Routinely collected data on total trihalomethane (TTHM) concentrations was obtained from a United Kingdom water company in the north west of England for the years 1992-1996. Information was gathered on water company supply zones including their geography, the type of water each received and the population residing in each. Water zones varied from each other in the area, the number of people served and the volume of water passing through.

The area served by the water company is divided into 288 water zones serving about 6.8 million people. Water zones were sampled on average 11.1 times a year and a range of TTHM concentrations across all water zones of 1.65-188.7 micrograms/L was found. Over the five-year period studied, the mean annual zone TTHM concentrations were similar and all were less than half the statutory limit of 100 micrograms/L. Maximum concentrations reduced considerably over the years suggesting improvements in treatment have been successful in reducing byproduct levels. The mean concentrations for chloroform were similar over the years studied, while for bromodichloromethane (BDCM) and dibromochloromethane (DBCM) the means rose slightly over time.

When variation over the years was assessed, the correlation between the years was high and the correlation between the mean annual zone concentrations for the individual THMs was also high. Correlations between individual THMs and TTHM were analysed. Chloroform correlated well with TTHM, less well with BDCM and there was no correlation with DBCM. There was more variation between zones for chloroform and BDCM than within zone variation, thus classification of exposure levels by zone of residence appears valid for epidemiological studies. In contrast for DBCM, variations within a zone were much more marked and were higher than variations between zones. In this case, assignment of exposure on a zonal basis is likely to lead to a significant degree of misclassification that may affect risk estimates. Little seasonal variation was seen for TTHMs which suggests that the annual mean may be a good estimate for exposure levels. Some monthly variation was found however no consistent trend was seen.

The results suggest that for this study area, annual water zone means calculated from routinely collected data may be a good measure of exposure to particular disinfection byproducts for epidemiological studies.

*Comment This study illustrates the importance of understanding the characteristics of the individual water supply system when assigning exposure levels in epidemiological studies of disinfection byproducts. Preliminary work of this nature will indicate whether routinely collected measurements will provide a reasonably accurate exposure classification for the DBP of interest, and whether one compound can be used as a surrogate exposure measure for others.*

**Foetal growth and duration of gestation relative to water chlorination.**
Jaakkola JJK, Magnus P, Skrondal A, Hwang B-F, Bacher G, Dybing E. Occup Environ Med (2001) **58** p437-42.

The objective of this study was to assess the effect of exposure to chlorination byproducts during pregnancy on foetal growth and pregnancy duration. The study included 137,145 live newborn infants registered by the Norwegian birth registry for the years 1993-5, excluding those with missing data on maternal water source or birth weight, and those with congenital birth defects. Information was obtained on birth weight, gestational age and some potential confounders. Three measures of foetal growth were used: birth weight, low birth weight (below 2500g) and small for gestational age.

Exposure was based on municipal water quality information on chlorination and natural organic matter content of raw water and on mothers' place of

residence during pregnancy. Exposure categories were constructed on the basis of chlorination and weighted mean colour (a quantitative measure of the dissolved organic carbon). High colour and chlorination was compared to low colour and no chlorination (the reference category).

The adjusted odds ratio (OR) contrasting the chlorination and high colour category with the reference category for low birth weight was 0.97 (95% CI= 0.89 to 1.06) and for small for gestation age was 1.00 (95% CI= 0.91-1.10) and therefore neither of these outcomes were significantly related to exposure. The risk of preterm delivery was slightly lower among the exposed population than in the reference category, adjusted OR= 0.91 (95% CI =0.84-0.99). This study found no association between foetal growth and exposure to chlorination byproducts during pregnancy.

**Assessing Exposure to Disinfection By-products in Women of Reproductive Age Living in Corpus Christi, Texas, and Cobb County, Georgia: Descriptive Results and Methods.**
Lynberg M, Nuckols JR, Langlois P, et al. Environ Health Perspect (2001) **109**(6) p597-604.

