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Editor	Martha Sinclair
Assistant Editor	Pam Lightbody

National Workshop on Drinking Water Quality Management

A workshop was convened by the NHMRC in Adelaide on 8 October to discuss the development of national guidelines for drinking water quality management. Representatives from water authorities, state and territory health departments, catchment and environmental organisations, the Consumers' Health Forum, and the NHMRC/ARMCANZ Drinking Water Review Coordinating Group attended the workshop together with specialists in environmental risk management and public health.

Professor Don Bursill, CRCWQT Director and Chair of the NHMRC/ARMCANZ Drinking Water Review Coordinating Group, opened the meeting with a background to the workshop including an overview of the Australian Drinking Water Guidelines, and the rolling revision process that was adopted in 1996 to ensure that the guidelines are continually kept up to date with evolving scientific knowledge.

There is some concern that the Australian Drinking Water Guidelines are used in the industry mainly as a focus for compliance-based management strategies without sufficient recognition of the importance of overall system management for assuring safe drinking water. Furthermore, with the rapidly changing environment of the water industry in Australia and the trend toward increasing fragmentation and disaggregation, the Guidelines need to reflect this to allow for greater divergence of responsibilities and accountabilities across multiple agencies.

As part of the second round (1999/2000) of the ongoing review process of the Australian Drinking Water Guidelines, increased emphasis will be given to the preventive nature of the Guidelines by expanding and reorganising the relevant information as a practical and

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comprehensive risk management approach to drinking water quality management from catchment to tap. In addition to emphasising prevention rather than corrective action (reaction), this approach will allow the numerical limits of the Guidelines to be viewed in the proper perspective as providing verification that the management systems are effective rather than being viewed as the primary means of protecting public health.

CRCWQT researchers, in cooperation with the Coordinating Group, have developed a discussion paper detailing a suggested scope and structure of a framework for drinking water quality management. The framework was derived by supplementing the information on preventive system management already provided in the current Australian Drinking Water Guidelines with principles from existing systems for quality management and risk assessment/management including:

- ISO 9001- Quality Systems
- ISO 14001- Environmental Management Systems
- AS/NZS 4360 -Risk Management
- AWWA/US EPA Partnership for Safe Water
- Hazard Analysis Critical Control Point (HACCP) (food industry)
- Responsible Care Initiative (chemical industry)

This framework and paper formed the basis for discussions at the workshop.

Following Professor Bursill's introduction, Professor Steve Hrudey from the University of Alberta, noted expert in environmental risk management and recent Visiting Professor at the CRCWQT, presented an overview of essential risk management principles for effective drinking water quality management. He emphasised the particular importance of anticipating and preventing harm in water quality management rather than just reacting to problems after they arise. Risk assessment can be a useful tool in this process; however the degree of scientific uncertainty inherent in the process must be

recognised with due regard for the contributions of direct evidence, scientific inference and policy-based assumptions. Risk management decisions must be informed decisions, but should include recognition of how much uncertainty exists.

Research Fellow Samantha Rizak from Monash University reviewed the proposed framework for drinking water quality management and the benefits offered by its adoption. The framework is intended to provide the directional guidance on a comprehensive preventive strategy to drinking water quality management from source to tap. Key features of the framework include:

- management support and commitment to improve the performance of an authority's activities relating to water quality,
- an in-depth systematic analysis of the water supply system from catchment to tap to understand the key factors that affect it,
- the identification of hazards and assessment of risks,
- the identification and implementation of the specific preventive measures to control hazards emphasising elements that can be monitored, and verified, in real time, and
- the documentation and performance evaluation of the approaches used to manage drinking water quality.

The perspective of health authorities was summarised by Dr. David Cunliffe of the South Australian Department of Human Services. All Australian jurisdictions face the challenges of increasing requirements for surveillance of water quality and the trends to increase legislative controls. Dr Cunliffe also noted that the proper management of water quality includes management of all components of water supplies from catchment to tap and requires involvement of all stakeholders. Health authorities have a key role in supporting this process. The proposed framework provides the opportunity for all stakeholders to become involved and offers the outcome of a cooperative and coordinated approach with improved understanding of the roles and responsibilities of all parties.

The Water Corporation of Western Australia has recently undertaken work to improve its activities relating to water quality management. Mr Richard Walker, Water Quality Manager, presented the process and findings of the risk assessment workshop that the Water Corporation recently conducted. This has involved systematic risk assessment of several water systems representing different types of catchments, and the identification of potential risk management strategies. The process particularly highlighted the need for improved information flow between water authorities and other bodies with responsibility for land management in catchments.

In the discussions that followed, the benefits of adopting a national approach to drinking water quality management were evident. It was agreed that a comprehensive and preventive framework jointly developed by major stakeholders could provide a flexible and effective means of assuring the protection of public health, as well as increasing communication and defining responsibilities of the various agencies and stakeholders involved in the supply of water. The framework will also provide a common and unified approach throughout the industry which can establish due diligence and credibility.

However, it was stressed that whatever approach is developed must remain flexible and adaptable to local conditions to reflect the wide range of differences in Australian water supplies and the varying organisational and jurisdictional arrangements. Further, the importance that the system be industry-supported was highlighted and it was suggested that external auditing protocols for drinking water quality management will be helpful for establishing credibility and maintaining consumer confidence. The preference for industry-specific and industry-developed external auditing protocols was emphasised.

The Coordinating Group is now developing a work plan to develop the Drinking Water Quality Management Framework. This will commence with a series of desktop trials of the draft framework by teams from several water

authorities. The first set of trials will involve Melbourne Water, Sydney Water, the Power and Water Authority of the Northern Territory and the Water Corporation of Western Australia. The framework will be refined following feedback from these trials and then tested by a larger number of water authorities. Both rounds of trials are expected to be completed by mid-2000.

Updates on the progress of the Rolling Revision of the Australian Drinking Water Guidelines can be found on the web site of the CRCWQT.



Cryptosporidium and water - the numbers game

Over the last decade the threat of waterborne disease from *Cryptosporidium parvum* has become a major influence on drinking water regulation in the developed world. This protozoan pathogen is common in surface water supplies and is resistant to the levels of chlorination that can be applied to drinking water. While unfiltered water supplies are generally believed to be at highest risk of outbreaks, the Milwaukee outbreak clearly demonstrated that even filtered supplies can be endangered if the pathogen load is high and the filtration process is not efficient.

The presence of *Cryptosporidium* oocysts in virtually all surface water supplies has raised the question of whether exposure to oocysts in drinking water could be causing low levels of illness in communities (endemic disease) in the absence of recognised outbreaks. This question is very difficult to answer since we do not yet have reliable tests to determine whether oocysts are capable of causing human infection, and cases of illness arising from waterborne exposure cannot be distinguished from illness transmitted by other routes except in the context of outbreaks.

The US Environment Protection Agency has adopted a quantitative risk analysis process to estimate the current magnitude of endemic waterborne cryptosporidiosis and derive predictions for the reduction in illnesses which would be achieved by improved water treatment. These calculations are the main driving force

behind the Interim Enhanced Surface Water Treatment Rule⁽¹⁾, which must be implemented in most US surface water supplies serving more than 10,000 people by December 2001.

Recently, an independent estimate of the occurrence of cryptosporidiosis in the community has been made by the Centres for Disease Control and Prevention as part of the process for deriving a national estimate of foodborne disease⁽²⁾. Comparison of these two sets of calculations makes for some interesting reading.

US EPA estimate

The risk analysis considered a number of factors influencing the risk of infection in consumers, and made assumptions about their likely values based on published literature and other data.

