Health Stream

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UK DBP And Birth Study

British researchers have published the results of a large study investigating the possible relationship between exposure to trihalomethanes in public water supplies, low birth weight and rates of stillbirth (1). The study, the largest of this nature yet undertaken, examined nearly one million births and stillbirths in areas supplied by three major water supply companies in England and Wales.

Low birth weight remains a significant risk factor for stillbirths (also known as fetal deaths) and neonatal deaths in developed nations despite marked improvements in neonatal care in recent decades. For example in Australia during 1999, low birth weight infants accounted for 6.7% of births but comprised 71.4% of stillbirths and 72.1% of neonatal deaths (defined as infant deaths within 28 days of delivery).

Low birth weight (LBW) may be due to premature delivery of an infant that has been growing at a normal rate, or delivery at full term of an infant that has been growing more slowly than normal. These two mechanisms are known to be associated with different risk factors. In developing countries with high rates of LBW, most cases are attributable to reduced fetal growth rates associated with low maternal energy intake and low pre-pregnancy maternal body weight. In developed countries premature delivery is a relatively more important cause of LBW, with urogenital tract infections being the most frequent known cause. Maternal smoking is a risk factor for both categories of LBW in developing and developed countries.

Surviving premature infants are at increased risk for short and long term pulmonary, neurological and ophthalmological illnesses, and delayed psychomotor development. Surviving growth-restricted infants are at short term risk for biochemical imbalances and neonatal death, and may have permanent deficits in neurocognitive development and growth. Recent research also indicates that growth restriction in-utero is significantly associated with the development of type-2 diabetes, high blood pressure and coronary artery disease later in life, although the biological basis for this relationship is unclear.

A number of epidemiological studies have examined possible associations between exposure to disinfection byproducts (DBPs) in drinking water supplies and a range of reproductive outcomes including stillbirth and low birth weight. The results have been mixed, with some studies showing statistically significant associations of adverse outcomes with DBP exposure, and others finding no association. However given the potential public health importance of the issue, efforts to clarify the question through larger and better designed studies are continuing.

Study design The UK study, undertaken by the Small Area Health Statistics Unit (SAHSU), used routinely collected data on singleton births and stillbirths from a national database. The pregnancy outcomes assessed were:

- Low birth weight (LBW) – defined as less than 2,500 g at delivery
- Very low birth weight (VLBW) – defined as less than 1,500 g at delivery
- Stillbirth – defined as a fetal death after 24 weeks of completed gestation

The postcode of the mother's residence at the time of delivery was used to define her total trihalomethane (TTHM) exposure level for the last three months before the birth event. Information on water supply zones was provided by Northumbrian Water (supplying 2.6 million people in 120 water zones), United Utilities (6.8 million people in 315 water zones) and Severn Trent Water (7.4 million people in 300 water zones). Water zone boundaries were plotted in a Geographic Information System and individual residential addresses were matched to the water zones. A separate linkage file was made for each year of the birth data to allow for movements in postcode boundaries.

UK regulations for THM monitoring specify a basic sampling frequency of at least four samples per year in each water zone, however the number of samples may be increased or decreased depending on the results of sampling. If all samples taken in a zone for one year are less than 50% of the UK standard of 100 micrograms/L, then the sampling frequency may be reduced to one per year. In the event that the rolling 3-month average for a zone exceeds 100 micrograms/L, then sampling frequency must be increased to at least 12 samples per year (or 24 samples per year for large water zones). As a consequence of this variability in sampling frequency, the number of THM data points available for different water zones in the study ranged from as few as one to as many as 80 samples per year.

A complex hierarchical mixture modelling method was used to derive estimates of mean THM concentrations in each water zone. The model was used to calculate the mean annual concentrations of the four individual THMs for each zone, then the zone was assigned to one of three water source types based on the THM profile. The three water types were "ground", lowland surface" and "upland surface". The modelling technique allowed zones to "borrow" information from other zones of the same water type, thus providing more stable estimates of THM levels for zones where few data points were available. For samples which were below the detection limit, modelling was undertaken to give an estimated concentration between zero and the detection limit. Seasonal variation was incorporated by estimating a quarterly effect common to all zones with the same water source type.

The time period analysed for each water supplier was different with six years included for Severn Trent Water (1993-1998), five years for United Utilities (1993-1997) and one year for Northumbrian Water (1997). A total of 1,023,665 births and stillbirths were registered in the three regions during these time periods. Of these 54,361 (5.3%) were excluded from

analysis due to inability to match residence with water supply area, private water supplies or multiple births. For the remaining 969,304 birth records, individual maternal exposure during the last 93 days before the birth event was estimated using a weighted average of the modelled quarterly TTHM estimates for the water zone of residence. Births during the first 93 days of the study period for each water company were excluded from analysis. Maternal exposure level was then classified into three categories: low TTHM (less than 30 micrograms/L), medium TTHM (30-60 micrograms/L) and high (greater than 60 micrograms/L). The number of birth events included in the analysis for each water company region was 20,624 for Northumbrian Water, 412,973 for United Utilities and 486,974 for Severn Trent Water.

Statistical analysis was carried out in a descriptive manner for each outcome and each water company region, and by univariate and multivariate logistic regression modelling with adjustment for measured potential confounders. Potential confounders included in the analysis at the level of the individual pregnancy were the gender of the fetus and the maternal age (categorised as less than 20 years, 21-25, 26-30, 31-35, and 36 or older). Socio-economic deprivation was also considered at the level of census data collection districts (corresponding to a small area containing 400 residents on average) using the Carstairs index. This index is derived from four measures: the percentage of people with no car, in overcrowded housing, with the head of the household in an unskilled or semi-skilled occupation, and the percentage of men unemployed. High values for the Carstairs index represent more deprived status relative to low values. Pregnancies were classified in quintiles of the Carstairs index score.