The objective of this field study was to describe the relationship between different measures of exposure to disinfection by-products (DBP's) within individuals and between populations served by water systems with very different concentrations and speciation of trihalomethane compounds (THM).

This study assessed exposure in women from two areas: Corpus Christi, Texas (with predominantly chlorinated DBPs) and Cobb County, Georgia (with predominantly brominated DBPs). Subjects were selected among mothers who had given birth within the previous 18 months. Mothers were selected from hospital records and met inclusion criteria if they had given birth to healthy infants from June 1998 to May 1999. Twenty-five women from each site participated in the study.

Exposure was assessed to DBPs by telephone interviews on water use and consumption and through in-home visits where on 2 consecutive days a diary was completed concerning water use and consumption patterns. Two 10-mL blood samples were taken during the visits, just before and just after showering, as well as duplicate tap water samples. Water samples were also collected from the water-treatment plants and the distribution system. Other measures of exposure assessed included residential water flow, tap water quality, blood THM levels and residence characterisation which was used in total exposure modelling to THMs through inhalation, dermal absorption and ingestion.

Brominated compounds in tap water samples from Corpus Christi accounted for 71% of the total THM concentration by weight as compared to Cobb County where they accounted for less than 16%. The median total THM levels at the plant, in the distribution system and in the homes were higher in Cobb County than in Corpus Christi. Pre-shower blood levels of THMs were compared between the two sites and were significantly different for each of the THM species except for bromodichloromethane. After-shower blood levels were also significantly different between the two sites for all THMs. When the change in blood levels during showering were compared between the sites, except for bromodichloromethane, increases in chloroform and total THM blood levels were significantly greater in Cobb County than in Corpus Christi. Increases in bromoform and dibromochlormethane blood levels were significantly greater in Corpus Christi.

The results show that blood levels of THM species vary greatly from one population to the next and depend on the characteristics of the water and water use activity in the home. The information obtained from this study can be used for epidemiological studies on the potential health effects of DBPs.

<u>Fluoride</u>

**Effect of long-term exposure to fluoride in drinking water on risks of bone fractures.**
Li YM, Liang CK, Slemenda CW, et al. J Bone Miner Res (2001) **16**(5) p932-9.

This study was undertaken to determine the prevalence of bone fractures in Chinese populations residing in rural communities in areas which have varying amounts of fluoride. In these rural populations fluoride exposure comes almost entirely from drinking water and food, with little contribution from toothpaste, mouthwashes or dietary supplements.

Subjects aged 50 years of age or more were recruited from communities with water fluoride concentrations ranging from 0.25 to 7.97 ppm. Subjects had lived for a minimum of 25 years in the study communities and had lifelong exposure to the specified fluoride level in drinking water. The residence of each participant was determined and samples of drinking water were collected and analysed for fluoride and eight other elements. The fluoride content in ambient air was determined. Surveys were conducted to confirm that participants had no other source of fluoride exposure. Information was collected from subjects on their medical history, demographic information, bone fractures, physical activity, tea drinking, cigarette smoking and alcohol consumption. Extra information was obtained if the subject had had a bone fracture. A randomly selected 10% of subjects completed a 3-day dietary survey and dietary intake of calcium, protein and fluoride were analysed.

There were a total of 8,266 study participants. The first analysis included total, spinal and hip fractures since age 20 years. The populations with the lowest (0.25-0.34ppm) and the highest (4.32-7.97 ppm) fluoride in drinking water showed a significantly higher prevalence of overall fractures ($p$=0.01) than those living in areas where fluoride concentration in water was 1.00-1.06 ppm.