Dose response slope parameter

Information from the only human feeding trial published at that time⁽³⁾ was used to derive a slope constant k , which is part of the equation used to relate ingested dose with probability of infection.

Daily water consumption

It was assumed that water consumption in a population was lognormally distributed with a mean of 1.948 litres per day and the maximum capped at 3 litres per day.

Cryptosporidium in raw water sources

Data from a 1996 survey of 69 sites were used to estimate the occurrence of oocysts. This relatively limited data suggested that mean oocyst concentrations could be described by a lognormal distribution. Two sources of error in the data were assumed to cancel each other; firstly the sampled sites were in areas which might have higher concentrations than the US as a whole, secondly the recovery efficiency of the method was poor and thus the measured concentrations would have been underestimates.

Effect of current water treatment (filtration)

Information from studies at pilot and full scale water treatment plants was assessed together with consideration of more recent trends towards improved filtration efficiency.

Two sets of assumptions were used to assess the impact of different treatment efficiencies. The first set assumed that the performance of current treatment plants was normally distributed with a mean removal of 2.5 logs and a standard deviation of 0.63 logs. The second set of assumptions assumed the current mean removal was 3 logs, again with a standard deviation of 0.63 logs.

Viability of oocysts

Current detection methods cannot reliably determine whether *Cryptosporidium* oocysts detected in water supplies belong to the single species known to infect humans, nor whether they are viable and capable of causing infection. For the analysis it was assumed that viability had a mean of 10% with a uniform distribution ranging between 5% and 15%.

Morbidity ratio

Based on the observations from the only human feeding trial published at that time, it was assumed that 39% of infected people would become ill (with 95% confidence limits of 19 to 62%).

Mortality ratio

The probability of mortality among ill people was estimated at 0.000125 based on data from the Milwaukee outbreak.

Exposed population

It was estimated that 139.2 million people are supplied by the 1,381 water systems subject to the IESWTR. This represents 51% of the total US population.

Using the assumptions outlined above, a Monte Carlo simulation was carried out to estimate the current number of illnesses and deaths predicted to be due to *Cryptosporidium* exposure from water supplies subject to the IESWTR. This type of simulation treats each parameter as a probability distribution and carries out repeated calculations selecting a value for each parameter in turn based on their individual distribution. This results in the generation of another probability distribution of the estimated number of infections and illnesses. From this distribution

the mean (expected value) and range of risk is calculated.

The risk estimates

These simulations resulted in the following estimates for current infection and illness rates due to *Cryptosporidium* in drinking water:

Assumed effect of water filtration	2.5 log removal	3.0 log removal
Estimated illnesses	643,000	208,500
Estimated deaths *	80	26

* not stated in reference - estimated from data supplied

The higher figure of 643,000 illnesses attributable to *Cryptosporidium* infection from current water supplies is most commonly used in EPA documents.

It should be noted that these figures apply to the 139.2 million people served by the water supplies which are subject to the IESWTR (this corresponds to about 52% of the total US population). The remainder of the population is served by surface water supplies not covered by the Rule (ie less than 10,000 people, or larger surface supplies not required to filter their water) or by groundwater supplies or private supplies.

CDC estimate

The CDC paper on foodborne disease estimates the annual number of cases of gastrointestinal illness and death in the US from all sources including known pathogens, unknown pathogens and noninfectious causes, and then estimates the proportion that are attributable to food. A variety of data sources are used including the FoodNet active surveillance system, passive surveillance systems, outbreak investigation and specific surveys. For each known pathogen, the data sources and assumptions made to derive the estimate are summarised in a detailed Appendix.

The authors comment that the number of cases of illness reported to any surveillance system is considerably less than the number which occur in the community, as many people with mild illness do not seek medical attention, most who see a doctor do not give a faecal specimen for analysis, the relevant tests may not be performed on faecal

specimens, and test results may not be reported to surveillance.

Some information on the degree of under reporting has been gained from specific studies on *Salmonella* and *E.coli* O157:H7. *Salmonella* (which typically causes non-bloody diarrhoea) is under reported by a factor of about 38-fold in the US, while *E.coli* O157:H7 (which typically causes bloody diarrhoea) is under reported by a factor of about 20-fold.

For *Cryptosporidium parvum* the number of total cases in the US was estimated from the observation that about 2% of stool specimens tested for *Cryptosporidium* are positive for this organism. It was assumed that 2% of the 15 million people who see a doctor for acute gastroenteritis would have a *Cryptosporidium* infection - giving an estimate of 300,000 cases per year. This number is vastly in excess of the number of cases reported to active surveillance (6,630) or to passive surveillance (2,788).

The ratio of cryptosporidiosis cases reported to active surveillance to the estimated total cases is about 45-fold, which may perhaps be explained by the fact that tests for this organism are less commonly performed than those for common bacterial pathogens such as *Salmonella*. The total number of deaths attributable to *Cryptosporidium* infection from the estimated 300,000 cases was estimated at 66 per year based on the fatality rate in cases reported to FoodNet.

This estimate does not take into account the number of people who become ill with cryptosporidiosis but do not seek medical attention. A recent British study estimated that about 1 in 2 people who have symptomatic cryptosporidiosis see a doctor because of their illness⁽⁴⁾. If a similar figure applies in the US, then the total number of illnesses due to *Cryptosporidium* would be around 600,000 cases.

Differences in the healthcare systems between the two countries may mean that a smaller proportion of people in the US seek medical attention, and this would have the effect of increasing the estimate of the total number. However the British

study also found that testing of stool specimens was related to severity of symptoms, and that people who saw a doctor with cryptosporidiosis were more likely to have a specimen tested than the average gastroenteritis patient. Thus the US assumption that the 2% positivity rate for *Cryptosporidium* would apply to all people who visited a doctor for gastroenteritis is likely to be an overestimate. This factor would tend to reduce the estimate of total cases of illness.

How do the numbers compare?

The EPA figure relates only to waterborne illness in that portion of the population which is served by supplies subject to the IESWTR - it does not incorporate illness due to other routes of transmission in this population or in the remainder of the US population. At this time there is no numerical data available on exposures to *Cryptosporidium* oocysts by non-water routes (for example in foodstuffs and drinks which are consumed without heating, from recreational water use, by animal to person contact, or person to person contact). Therefore it is not possible to apply quantitative risk analysis techniques to these exposures. However examination of serological data may perhaps give some insight in to the contribution of non-water sources.

Antibodies against *C. parvum* have been found in 15% to 60% of US adults in various studies. These antibodies are believed to decline below detectable levels within about 18 to 24 months if exposure does not recur in this period. Therefore the presence of antibodies is taken to represent fairly recent exposure to *C. parvum*.

If it is assumed that infections resulting in illness occur in the same proportion as exposures from different sources which lead to antibody formation, then comparison of antibody prevalence rates in populations with differential waterborne exposure may indicate the relative importance of water as a route of transmission. It should be noted that this assumption has not been proven, although it is one of the arguments used to support the view that water is a major transmission pathway for endemic disease due to *Cryptosporidium*.

Comparison of antibody prevalence rates in populations served by groundwater sources (assumed to have virtually zero waterborne transmission) with those in populations served by surface waters of varying quality, suggests that non-water sources are responsible for at least 50% of exposures. If we assume that the same holds true for illnesses then we would predict that communities subject to the IESWTR are experiencing at least 643,000 cases of non-waterborne cryptosporidiosis per year in addition to the 643,000 cases attributable to water.

If it is assumed that the population served by sources not affected by the IESWTR has zero waterborne risk, then we would predict that they experience about 617,000 cases of illness from other sources (48% of the US population x 643,000 cases). This would give an overall estimate of at least 1,903,000 symptomatic cases of *Cryptosporidium* infection each year in the US. By the same logic, the total number of deaths predicted from EPA estimates of *Cryptosporidium* infection would be about 237 per year in the US. In contrast, the corresponding figures from the CDC estimate would be around 600,000 illnesses (using the multiplier factor from the British study) and 66 deaths per year.

Clearly the large discrepancy between these estimates raises some concerns - particularly as the EPA figures have been used in cost-benefit analyses to justify the costs entailed in implementing the IESWTR (approximately \$307 million annually). If the current number of waterborne *Cryptosporidium* illnesses has been substantially overestimated, then the number of cases prevented by improvements in drinking water filtration will also have been overestimated. The CDC estimate for cryptosporidiosis also involves a number of assumptions and uncertainties, although fewer than the EPA estimate, and these are arguably more amenable to direct investigation and resolution with currently available methodologies, including epidemiological studies of community gastroenteritis to determine the true rate of disease.

- (1) Regli S, Odom R, Cromwell J, Lustic M and Blank M (1999) Benefits and costs of the IESWTR. J American Water Works Association **91** (4) p148-158.
- (2) Mead, P. S., L. Slutsker, et al. (1999). Food-Related Illness and Death in the United States. Emerging Infectious Diseases **5**(5): 607-25.
- (3) See *From the Literature* section for the most recent publication on *Cryptosporidium* infectious dose.
- (4) Wheeler, J. G., D. Sethi, et al. (1999). Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reported to national surveillance. British Medical Journal **318**(17 April): 1046-50.



US EPA sued over chloroform

Legal action has been taken against the US Environment Protection Agency by the Chlorine Chemistry Council, an organisation representing manufacturers of chlorine and chlorinated products. The action stems from withdrawal of the EPA proposal to relax the Maximum Contaminant Level Goal (MCLG) for chloroform in drinking water. The MCLG is not an enforceable standard but rather provides a target for water utilities to aim for. MCLGs are defined under the US Safe Drinking Water Act as levels "at which no known or anticipated adverse health effects occur, allowing for an adequate margin of safety".

The proposal, released for public comment in March 1998, would have raised the MCLG for chloroform from zero to 300 micrograms /litre, while setting the Maximum Contaminant Level (an enforceable level) at 80 micrograms /litre for total trihalomethanes (including chloroform). However in its final version of the Disinfection /Disinfection Byproduct Rule released in November 1998, the EPA withdrew the proposed change and retained the previous chloroform MCLG of zero.

The proposal to raise the MCLG was based on advice from an expert panel convened by the EPA to examine evidence on the carcinogenicity of low level chloroform exposure. The panel concluded that early rodent experiments which employed single high daily doses of chloroform in corn oil were flawed in design and did not

provide useful information on the risks of exposure to chloroform in drinking water.

More recent experiments comparing high doses of chloroform delivered in corn oil and the same doses in drinking water clearly showed liver cell toxicity and stimulation of cell growth only with the corn oil vehicle. These effects on cell function are responsible for increased rates of liver cancer development when corn oil is used for dosing. In contrast, no impact on cancer rates was seen in mice with drinking water exposures as high as 1800 milligrams /litre.

The second major factor in the expert panel's decision was the accumulation of evidence that chloroform does not act directly on genetic material (DNA). Substances which are able to directly damage DNA are by convention deemed to have no threshold for carcinogenic action, since a single mutation induced by such damage could potentially be inherited by daughter cells and perhaps lead ultimately to cancer. The EPA's risk assessment procedure for such substances is based on the assumption that any exposure results in some finite risk of cancer (modelled as a linear no-threshold dose response curve).

There is now a substantial body of evidence that chloroform does not directly damage DNA, thus the appropriate method to assess the cancer risk is to adopt a model which allows for a no-effect threshold level (modelled as a non-linear dose response curve). However while the EPA issued a statement that it "*believed the non-linear cancer extrapolation approach is the most appropriate means to establish an MCLG for chloroform based on carcinogen risk*", it nevertheless did not accept the outcome of this analysis as a basis for setting the MCLG. The reason for this decision appears to be the strong negative opinions expressed by environmental groups during the public comment period on the proposed revision of the chloroform MCLG.

The EPA decision to disregard expert advice has been cited as an example of how the rigid regulatory structures which exist in the US may render any "relaxation" of environmental standards virtually impossible even when such

action is clearly justified by rigorously assessed scientific evidence.

The Chlorine Chemistry Council has launched legal action on the grounds that the EPA has failed to follow the statutory requirements of the Safe Drinking Water Act to use the "best available peer-reviewed science" in setting the MCLG for chloroform. The case is due to begin before a panel of judges in the Washington DC Circuit Court of Appeals on 11 February 2000.



Cryptosporidium detection methods

The lack of a rapid reliable assay to determine whether *Cryptosporidium* oocysts detected in water are infectious for humans has been a major problem in risk assessment and development of water treatment techniques. This has been compounded by problems with the efficiency and reliability of oocyst recovery from water samples. Several recently published papers suggest that rapid improvements are occurring in both these areas of research.

Di Giovanni and coworkers⁽¹⁾ have reported the use of an integrated cell culture-PCR technique to detect infectious oocysts in both seeded and unseeded water samples and filter backwash. Oocysts were recovered from 10 litre samples (seeded where appropriate with 1600 to 2900 oocysts) using immunomagnetic separation (IMS). The washed and resuspended oocysts were inoculated into cell cultures of human ileocecal adenocarcinoma cells and incubated for 72 hours at 37C. The cell monolayers were washed to remove non-excysted oocysts and then harvested. The presence of viable *C parvum* was detected by PCR of the hsp70 gene. The identity of PCR products was confirmed by DNA sequencing. For comparison, oocysts were also concentrated by conventional percoll-sucrose flotation. Aliquots from both methods were also examined by immunofluorescence microscopy (IFA).

The spiking experiments showed higher recoveries with immunomagnetic separation compared to flotation but this was not statistically

significant. Recoveries were higher with both methods for seeded raw water than for seeded backwash water. The results of PCR detection (positive/negative) agreed with detection by microscopy following either IMS or flotation.

A total of 122 raw water samples and 121 filter backwash samples from 25 different sites were tested. Oocysts were detected in 16 (13.1%) of raw water samples and 7 (5.8%) of backwash samples by flotation - IFA, and in 6 (4.9%) of raw water samples and 9 (7.4%) of filter backwash samples by cell culture- PCR. However only 2 samples tested positive by both methods. The flotation-IFA method should detect all *Cryptosporidium* species whether dead or alive, while the cell culture - PCR technique should detect only viable *C. parvum*.

The cell culture technique (without PCR) has been adapted by other researchers to provide a Most Probable Number method for estimating oocyst numbers⁽²⁾. In this case cell cultures were grown in 8 well slides prior to inoculation with oocysts, then incubated for 48 hours prior to fixing. Slides were stained with a 2-stage antibody procedure, then examined under a microscope for signs of sporozoite invasion (initial infection) and clustering (indicating secondary infection after completion of the first replication cycle). Wells were scored as negative unless both invasion and replication were present. The viability of lots of oocysts was also evaluated using vital dyes and mouse infection tests.