Fracture prevalence in relation to water fluoride concentration approximated a U-shaped pattern. The risk for hip fracture was significantly higher in the highest fluoride group (4.32-7.97 ppm) than in the population with 1.00-1.06 ppm fluoride, which had the lowest prevalence. Hip fracture prevalence rose for levels above 1.06 ppm fluoride, although the difference was not statistically significant until the highest category. For spinal fractures there were no statistically significant relationships. The data was also analysed for overall bone fractures since age 50 years. The pattern found was similar to the pattern found for overall fractures since age 20 years but not so pronounced.

Overall this study showed long-term fluoride exposure from drinking water containing 4.32 ppm or more increases the risk of overall fracture and hip fracture. Water fluoride levels of 1.00-1.06 decrease the risk of overall fractures relative to negligible fluoride levels, however there was no significant protective effect for hip fractures.

Helicobacter

**Helicobacter *pylori* Prevalences and Risk Factors among School Beginners in a German Urban Center and Its Rural County.**
Herbarth O, Krumbiegel P, Fritz GJ, et al. Environ Health Perspect (2001) **109**(6) p573-7.

This study was conducted to determine potential sources of *Helicobacter pylori* in the environment of young children in Germany. Preschool children are thought to be the main risk population, however a major route of transmission has not been identified.

A *H. pylori* colonisation screening test was administered to children eligible to enter grade one in the fall of 1998 in Leipzig, Germany as well as to its rural region, the County of Leipzig. The gastric *H. pylori* colonisation test using the stable isotope-aided *in vivo* [$^{13}$C] urea breath test was administered to children on a voluntary basis as part of a mandatory medical examination. Parents completed a detailed self-administered questionnaire.

A total of 3,347 school beginners participated in the breath test and 2, 888 parents completed the questionnaire. *H. pylori* infection was found in 179 children (6.5% city and 5.7% country) of this preschool population. A cluster analysis was conducted to identify the most important variables in terms of risk associated with *H. pylori* positivity. For the city children significant associations with *H. pylori* were found for contact with pet hamsters (OR =2.4; 95% CI, 1.2-4.7; $p$= 0.015) and travels to Asian countries (OR = 3.7; 95% CI, 1.6-8.7; p=0.002). For the country children the significant associations were drinking of water from nonmunicipal sources (OR = 16.4; 95% CI, 3.1-88.5; $p$=0.001), more than 3 children living in a household (OR = 4.2; 95% CI, 1.2-14.6; $p$=0.02), and contact with pet hamsters (OR = 2.4; 95% CI, 1.0-5.7; $p$=0.04). Reported clinical symptoms did not significantly contribute to the prediction of *H. pylori* positivity.

The authors suggest the significant association of *H. pylori* positivity with drinking nonmunicipal water found among country children might reflect contamination well water by human excrement used as garden fertiliser. The results of this study suggest that indirect faecal-oral transmission and living conditions may play a major role in the spread of *H. pylori* infection.

Nitrate

**Agricultural contamination of groundwater as a possible risk factor for growth restriction or prematurity.**
Bukowski J, Somers G, Bryanton J. J Occup Environ Med (2001) **43**(4) p377-83.

A case-control study was undertaken on Prince Edward Island (PEI), Canada to examine the associations between intrauterine growth restriction (IUGR) and premature birth and elevated levels of nitrate in drinking water. The drinking water on PEI comes entirely from groundwater, including both reticulated municipal supplies and private wells. Agricultural and residential areas are interspersed over the area of the island, in some intensively cultivated areas higher than average levels of nitrate have been found in groundwater. Nitrate levels may represent a surrogate for agricultural contamination and elevated levels have been found to be associated with adverse reproductive outcomes in some studies.

Cases of IUGR and prematurity that occurred on PEI for the years 1991 to 1994 were identified from the Reproductive Care Program database of all births. A nitrate level exposure map was developed using Island-wide data from public and private wells for the years 1990 to 1993. The island was divided into 47 areas based on contiguous postal codes that had similar water supplies. Nitrate levels were classified into 6 categories with median values of 0, 1.3, 2.3, 3.1, 4.3, and 5.4 mg/L Nitrate-Nitrogen. Exposure levels for women during pregnancy were assumed from the residential postcode at the time of delivery. Statistical analysis was adjusted for a number of factors known to influence IUGR and prematurity including third-trimester smoking, previous history of low birth weight or prematurity, parity, maternal age and height, insufficient maternal weight gain, history of abortion or pregnancy-induced hypertension.