The results showed considerable variability in the infectivity of different lots of oocysts (all from the Iowa strain), suggesting that preparation techniques may be responsible. The cell culture infectivity of all tested lots decreased over time, but the vital dye and excystation assays showed little change. This reinforces observations from other studies that such markers do not accurately reflect infectivity. This type of cell culture assay may have advantages over those employing molecular techniques (eg PCR) since only oocysts capable of undergoing more than one round of replication will be scored positive. This will prevent over estimation of viable oocyst numbers

as some oocysts in environmental samples have been shown to be able to invade cells but not proceed to the secondary infection stage.

Zuckerman and coworkers have tested a portable continuous flow centrifuge for concentrating oocysts from water samples, and suggest it may have advantages over current cartridge filtration and calcium carbonate flocculation methods⁽³⁾. This centrifugation technique has been previously reported for oocyst recovery, but only with large non-portable equipment. The results of spiking experiments and field tests with natural water samples comparing the three methods by these authors suggest that continuous flow centrifugation shows the best recovery.

(1) Detection of infectious *Cryptosporidium parvum* oocysts in surface and filter backwash water samples by immunomagnetic separation and integrated cell culture-PCR. Di Giovanni, G. D., F. H. Hashemi, et al. (1999). *Appl Environ Microbiol* **65**(8): 3427-32.

(2) A most-probable-number assay for enumeration of infectious *Cryptosporidium parvum* oocysts. Slifko, T. R., D. E. Huffman, et al. (1999). *Appl Environ Microbiol* **65**(9): 3936-41.

(3) Evaluation of a portable differential continuous flow centrifuge for concentration of *Cryptosporidium* oocysts and *Giardia* cysts from water. Zuckerman, U., R. Armon, et al. (1999). *J Appl Microbiol* **86**: 955-61.



News Items

UK *Cryptosporidium* outbreaks linked to pools

Health authorities in Britain have linked several recent small outbreaks of cryptosporidiosis to swimming pools. Over 90 confirmed cases have been recorded in four separate towns since August. In two outbreaks the pools were reported to be using ozonation as well as chlorination.

Australian water still low cost

A survey by the National Utility Service has shown that Australians still pay less for their water than most western countries. Australian water charges were rated the 5th cheapest among 15 countries, compared to 3rd cheapest in last years survey. The highest prices were reported for Germany (\$2.73 per cubic metre) and

Denmark (\$2.43 per cubic metre). Countries with cheaper water prices than Australia were Canada (62 cents per cubic metre), Sth Africa (75 cents), the United States (80 cents), and Spain (82 cents). According to the survey, Australian prices rose by about 3% during the last year.



Hurricane provokes storm over pig farm waste

A political battle has erupted in North Carolina US over plans to rebuild waste lagoons at pig farms damaged by Hurricane Floyd. The eastern part of the state contains many intensive pig farms, established since the 1980s, which have been permitted to dispose of animal waste in open waste pits with little protection of local water supplies. Flooding from the September hurricane resulted in widespread pollution of surface water sources, and there are indications that seepage is also affecting groundwater supplies which serve up to half the residents in the worst affected areas.

Moves to tighten regulation of the pig farming industry began in the early 1990s but little progress has been made due to strong opposition from major producers, and the economic importance of the industry. Now, opponents say that federal aid should not be approved to rebuild the same inadequate waste storage facilities which threaten the environment.



Ulcers linked to *Helicobacter*

Researchers at the Pennsylvania State University have reported evidence of a direct link between the presence of the bacterium *Helicobacter pylori* in unchlorinated well water and stomach ulcers in consumers. The research team had previously reported finding the microorganism in samples from many private wells in the state. According to a press release from the University they have now conducted interviews with residents and found a statistically significant association between cases of stomach ulcers among consumers and the presence of *Helicobacter* in water samples.

Scientists plan subterranean lake exploration

Scientists from 14 countries have begun preparations to study a huge lake more than 2 miles under the Antarctic ice cap. Lake Vostok is believed to be one of the oldest of about 80 lakes formed by heat from the earth's core and pressure from the icecap above. The lake is permanently pressurised, cold and dark, and may have formed as long as 40 million years ago. Despite these extreme conditions, some researchers speculate that microorganisms may have evolved there.

An expedition using a small robotic submarine to explore Lake Vostok is planned to occur within 5 years. Knowledge gained from this project will be used by NASA to develop an exploration program to search for alien life forms in the oceans of Europa, one of Jupiter's moons.



Legionnaires disease outbreak in Belgium

Health authorities in Belgium are investigating an outbreak of Legionnaires disease at a trade fair in Kapellen in November. More than 80 of the 60,000 visitors to the exhibition developed symptoms of the infection and there have been at least 4 fatalities. Investigators believe whirlpool spa baths on display at the exhibition are likely to be the source of the outbreak.

Spa baths at a similar trade fair were responsible for a Legionnaires disease outbreak in the town of Bovenkarspel in the Netherlands in March. In this outbreak 226 confirmed cases were diagnosed and at least 18 people died.



Pumping water is child's play

An enterprising South African company has solved the problem of how to supply energy for extracting ground water by incorporating a pump into a children's merry-go-round. Sixty of the novel water pumps have already been installed in rural areas of the country.

The low maintenance "Playpumps" are capable of pumping up to 1,400 litres per hour to a 5,000 litre overhead storage tank, whereas conventional handpumps can pump only 150 litres per hour to ground level. The higher cost of the playpumps

(about \$7,000 in contrast to \$3,300) has been offset by selling advertising space on the storage tanks, which are a natural meeting place for villagers collecting water.



From the Literature

Aluminium

Disturbance of cerebral function in people exposed to drinking water contaminated with aluminium sulphate: retrospective study of the Camelford water incident.

Altmann P, Cunningham J, Dhanesha U, Ballard M, Thompson J, Marsh F. *BMJ* (1999) **319**(7213) p807-11.

This study was undertaken to establish whether people in the Camelford area of Cornwall in the south west of England, had suffered organic brain damage as opposed to psychological trauma after drinking water was contaminated with 20 tonnes of aluminium sulphate in July 1988. The aluminium sulphate was accidentally emptied into the treated water reservoir that served 20,000 people.

The study was undertaken three years after the incident during the process of litigation by the subjects, and has been published only after resolution of the legal case. The subjects comprised fifty-five adults all claiming to have suffered cerebral damage. Fifteen available siblings nearest in age to one of the exposed group who had not lived in the area of water contamination since before the incident were also studied.

A range of clinical and psychological tests were performed to determine the medical condition and the anxiety levels in the people affected. Normal serum concentrations of aluminium were measured and were less than 10 microgram/l. IQ was assessed using the national UK adult reading test. Psychomotor testing was carried out using a computerised battery of tests to reduce possible interference. Measurements of flash and pattern stimulated visual evoked potentials were conducted using standard techniques.

It was found that 42 out of the 55 exposed individuals had poor psychomotor performance with all except two having the worst results on the symbol digit coding test (the most sensitive psychomotor test for organic brain disease). Their performance as a group was notably worse than predicted from the IQ scores. Flash and pattern tests results of the exposed group were compared with results for 42 normal unrelated and unmatched controls. Flash pattern differences were greater in the exposed group than in the unrelated control subjects. The 15 unexposed siblings showed significantly better flash-pattern differences than their exposed sibling. There was no evidence that anxiety led to these abnormalities from the analysis of anxiety scores. No abnormalities were detected on physical examination, haematology or biochemistry.

The authors discuss their findings in relation to previous studies on the Camelford incident and concede that it is extremely difficult to provide "hard" evidence of cause and effect. However in this study they have endeavoured as much as possible to utilise tests and methods that minimise bias on the part of subject and the observer. They conclude that these results support the hypothesis that aluminium sulphate poisoning probably led to long term cerebral impairment of some people residing in the Camelford area.

Comment At the time of writing Health Stream has been unable to locate any information on the levels of aluminium in the water during the Camelford incident. Water pH was reported to be very low, and this may have enhanced absorption of ingested aluminium. According to this article, up to 400 people may have been affected by similar symptoms, and in some cases these appear to have persisted to the present day.

Arsenic

Cancer incidence and high environmental arsenic concentrations in rural populations: results of an ecological study.

Hinwood AL, Jolley DJ, Sim MR. Internat J Environ Health Research. (1999) 9(2) p131-141.

This study investigated the relationship between environmental arsenic exposure from contaminated soil and drinking water and the incidence of cancer. Several previous studies have shown an association between a range of cancers and arsenic exposure from occupational and environmental settings.

Twenty-two rural areas in Victoria, Australia were selected for the study on the basis of previous documented soil and water arsenic concentrations. These areas had one or more samples recorded of soil arsenic concentrations in excess of 100 mg/kg and/or either surface or ground water arsenic concentrations in excess of 0.01 mg/l. Cancer data was obtained from the Victorian Cancer Registry for the years 1982-1991. Standardised incidence ratios (SIRs) for cancer were calculated for the 22 areas and for combined areas according to exposure type. Victorian cancer rates were used as a baseline.

Of the cancers previously reported to be associated with arsenic exposure (nasal cavity, prostate, liver, bladder, kidney) only prostate cancer showed a small but significant excess, SIR 1.14 (1.05-1.23). Of the "other cancers" examined, SIRs for melanoma 1.36 (1.24-1.48), breast 1.10 (1.03-1.18) and chronic myeloid leukemia (CML) 1.54 (1.13-2.10) were all elevated. Areas were stratified by exposure type and divided into three arsenic exposure groups: high water/high soil, high water/low soil, high soil/low water. Analysis by exposure type for previously studied cancers showed a small excess in all three categories for prostate and kidney cancers with prostate cancer in the high water/high soil category being statistically significant. Of the "other cancers" the SIR for melanoma was significantly raised for all three exposure types. The SIR for CML was significantly increased for the high water/high soil category also. No significant dose-response relationship was found for drinking water and individual cancers.

This study does not support previous findings of an association between environmental arsenic and internal cancers of the bladder, lung, liver or nasal

cavity. However this study was limited by its ecological design which prevented assessment of individual exposure levels to arsenic and potential confounding factors, and also by small population sizes, which resulted in low power to detect cancer excess. Further investigation is needed to explore the relationship between cancers of the prostate and kidney and environmental arsenic exposure. The significant excess of CML in rural areas also warrants further investigation.

Arsenic concentrations in well water and risk of bladder and kidney cancer in Finland.

Kurtio P, Pukkala E, Kahelin H, Auvinen A, Pekkanen J. *Environ Health Perspect.* (1999) **107**(9) p705-710.

This case-cohort study was undertaken to determine whether arsenic exposure from well water is associated with an increased risk of bladder and kidney cancers. About 12-14% of the Finnish population use private wells as their water supply sources, and there is little information on arsenic exposure from these sources.

Villages were identified in which less than 10% of the population belonged to the municipal drinking water system. From the Population Registry, 144,627 persons were identified who were born between 1900-1930 who had lived in these areas at the same address from at least 1967 to 1980. The Finnish Cancer Registry was used to identify bladder and kidney cancer cases from within this cohort. The study population consisted of 61 bladder cancer cases, 49 kidney cancer cases and 275 persons selected as the reference cohort.

Information was obtained via a questionnaire on residential history, drinking-water consumption, education, occupation and potential confounders. Information was also obtained from the Population Censuses of 1970, 1975 and 1980. Samples of water from wells used by the study population from at least 1967 to 1980 were collected. Exposure to arsenic was estimated in three ways, as: arsenic concentration in the well water, daily dose and cumulative dose of arsenic.

The arsenic concentrations in the reference wells ranged from <0.05 to 64 microgram/L. The median daily dose of arsenic from well water was 0.2 microgram, and the cumulative dose before 1980 was 0.8 mg.

No association was found between arsenic concentration, daily dose or cumulative dose and risk of kidney cancer. For bladder cancer some increased risk was associated with arsenic concentrations and daily dose 2 to 9 years before diagnosis and there was some suggestion of a synergistic effect between arsenic and smoking. For arsenic concentrations > 0.5 microgram/L a statistically significant elevated risk of bladder cancer was found.

The study was not able to investigate the role of nutritional factors and the authors note that low selenium intake (common in Finland prior to the introduction of selenium supplementation of fertilisers in 1985) may enhance the toxicity of arsenic. The authors comment that more studies need to be conducted at low exposure levels to investigate the apparent association between arsenic and bladder cancer.

The relationship of arsenic levels in drinking water and the prevalence rate of skin lesions in Bangladesh.

Tondel M, Rahman M, Magnuson A, Chowdhury IA, Faruquee MH, Ahmad SA. *Environ Health Perspect.* (1999) **107**(9) p727-729.

A cross-sectional study was conducted in Bangladesh to determine the relationship between arsenic-associated skin lesions and the degree of exposure to arsenic. Four villages were included in the study in four districts of Bangladesh. The villagers were mainly dependent on wells for drinking water.

A total of 1,794 eligible subjects ≥ 30 years of age were identified, who had lived in the study area throughout their lifetimes and had used the same well as long as it had existed. Of these, 1,481 individuals had histories of arsenic exposure and were interviewed by questionnaire and examined for skin lesions. Skin lesions were found in 430 subjects. Individual exposure was

assessed by current arsenic concentration in the drinking water and using a dose index based on the present arsenic level divided by the individual's body weight. Arsenic concentrations in well water ranged from 10 to 2,040 microgram/L.

The crude overall prevalence of skin lesions 29/100 study subjects. The male to female ratio was 1.2:1, with males having higher rates in almost all age groups. A dose response relationship was seen between water levels of arsenic and the prevalence rate of skin lesions ($p < 0.05$). A stronger dose response relationship was found for prevalence rate of skin lesions by dose index. Almost one-third of the study population in the ≥ 30 years of age group had skin lesions due to chronic arsenic toxicity. These data support an urgent need for the provision of good quality drinking water in Bangladesh to replace arsenic contaminated supplies.



Chlorination

Poor efficacy of residual chlorine disinfectant in drinking water systems to inactivate waterborne pathogens in distribution systems.

Payment P (1999) *Can J Microbiol* **45** 709-715.

This paper reports a series of experiments on the effect of disinfectant residuals in two Canadian municipal chlorinated water supplies on a range of indicator microorganisms, and native sewage microorganisms.

Water samples from points representing the treatment plants, the middle and the end of the distribution systems were inoculated with *E. coli*, *Clostridium perfringens* spores, a somatic coliphage and Poliovirus. Samples were held at 4°C or 20°C and aliquots were removed for enumeration over a 24 hour period. It was found that *E. coli* was inactivated fairly rapidly, but other microorganisms declined much more slowly. When sewage supernatant was added to water samples, native faecal coliforms were inactivated relatively rapidly, but native *Clostridium perfringens* spores persisted for several hours.

These results suggest that the residual chlorine levels tested here (0 to 0.9 mg/litre) may be ineffective for inactivation of relatively resistant microorganisms including some pathogens (such as human viruses and protozoa). The author argues that monitoring for levels of faecal coliforms or *E. coli* may give a false sense of security, and that contamination by pathogens may lead to waterborne illness even in systems with substantial residuals.