The study included 210 IUGR cases, 336 premature births and 4098 controls. A significant dose-response relationship was found between nitrate level and IUGR, although excess risk was clustered in the higher median exposure categories of 3.1 mg/L and 4.3 mg/L. There was no excess risk in the highest median category of ≥5.4 mg/L, which only contained 3 cases. There was a strong association between nitrate exposure category and prematurity, with a significant dose-response trend ($P$=0.001). The excess risk was greatest in the highest exposure category of ≥5.4 mg/L. The current Canadian guideline for nitrate in drinking water is 10 mg/L Nitrate-Nitrogen.

The study found quite consistent increased risks for those living in the higher nitrate exposure categories. However the authors note the results must be interpreted with caution because of the ecological nature of the nitrate exposure categories with no information on individual nitrate levels and the potential for serious confounding. Although adjustments were made for socioeconomic status based on postcode areas, significant variations between individuals are likely to exist in any one area and these may affect pregnancy outcomes. Therefore the possible association observed here needs to be confirmed by a more thorough exposure assessment on the individual level.

**Municipal Drinking Water Nitrate Level and Cancer Risk in Older Women: The Iowa Women's Health Study.**
Weyer PJ, Cerhan JR, Kross BC, et al. Epidemiology (2001) **11**(3) p327-8.

In Iowa the heavy use of nitrogen fertilisers over a prolonged period of time had resulted in 30-40% of finished public water supplies being contaminated with nitrate-nitrogen at levels above 5mg/L. When nitrate is ingested some of it is reduced to nitrite which can then form *N*-nitroso compounds that are highly carcinogenic. The role of nitrate in drinking water and cancer incidence was evaluated in the Iowa Women's Health Study; a large prospective cohort study conducted from 1986 through 1998.

In 1986 a baseline survey was mailed to women 55 to 69 years of age and information on demographics, a variety of risk factors for cancer and prevalent medical conditions was obtained. A food frequency questionnaire was also included. In 1989 a follow-up questionnaire was mailed out and participants were asked their main source of drinking water at their current residence and how long they had been drinking that type of water.

Exposure to nitrate in drinking water from 1955 through to 1988 was assessed by using historical analytical data on Iowa municipal water supplies. Each women was assigned an average level of nitrate exposure calculated on a community basis (quartile

cutpoints of 0.36, 1.01 and 2.46 mg/L nitrate-nitrogen were used). For the women who used private wells no nitrate data was available. The cohort was examined annually for incidence of cancer by linking personal identifiers to the State Health Registry of Iowa's cancer database. Mortality was determined by linkage with the National Death Index.

There were 21,977 women in the analysis with 75% using municipal water and 25% using private wells. There were 3,150 cases of cancer from 1986 through 1998. A positive trend between level of nitrate in municipal water and risk of bladder and ovarian cancers was found. The relative risks (RRs) across nitrate quartiles for bladder cancer were 1, 1.69, 1.10 and 2.83, although statistical significance was not reached. For ovarian cancer RRs were 1, 1.52, 1.81 and 1.84 although again the elevation in risk was not statistically significant.

There was an inverse trend for cancer of the uterine corpus and rectum and municipal water nitrate levels. RRs for uterine cancer were 1, 0.86, 0.86 and 0.55 with the reduction in risk being statistically significant for the highest exposure level. For rectal cancer the RRs were 1, 0.72, 0.95 and 0.47, with a statistically significant reduction in the highest exposure category. These associations were still present after adjustment for common cancer risk factors, modulators of nitrosation (smoking, vitamin C and vitamin E), dietary nitrate and water source.