Comment The role of chlorine residuals in distribution systems is a topic of vigorous debate in the international water industry. The arguments for and against the maintenance of residuals were the subject of an entire issue of the *Journal of the American Waterworks Association* (Vol. 9(1) 1999) early this year.



Cryptosporidium

Virulence of three distinct *Cryptosporidium parvum* isolates for healthy adults.

Okhuysen PC, Chappell CL, Crabb JH, Sterling CR, DuPont HL (1999). *J Infect Dis* **180**(4) 1275-81.

The authors of this paper have carried out a series of human volunteer experiments using 3 different isolates of *Cryptosporidium parvum*, and here summarise the outcomes. Two of the isolates originated from calves (Iowa and UCP isolates) and one from a human subject who was believed to have been infected while examining a foal which had died after suffering diarrhoeal illness (TAMU isolate). All isolates were propagated in newborn calves prior to use in experiments.

Serologically negative healthy adult volunteers ingested various doses of oocysts and were observed over a 6 week period. For the Iowa isolate 29 volunteers were used, for the UCP isolate 17 volunteers, and for the TAMU isolate 14 volunteers. Subjects were classified as having a confirmed infection (oocysts detected in faeces) or presumed infection (diarrhoeal illness or enteric symptoms without oocysts detected in faeces).

The 3 isolates showed substantial differences in ID₅₀ values (the dose required to infect 50% of exposed people):

	confirmed infection	presumed infection
Iowa	75	87
UCP	2788	1042
TAMU	125	9

The attack rates were also variable with 86% of people exposed to the TAMU isolate developing diarrhoea, compared to 52% of those exposed to the Iowa isolate and 59% of those exposed to the UCP isolate. The TAMU isolate also had shorter incubation period: mean onset of 5 days, compared to 9 days (Iowa) or 11 days (UCP). However the duration and intensity of diarrhoeal symptoms was not significantly different between the isolates.

In discussing the differences between isolates, the authors note that the TAMU isolate has been subject to fewer passages in cattle than the other two isolates, and this may account for its higher virulence in humans. Alternatively, the observed differences may reflect genetic variations that are not affected by passage in different hosts. A number of in vitro and animal infection studies suggest that considerable variability in infectivity exists among *C parvum* isolates.

Comment These observations of substantial variation in infectivity even among fresh viable oocysts from different isolates shed further light on the reasons why there is no clear relationship between the number of oocysts detected in water supplies and the risk of illness in consumers. (Refer to Health Stream Issue 2 for a more detailed description of the studies on the Iowa isolate.)



Disinfection byproducts

Drinking water source and chlorination byproducts in Iowa. III. Risk of brain cancer.

Cantor KP, Lynch CF, Hildesheim ME, Dosemeci M, Lubin J, Alavanja M, et al. Am J Epidemiol. (1999) 150(6) p552-560.

This paper is one of several arising from a population based case-control study conducted in Iowa USA to evaluate the associations between brain and other cancers and chlorination byproducts. This article focuses on glioma - a type of brain cancer.

Cases were identified from the State Health Registry of Iowa, supplemented by a rapid reporting system during 1987. There were 375 cases aged between 40 and 85 years, newly diagnosed with glioma between January 1984 to December 1987 and without a previous diagnosis of malignant cancer. Controls aged under 65 years were selected randomly from computerised state driver's license records. Those over 65 were selected from US Health Care Financing Administration listings. Controls totaled 2,434 people without a previous cancer diagnosis.

Subjects completed a postal questionnaire or telephone interview from which information was gathered on lifetime residential history, sources of drinking water, beverage intake and other potential risk factors. Where the case was deceased or too ill to be interviewed, a proxy respondent (close relative or friend) was interviewed. Information was collected on water sources and treatment used by the Iowa water utilities since inception. Water samples were taken from each utility at the entry point to the distribution system and trihalomethanes (THM) measured.

Exposure to chlorination byproducts in water was calculated from questionnaire data, the water utility survey and the recent THM measurements of water samples. In order to minimise misclassification of exposure only people with water quality information available for at least 70% of lifetime years were included in the analysis. This reduced the number of cases to 291 and controls to 1,983. Of the cases, 210/291 (74.4%) were represented by proxies, but only 1/1983 controls was represented by a proxy interviewee.

Initial analysis using only adjustment for age and sex showed a non-significant trend to increasing glioma risk in residents of smaller sized towns,

and a significant association of glioma with farm occupations (OR 1.5, 95% CI 1.1-2.1). Most farms in Iowa are served by unchlorinated well water and thus have low exposures to DBPs.

Examination of the association between glioma risk and tap water intake appeared to show a trend for increasing risk with increasing consumption in men but not women. However information gathered during the study suggested that proxy respondents for both cases and controls were overreporting water intake compared to direct respondents. When correction was made for this factor, no association was seen with water intake.

The analysis showed odds ratios for brain cancer of 1.0, 1.1, 1.6, and 1.3 for a duration of exposure to chlorinated surface water of 0, 1-19, 20-30 and ≥ 40 years (p trend = 0.1). When the sexes were analysed separately there was a consistent trend of increased risk with increasing duration of exposure for men, with odds ratios of 1.0, 1.3, 1.7, and 2.5 (p trend = 0.04). However in women no trend was seen, with odds ratios of 1.0, 1.0, 1.6, and 0.7 (p trend = 0.7).

When exposure was estimated in terms of lifetime average THM exposure, men showed a similar but weaker trend to increasing risk with increasing exposure. Again no such trend was observed in women. An association was found among men with above to median tap water consumption and glioma. A dose-response relationship among men was found between brain cancer risk and duration of consuming chlorinated drinking water, especially in those that consumed large quantities of drinking water.

The causes of brain cancer are poorly understood, and there is some evidence that brain cancer incidence may be increasing, although it is difficult to determine whether this may be at least partly due to improvements in diagnosis. As this is the first evaluation of chlorination byproducts as risk factors for brain cancer in a population-based study, the authors caution that further research to provide confirmation of the results is required.

Comment In common with most other studies of DBPs, this study uses THM levels measured at water treatment plants as a measure of exposure for people living at various points in the distribution system. However in reality the levels of THMs and other DBPs vary throughout the system and over time. Changes in raw water quality and water treatment practices over the decades of exposure would also contribute to inaccuracy in the exposure assessment. The use of proxy respondents for a large proportion of cases but not controls is also of some concern in terms of accuracy of recall. While this is unavoidable in studies of fatal diseases, it would be better practice to interview a corresponding proportion of proxy controls also.

The differential findings in men and women are puzzling and no obvious explanation is apparent. There is some evidence that hormonal influences may affect brain cancer risk in women, but this remains an area of dispute. The observation of increased risk in men but not women has been reported recently in some other studies of DBPs and cancer, and suggests the possibility of either a sex-specific effect or an uncontrolled or inadequately controlled confounding factor in male subjects.

Water chlorination and birth defects.

Magnus P, Jaakkola JJK, Skrondal A, Alexander J, Becher G, Krogh T, et al. *Epidemiology*. (1999) **10**(5) p513-517.

In Norway drinking water commonly comes from surface water sources but the use of chlorination is variable. This study examined the association between chlorination and water colour (a surrogate for dissolved organic carbon content) and the occurrence of birth defects.