There was however, no consistent trend between municipal water nitrate levels and cancer risk for all sites, leukemia, NHL, melanoma, or cancers of the colon, kidney, breast, or lung. To evaluate the role of a longer induction period the association between nitrate levels from 1955-1964 with cancer incidence from the period 1986-1998 among women who had the same municipal water supplies for more than 20 years was analysed. The results from this analysis were similar to the results from the full analysis.

The authors note that the positive association found here for bladder cancer has been found in some other studies and is biologically plausible. The positive association with ovarian cancer and the inverse associations with uterine and rectal cancer have not been previously documented and were unexpected results.

**Residential Water Source and the Risk of Childhood Brain Tumors.**

Mueller BA, Newton K, Holly EA, Preston-Martin S. Environ Health Perspect (2001) **109**(6) p551-6.

A case-control study was conducted to investigate the association between source of residential drinking water during pregnancy and childhood brain tumour (CBT) occurrence. CBT may potentially be associated with exposure to nitrate in drinking water which when reduced to nitrite can then form *N*-nitroso compounds that are highly carcinogenic. Private wells are not subject to regulation and may have higher nitrate levels than public water supplies.

Children younger than 20 years who were diagnosed with primary tumours of the brain, cranial nerve, or meninges were identified from three cancer registries containing data for 19 counties on the US west coast. Subjects were from Los Angeles County, the San Francisco Bay area of California and the Seattle-Puget Sound area of western Washington State. A control group was identified from these regions using a random digit dialling procedure.

A total of 540 mothers of cases and 801 mothers of controls were interviewed and a detailed questionnaire was administered. Information on demographics and potential exposures from the time of pregnancy with the index child to the date of the child's tumour diagnosis was obtained; for controls a similar date was used. Mothers were asked about sources of household water during the prenatal and early childhood period and estimated the proportion of bottled water consumed during pregnancy. Mothers living in the same residence as during pregnancy with the index child had dipstick measurements of nitrate and nitrite in the tap water taken.

No increased risk of CBT was associated with use of any well water relative to use of at least some public water, (OR=1.1; 95% CI, 0.8-1.7). An increased risk of CBT was found among children in western Washington whose mothers used well water as the only source of household water supply during pregnancy (OR=2.6; 95% CI, 1.3-5.2), however a decreased risk of CBT was found in the Los Angeles County group who used only well water (OR=0.2; 95% CI, 0.1-0.8). No increased risk was observed in the San Francisco area well users (OR=0.7; 95% CI, 0.1-6.6). Of the subjects who had dipstick

measurements taken of tap water, the risk of CBT associated with the presence of either measurable nitrite and/or nitrate was not significantly elevated (OR=1.1; 95% CI, 0.7-2.0).

The results of the study do not provide strong support for the hypothesised association between increased risk of CBT and wells as the source of residential water. However, regional differences in the content of well water may exist, and the association between well water use and CBT in western Washington state requires further investigation.

Outbreaks

**Community surveys of self-reported diarrhoea can dramatically overestimate the size of outbreaks of waterborne cryptosporidiosis.**
Hunter PR, Syed Q. Wat Sci Tech (2001) **43**(12) p27-30.

Recent evidence from the UK suggests that the self-reporting of diarrhoeal disease in retrospectives surveys may be dramatically overestimating the true population level of illness. If this is correct then the large number of cases of cryptosporidiosis attributed to the 1993 Milwaukee outbreak (403,000) may also be an overestimate. An outbreak in North West England of cryptosporidiosis was used to conduct a study into the validity of population-based surveys for estimating the accurate size of waterborne outbreaks.

The outbreak occurred during April and May 1999 with a total of 308 laboratory confirmed cases of cryptosporidiosis in four health authority areas. A single reservoir in the English Lake District was implicated as the source of the contaminated drinking water. A community survey was conducted in 8 towns, 4 of which were in the area supplied by the suspect reservoir and 4 were outside the affected area (the control towns). A questionnaire was sent randomly to 120 households in each town.

A total of 1,613 individuals were included in the study. The attack rate for those towns in the outbreak area was 12.8% (95% CI, 10.5-15.2), and the attack rate for the control towns was 13.5% (95% CI, 11.2-16.1). There was no significant difference in the rates of illness in the two areas despite the occurrence of a detectable outbreak. The same approach as the Milwaukee outbreak was used to estimate the size of the outbreak in North West England by extrapolating from the survey to the whole population, then subtracting the assumed background rate of disease to estimate the size of the outbreak. A figure of 151,800 cases related to the outbreak was calculated.

The authors suggest that there are two interrelated sources of error in the approach used in Milwaukee. The first is the estimation of background disease incidence and the second is the potential for recall-bias. It is suggested that the background level of disease is much higher than the 0.5% used in the Milwaukee estimate. With the annual diarrhoeal risk of about 1.4 episodes per person per year reported in the US, a monthly level of 11.7% is calculated, therefore the actual number of cases in the Milwaukee outbreak would be decreased to 42,260. A number of studies have shown that retrospective surveys seem to over-estimate levels of diarrhoeal illness by a factor of about 2.8 compared to prospective studies. Applying this factor to the Milwaukee figures would further reduce the number of outbreak cases to 15,090.

The control towns in this study were in close proximity to the outbreak area and the high rates of diarrhoeal illness reported in these towns may be due to many respondents believing they were in the area at risk which may have increased the incidence of recall bias. The media attention surrounding the outbreak may also have added to the recall bias, with people more likely to say they suffered from diarrhoea in the past few weeks.

The authors suggest that the Milwaukee outbreak numbers are overestimated by a factor between 10 and 100. This has implications for the validity of quantitative microbial risk assessment, which is used for estimating the burden of microbial disease in the community.

*Comment This paper points out the difficulty in estimating the true rate of disease in the community during outbreaks, particularly where widespread publicity has occurred, but also under normal circumstances. In the last issue of Health Stream we reviewed a paper on serological data from Milwaukee children that suggested a very high rate of exposure to Cryptosporidium during the period of the outbreak (McDonald AC et al. 2001).*

**Waterborne epidemics in Finland in 1998-1999.**
Miettinen IT, Zacheus O, von Bonsdorff CH, Vartiainen T. Wat Sci Tech (2001) **43**(12) p67-71.

In Finland the majority of drinking water comes from groundwater or is produced by using artificial groundwater recharge techniques. Eighty-seven percent of the population uses drinking water produced by public waterworks. Groundwater supplies usually serve small communities of less than 500 consumers, in contrast to surface water supplies which serve the large population centres. Groundwater quality is good and disinfection is seldom needed whereas surface water contains much humic matter and requires treatment before distribution. Since 1997, municipal health authorities in Finland have been required to report all foodborne and waterborne epidemics to the National Public Health Institute.

During the period 1998-1999 there were a total of 14 waterborne epidemics registered in Finland causing about 7,300 cases of illness. Of these outbreaks, 13 occurred in communities using undisinfected groundwater and one was related to water produced by surface waterworks. Of the waterborne outbreaks, 50% were associated with public water services and the other half with private drinking water systems. The majority of cases of illness were reported in epidemics related to public water services and only 290 cases were associated with private water systems.

Reasons for contamination of drinking water were fissures in bedrock, flooding, leakage in pipelines, surface runoffs and insufficient treatment. The cause was not identified for four outbreaks. Actions taken to end the epidemics were most commonly boiling of drinking water. Private water systems stopped using the contaminated water and used alternative sources. Public water works used chlorination and flushing of the pipeline network to remove contamination.