The Norwegian national waterwork registry for 1994 containing data on chlorination practice and colour was linked with the national birth registry. A weighted mean colour number of the drinking water source for each municipality was calculated as well as the proportion of the population exposed to chlorination. The study population consisted of 141,077 children of mothers included

in the Norwegian Birth Registry between 1993-1995, for which the chlorination status in a least one water work was known and the weighted mean colour number of their drinking water was possible to calculate.

There were 2,608 newborns identified with birth defects among the 141,007 children. When a comparison was made between areas with chlorination and high colour and those with no chlorination and low colour, small but statistically significant increases were seen for neural tube defects (OR=1.26, 95% CI=0.61-2.62) and urinary tract defects (OR=1.99, 95% CI=1.10-3.57).

Non significant adjusted odds ratios were found for cardiac defects, oral cleft defects, for respiratory tract defects. This study suggests that the risk of birth defects is highest in municipalities with both a high content of organic compounds in drinking water and the presence of chlorination. An excess risk of about 15% compared with municipalities with no chlorination and low colour was found. Results of this study concur with two previous studies which both found an increased risk of total birth defects related to consumption of chlorinated surface water.

Comment This study used the combination of water colour and chlorination as a rather indirect measure of exposure to DBPs. As for the previous paper on cancer risks, such system wide estimates based on measurements at the treatment plant cannot adequately describe exposures at different points in the system. It is also debatable whether two systems with the same colour value would necessarily have similar DBP profiles.

The water consumption of individual women was not assessed, and during analysis adjustment was made only for a few factors which were available from the data sources used (eg maternal age, parity, population density). There was no assessment of potentially important risk factors such as maternal alcohol intake, smoking or diet, which may have influenced the result.

Random-effects meta-analyses are not always conservative.

Poole C and Greenland S. (1999) Am J Epidemiology **150**(5) p469-475.

This paper discusses aspects of meta-analysis of epidemiological studies using the published work of Morris et al. as an example (Am J Public Health **82** p955-63, 1991). The Morris paper bolstered the argument for an effect of DBPs on cancer risks using meta-analysis to assess 64 published studies. From this analysis the authors concluded that the evidence supported a statistically significant association of DBP exposure with bladder cancer and rectal cancer. While this paper contained a number of cautions about assuming a cause and effect relationship, it also included calculations of the number of cases of these cancers "attributable" to DBP exposure. Such calculations have since become commonplace in discussions of the risks of DBP exposure.

In simple terms, meta-analysis is a technique used to combine the results of different studies to provide an overall estimate of effect. It is generally used where the individual results have not reached statistical significance or where barely significant results have been obtained. This technique was initially used in medicine to analyse randomised controlled clinical trials where "exposure" to an intervention is assigned by the investigator. The combination of such studies in a meta-analysis is based on the assumption that each study provides an unbiased estimate of the effect of intervention, and that variability between studies represents random variation. These assumptions are fulfilled when good quality randomised studies are selected with appropriate assessment of their design features (eg similarity of inclusion criteria, intervention, outcome measures).

However the application of meta-analysis to observational studies (where exposure is not assigned by the investigator) is not so straightforward. In this situation the observed differences between studies may be due to a number of additional factors including bias

(particularly for case-control studies), and confounders (particularly for cohort studies). This potential heterogeneity between studies means that combination of their observations may lead to statistically significant but erroneous associations being produced. This effect has been described as "spurious precision" as it produces an estimate with tight confidence intervals which give the false impression of reliability of the result (Egger M et al. BMJ **316** p140-4, 1998).

In the current paper the authors discuss the argument about the use of "fixed-effect" as opposed to "random-effect" assumptions on the outcome of meta-analysis. The Morris et al. paper used random-effect summaries and described these as "conservative" - generally a term implying assumptions that are less likely to encourage definitive conclusions. However when meta-analysis of the same studies is carried out using fixed-effects assumptions, the resultant estimates of relative risk for various cancers are lower. For one of the two cancers where Morris et al. found a significant increase in risk ($p < .05$) the new analysis gives a non-significant p value. Overall the fixed-effect method produced an equal number of relative risks values above and below 1.0, thus being more consistent with no effect of chlorination (ie conservative).

The authors however do not advocate the fixed-effect model but point out that neither type of analysis is appropriate when the individual results which are included in meta-analysis are strongly heterogeneous (ie when they have strongly conflicting results). This is evident with the studies on bladder cancer analysed by Morris et al., where very wide differences in confidence intervals were seen, which in some cases were non-overlapping. In these circumstances, the authors argue that meta-analysts should seek explanations for such heterogeneity by examining study designs and methodologies rather than attempting to produce a summary statistic by combining dissimilar studies together.

One plausible explanation for heterogeneity in this instance is that most studies have essentially compared surface water with ground water, and

these types of water supplies may differ in characteristics other than chlorination byproducts. Also discussed are the possible effects of publication bias, where low powered studies with positive results are more likely to be published than those of similar precision but with negative outcomes. Analysis of the individual studies used by Morris et al. suggests that this has occurred since the higher powered, more precise studies produce effect estimates close to zero (no risk associated with chlorination) while those with lower power have relative risks further from zero and mainly in the positive direction.

The authors conclude that they are not ruling out the possibility of a real effect of disinfection byproducts on cancer risks, but that the observed results may equally well be due to problems with methodology, confounding and publication bias. On the whole they feel that the computation of "attributable cases" of cancer from meta analysis without consideration of these factors "sets too low a standard for the use of meta analysis to guide public health decision making". Meta analysts should give more consideration to describing and investigating causes of heterogeneity, rather than attempting to arrive at a summary statistic which may be misleading.



E. coli

Potential health risks associated with the persistence of *Escherichia coli* O157 in agricultural environments.

Jones DL. Soil Use Manage. (1999) **15**(2) p76-83.

Escherichia coli serotype O157 is an increasing public health problem. This organism has been widely implicated in outbreaks of foodborne illness throughout most of the world, and outbreaks have also occurred from drinking water and recreational water sources.

E. coli O157 in humans is highly infectious and it possesses an enhanced ability to colonise the human intestine and produce lethal toxins. The ingestion of only 10 to 50 cells can cause symptoms to develop. The most common

symptom is bloody diarrhoea appearing 1 to 5 days after ingestion. In the young, pregnant or elderly, life threatening complications can arise such as haemolytic-uraemic syndrome (HUS) and thrombotic thrombocytopenic purpura (TTP).

The primary reservoir of *E. coli* 0157 in the environment is cattle, although other animals such as sheep and pigs have been shown as carriers. It has been estimated that 1 to 4% of UK cattle herds are infected with *E. coli* 0157, however one study reported a regional incidence of 16% in cattle. Excretion by cattle may persist for 2 to 4 months and appears to be seasonal with excretion highest in the spring and late summer. This reflects the start of the peak in reported human cases. *E. coli* 0157 can survive in cattle faeces up to 7 weeks, in non-aerated cattle manure for more than a year and in cattle slurry less than 10 days.

There is a lack of information relating to the survival of this pathogen in soil, however, one study found it persisted in turfgrass soil for up to 4 months. *E. coli* 0157 can survive at a range of temperatures, is extremely acid tolerant and can survive and grow in both aerobic and anaerobic environments. It can persist for more than 3 weeks in fruit and salad vegetables. *E. coli* 0157 can contaminate surface and ground waters and pollution of water sources by agricultural wastes such as cattle slurry had been a major problem in the UK. Contamination of groundwater supplies by animals or their faeces has been implicated in cases of *E. coli* 0157 worldwide. *E. coli* 0157 has been reported to survive up to 90 days in river water depending on water source and temperature and more than 300 days in bottled water.