The microorganism causing the epidemic was identified in most cases. In eight of the waterborne epidemics Norwalk-like viruses were responsible, and *Campylobacter sp*. were responsible for three outbreaks. Most cases of illness were caused by Norwalk-like viruses (68%) followed by *Campylobacter* (31%). For the other 1% of cases no causative agent could be identified.

Water Quality

**Correlations between microbial parameters from water samples: expectations and reality.**
Tillet HE, Sellwood J, Lightfoot NF et al. Water Science and Technology (2001) **43**(12) p19-22.

This paper highlights issues surrounding the use of microbial test results, in particular the examination of correlations between parameters. The authors emphasise that the random variation in the numbers of microorganisms even in well mixed samples means that simplistic approaches to sampling and data analysis are likely to be invalid. The authors suggest that a more systematic approach to sampling design is needed to ensure that sufficient data are collected to characterise natural variations, and allow relationships between parameters to be distinguished.

**Economic study of the treatment of surface water by small ultrafiltration units.**
Drouiche M, Lounici H, Belhocine D, Grib H, Piron D, Mameri N. Water SA (2001) **27**(2) p199-204.

This study investigated the operation and efficiency of ultrafiltration units to treat surface water to a drinking water standard for supply to small villages, not exceeding 3000 people, of the Kabylia region of North Africa. An economic study of the ultrafiltration process was also undertaken.

A pilot scale organic ultrafiltration membrane unit was used to treat surface water, which was collected from the Keddara Dam. The ultrafiltration process was found to be efficient for reducing suspended matter and natural organic matter, and bacterial levels were reduced by 4 to 6 logs. The results indicated that it was possible to produce satisfactory drinking water from surface water, and that long operation times could be achieved before membrane fouling occurred.

The total cost for establishment of the ultrafiltration treatment facility for water production of 20 $m^3$/h was about $210,000. An operational cost of $0.235 per $m^3$ of treated water was estimated. This was not considered excessively high for the states in the North African region since people in the region buy bottled drinking water at $0.2 per litre.

**Prevention of bacterial diarrhea by pasteurization of drinking water in Kenya.**
Iijima Y, Karama M, Oundo JO, Honda T. Microbiol Immunol (2001) **45**(6) p413-6.

A hospital based prevalence study of diarrhoea among children undertaken in a coastal rural area of Kenya (Malindi) revealed that infectious bacterial diarrhoea was primarily transmitted through drinking water. In 1995, an intervention study of water pasteurisation was undertaken in four agricultural villages around Malindi.

Information was obtained on household number, population and water source. Most of the residents had very low income levels and villages had no organised sanitation systems. A temperature of 70C was decided upon to pasteurise drinking water based on the heat susceptibility of four bacterial pathogens (diarrheagenic *E. coli*, *Salmonella*, *S. dysenteriae* and *V. cholerae).* A thermoindicator was used to assess the temperature of the water; this was a stainless steel plate with colour indicators of temperature. Drinking water was pasteurised in the houses by putting 3 to 10 litres of water in a pot or a kettle and heating it on burning firewood, measuring its temperature with the thermoindicator until the colour changed indicating approximately 70C. The pot or kettle was then removed and the heated water kept in a clean container. Nine women leaders from the villages taught the pasteurisation method to the people in 1,500 households. Residents were also given some primary health education on diarrhoea.

Between April and June 1995, drinking water was randomly collected from households using the pasteurisation method and the numbers of coliform bacteria in the water was estimated. The number of households which had no coliform bacteria in their drinking water increased from 10.7% to 43.1% after pasteurisation was implemented. Households were followed-up every 2 to 3 weeks for four months from August to November 1995. Cases of severe diarrhoea with watery and/or bloody stools more than five times a day were recorded. The number of severe cases of diarrhoea among people who drank pasteurised water (1,779 people) was compared with those drinking raw water (1,641 people). There were 45 (2.5%) severe cases among the pasteurised group and 74 (4.5%) among the raw water group (Odds Ratio =0.55, $P$=0.0016).