The spreading of untreated abattoir waste on soil may pose a major public health risk, and there have been several major incidents of surface and groundwater supplies becoming contaminated due to improper disposal of abattoir waste on land. Control measures are now being introduced in many countries to reduce the risk of *E. coli* 0157 infections.

Magnesium

Magnesium in drinking water and the risk of death from diabetes mellitus.

Yang CY, Chiu HF, Cheng MF, Tsai SS, Hung CF, Tseng YT. *Magnes Res.* (1999) 12(2) p131-137.

The aim of this study was to examine whether there is a relationship between the level of magnesium in drinking water and death from diabetes mellitus in Taiwan. It has been proposed that problems associated with diabetes mellitus are linked to tissue and serum magnesium deficiencies and therefore in magnesium-enriched environments the mortality from diabetes should be lower.

Of the 361 administrative districts in Taiwan, 322 were chosen for analysis. Information on deaths was obtained from the Bureau of Vital Statistics of the Taiwan Provincial Department of Health. Cases consisted of all eligible diabetes mellitus deaths occurring in people between 50 and 69 years from 1990 to 1994. The control group was formed using all other deaths excluding deaths that might confound results. Control subjects were randomly pair matched to cases by sex, year of birth and year of death. To be eligible for the study subjects had to have residence and place of death in the same municipality.

A total of 6781 cases and 6781 controls were included in the study. The Water Quality Research Center of the Taiwan Water Supply Corporation supplied information on calcium and magnesium levels in each municipality. The municipality of residence of the cases and controls was assumed to be their source of exposure to calcium and magnesium in drinking water. The mean magnesium concentration in drinking water was 11.5 mg/L for cases and 11.6 mg/L for controls.

When deaths from diabetes mellitus were compared in areas with different magnesium concentrations in water, there was a trend to decreasing risk as magnesium concentrations increased. However, only the areas with the highest levels of magnesium in drinking water (≥ 16.2 mg/L) showed a significantly lower odds

ratio (OR=0.81, 95% CI 0.69-0.95). The results of this study showed a significant protective effect in the group with the highest intake of magnesium via drinking water, suggesting that intake above a certain level has a beneficial effect on the probability of dying from diabetes mellitus. However this study could not assess the effects of diet, exercise or obesity all of which can affect the risks of diabetes and its complications.



Pathogens

Committee report: Emerging pathogens - bacteria.

LeChevallier MW, Abbaszadegan M, Camper AK, Hurst CJ, Izaguirre G, Marshall MM, et al. J AWWA. (1999) **91**(9) p101-109.

This paper summarises the outcome of an exercise by the US AWWA Research Division Microbial Contaminant Committee members to evaluate the emerging bacterial pathogens they considered to be of greatest concern to the water industry. The four bacterial microorganisms examined were: *Myobacterium avium* complex, *Helicobacter pylori*, pathogenic *Escherichia coli* and *Campylobacter jejuni*.

For each of these bacteria this paper provides a brief description, consideration of health effects, occurrence, survival, outbreaks, analytical procedures for isolation and treatment, and research needs.

The committee ranked *Myobacterium avium* as highest on the list of priorities for the water industry. This was because it occurs commonly in water and causes health effects such as pneumonia and gastrointestinal illness particularly in the immunocompromised, it persists in the environment as it has the ability to regrow in distribution system biofilms and it is resistant to chlorine.

Helicobacter pylori was ranked second and of moderate priority because of its health effects which include ulcers and possibly stomach cancer. It is however sensitive to disinfection and there are no documented waterborne outbreaks. Its occurrence in water and environmental

persistence is still open to discussion. Of lowest priority were pathogenic *Escherichia coli* and *Campylobacter jejuni*, these are both sensitive to disinfection and have low environmental persistence. The committee concluded that more research needs to be undertaken into improved detection methods for these bacteria and a greater knowledge of their occurrence and control in water is required.

Committee report: Emerging pathogens - viruses, protozoa, and algal toxins.

LeChevallier MW, Abbaszadegan M, Camper AK, Hurst CJ, Izaguirre G, Marshall MM, et al. J AWWA. (1999) **91**(9) p110-121.

This companion paper to the one above reviews three viral and three protozoan microorganisms and one set of toxins.

The viruses examined were: the enteroviruses, Calicivirus, specifically the Norwalk viruses, and hepatitis A virus. The protozoa examined were: *Cyclospora*, microsporidia and *Toxoplasma* and the cyanobacteria toxins were also reviewed. This report describes each pathogen and considers their health effects. The occurrence, survival and associated outbreaks of each are examined, and water treatment and research needs are discussed.

Rated of moderate priority for the water industry were Norwalk virus and caliciviruses, *Cyclospora*, *Microsporidia* and cyanobacterial toxins, this is because for most of these little is known about their occurrence in water, the drinking water treatment required to remove them and their environmental persistence. None of these pathogens examined were of high concern. Of low concern were enteroviruses, hepatitis A virus and *Toxoplasma* because they can mostly be removed by conventional drinking water treatment. *Toxoplasma* was ranked low because it is a rare waterborne pathogen. Again the conclusion was that more research needs to be undertaken into detection methods for all of these pathogens and into their occurrence and control in drinking water.

List of Articles

Campylobacter

Seasonal variation of Campylobacter types from human cases, veterinary cases, raw chicken, milk and water.

Hudson, J. A., C. Nicol, et al. (1999). J Appl Microbiol **87**(1): 115-24.

Cancer

Trace element levels in drinking water and the incidence of colorectal cancer.

Kikuchi H, Iwane S, Munakata A, Tamura K, Nakaji S, Sugawara K. Tohoku J Exp Med. (1999) **188**(3) p217-225.

Cryptosporidium

Evaluation of immunomagnetic separation for recovery of infectious Cryptosporidium parvum oocysts from environmental samples.

Rochelle, P. A., R. De Leon, et al. (1999). Appl Environ Microbiol **65**(2): 841-5.

Disinfection byproducts

Neural Tube Defects and Drinking Water Disinfection By-Products.

Klotz, J. B. and L. A. Pyrch (1999). Epidemiology **10**(4): 383-90.

Trihalomethanes in Public Water Supplies and Adverse Birth Outcomes.

Dodds, L., W. King, et al. (1999). Epidemiology **10**(3): 233-37.

Reuse

Risk assessment for Cryptosporidium parvum in reclaimed water.

Jolis D, Pitt P, Hirano R. Wat Res. (1999) **33**(13) p3051-3055.

Potable use of reclaimed water.

Crook J, MacDonald JA, Trussell RR. J AWWA. (1999) **91**(8) p40-49.

Water Quality

A neural network approach to identifying non-point sources of microbial contamination.

Brion, G. M. and S. Lingireddy (1999). Wat Res **33**(14): 3099-106.

Application of laser scanning for the rapid and automated detection of bacteria in water samples.

Reynolds, D. T. and C. R. Fricker (1999).. J Appl Microbiol **86**(5): 785-95.



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To be placed on the Health Stream mailing list please contact:

Ms Pam Lightbody	Phone	+61 3 9903 0592
Epidemiology and Preventive Medicine	Fax	+61 3 9903 0576
Monash Medical School, Alfred Hospital	email	pam.lightbody@med.monash.edu.au
Prahran VIC 3181, AUSTRALIA		

To be placed on the Water Quality News mailing list please contact:

Mr Fred Lijauco	Phone	+61 8 8302 3068
School of Chemical Technology	Fax	+61 8 8302 3668
University of South Australia	email	fred.lijauc@unisa.edu.au
The Levels SA 5095, AUSTRALIA		