The reduction in diarrhoea found after pasteurisation was nearly equal to that achieved by boiling water and compared to boiling the risk of scalding was less and the energy savings were greater. Four years after the initial study, water was still pasteurised by 28.9% of households. The health education and pasteurisation was effective in reducing diarrhoea and was accepted by the villages.

**Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial.**
Roberts L, Chartier Y, Chartier O, Malenga G, Toole M, Rodka H. Bull World Health Org (2001) **79**(4) p280-7.

This study assessed the ability of a water container to prevent contamination of household water in a refugee camp in Malawi, Mozambique. A 20-litre container was used which had a constraining lid with an opening just large enough to permit efficient filling with hand pumps. The container had a spout and a handle to facilitate pouring of water. There was a symbol on the lid of a hand with a line through it to indicate no hand entry.

Every fourth inhabited hut in the southernmost part of the camp was visited by a Malawian field worker who administered a questionnaire regarding: family demographics, household conditions and hygiene habits. One quarter of the households were selected to receive the improved buckets in exchange for all their water collection vessels. Recipients were asked to never put their hands in the buckets and shown how to rinse them. Samples of water were taken from the improved buckets 6, 4, 2, and 1 hours after collection from the wells. Households were visited twice a week and asked whether they had experienced diarrhoea.

The well water had low bacterial levels with all samples containing less than 100 coliforms per 100ml. Water sample analysis found a 69% reduction in the geometric mean of faecal coliform levels in the household water and 31% less diarrhoeal disease in children under 5 years among the group using the improved bucket compared to those using the standard ration buckets. The protective effect was confirmed by regression models examining diarrhoea in children under 5. This study showed that protection of water could produce a health benefit without the use of chlorine disinfection which is disliked by the residents of the camp.

# Additional Articles

**Genetic toxicology of a paradoxical human carcinogen, arsenic: a review.**
Basu A, Mahata J, Gupta S, Giri AK. Mutat Res – Rev Mutat Res (2001) **488**(2) p171-94.

**Methemoglobinemia and consumption of vegetables in infants.**
Sanchez-Echaniz J, Benito-Fernandez J, and Mintegui-Raso S. Pediatrics (2001) **107**(5) p1024-8.

**Bacteriophages: Update on application as models for viruses in water.**
Grabow WOK. Water SA (2001) **27**(2) p251-68.

**Climate Variability and Change in the United States: Potential Impacts on Water and Foodborne Disease Caused by Microbiologic Agents.**
Rose JB, Epstein PR, Lipp EK, Sherman BH, Bernard SM, Patz JA. Environ Health Perspect (2001) **109**(Suppl 2) p211-21.

**A new analytical tool to assess health risks associated with the virological quality of drinking water (EMIRA Study).**
Gofti-Laroche L, Gratacap-Cavalier B, Genoulaz O et al. Wat Sci Tech (2001) **43**(12) p39-48.

**Marine swimming-related illness: Implications for monitoring and environmental policy.**
Henrickson SE, Wong T, Allen P et al. Envir Health Perspect (2001) **109**(7) p645-650.

**MTBE in California Drinking Water: An Analysis of Patterns and Trends.**
Williams PRD. Environ Forensics (2001) **2**(1) p75-85.

**Climate change and cryptosporidiosis: a qualitative analysis.**
Casman E, Fischhoff B, Small M, Dowlatabadi H, Rose J, Morgan G. Climate Change (2001) **50**(1-2) p219-49.

**GIS-based analysis of drinking-water supply structures: a module for microbial risk assessment.**
Kistemann T, Herbst S, Dangendorf F, Exner M. Int J Hyg Environ Health (2001) **203**(4) p301-10.

**Setting microbiological water quality standards for sea bathing - a critical evaluation.**
Mugglestone MA, Stutt ED and Rushton L. Wat Sci Tech (2001) **43**(12) p9-18.

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