Study Results The overall rates of the pregnancy outcomes, TTHM values and the mean Carstairs index in the three water company regions are shown in the Table in the next column. When the Carstairs index was examined for areas with different THM exposure levels within each water company region, the United Utilities region showed a tendency for increasing socio-economic deprivation as TTHM levels increased. The other two regions did not show this trend.

	North-umbrian	**United Utilities**	**Severn Trent**
Stillbirths	5.4	5.4	5.2
LBW	64.8	61.5	63.5
VLBW	10.7	9.1	9.7
TTHM			
Mean	56.6	52.0	35.8
Low	18.0	19.2	11.2
Medium	48.1	46.0	44.0
High	71.5	71.9	70.7
Carstairs Index	1.54	1.12	0.65

Prevalences of stillbirths, LBW and VLBW are per 1,000 births.
TTHM levels are in micrograms/L.

The descriptive analysis showed different trends for pregnancy outcomes in the different water company regions. The United Utilities region showed a pattern of increasing rates of stillbirth LBW and VLBW as TTHM exposure levels increased. In the Severn Trent region, the rates of LBW and VLBW tended to decline as TTHM exposure increased, but the rate of stillbirths remained fairly constant. In the Northumbrian region no particular pattern was seen.

Univariate logistic regression confirmed a trend to increasing prevalence of LBW, VLBW and stillbirths with increasing TTHM exposure in the United Utilities region but not in the two other regions. Multivariate logistic regression with adjustment for confounders had the effect of reducing Odds Ratios (ORs) but the associations remained statistically significant for the United Utilities region (see Table on next page). In the Northumbrian region there was a non-significant excess of the adverse pregnancy outcomes in areas with medium or high THM levels compared to low THM levels, and confidence intervals were wide due to the smaller number of births analysed in this region. In the Severn Trent region, Odds Ratios for stillbirth were slightly elevated for medium and high TTHM exposure but this was not statistically significant. The OR for LBW was slightly less in the high TTHM category relative to low or medium TTHM exposure, while for VLBW there was a statistically significant decrease in the OR in the highest TTHM exposure category (ie high TTHM exposure was associated with a significantly lower risk of VLBW in this region).

Adjusted Odds Ratios (95% CI) for Low, Medium and High TTHM exposure

	Stillbirth	LBW	VLBW
Northumbrian			
Low	1.00	1.00	1.00
Med	1.19 (0.51-2.75)	1.02 (0.80-1.30)	1.20 (0.66-2.18)
High	1.09 (0.46-2.55)	1.11 (0.87-1.41)	1.11 (0.61-2.03)
United Utilities			
Low	1.00	1.00	1.00
Med	**1.16** (1.00-1.35)	**1.11** (1.07-1.16)	1.09 (0.98-1.21)
High	**1.21** (1.03-1.42)	**1.19** (1.14-1.24)	**1.20** (1.07-1.34)
Severn Trent			
Low	1.00	1.00	1.00
Med	1.03 (0.95-1.13)	1.00 (0.98-1.03)	1.00 (0.94-1.06)
High	1.04 (0.93-1.18)	0.98 (0.95-1.02)	**0.90** (0.82-0.99)
Overall summary			
Low	1.00	1.00	1.00
Med	1.06 (0.99-1.15)	1.05 (0.96-1.15)	1.03 (0.96-1.10)
High	**1.11** (1.00-1.23)	1.09 (0.93-1.27)	1.05 (0.82-1.34)
Statistically significant Odds Ratios are shown as bold text.			

Odds Ratios for TTHM exposure and prevalence of LBW and VLBW showed statistically significant heterogeneity between water regions, however ORs for stillbirths did not. A random effects model was used to obtain overall summary estimates of risk across all areas. Only the results for stillbirth in the high TTHM exposure category were statistically significant in the overall summary estimates.

In addition to TTHMs the analysis also examined the effects of chloroform, bromodichloromethane and total brominated THMs. The results for chloroform were similar to those for TTHMs, while no associations were seen between adverse outcomes and bromodichloromethane or total brominated THM exposure levels.

Limitations of the study This study contained more birth events than the combined numbers in all previously published studies on either low birth weight or stillbirth, however the authors acknowledge that while the large sample size made possible by use of routine databases provides higher statistical power, it also precludes the use of direct exposure measures. While the TTHM modelling techniques used here were sophisticated, they still provide only an ecological measure of exposure as all women resident in a water zone are assigned the same exposure level. The methods also could not consider individual variations in exposure due to different water use behaviours (eg drinking bottled water, swimming), exposure to water from other zones (eg in the workplace) or the possibility that some mothers may have moved home during the 3-month exposure period that was considered.

The study also could not adjust for some risk factors which are known to be important for the outcomes under study, such as maternal smoking, as these were not recorded in the maternal database. Unfortunately the UK national perinatal database also does not routinely record information on gestational age at delivery so this study was unable to distinguish the different categories of LBW pregnancies (premature delivery vs growth retardation), and therefore could not test whether they showed same pattern of relationships with TTHM exposure. Some previous studies which have been able to examine the categories separately have found an association between THM exposure and growth retardation but not with premature delivery. The discussion of statistical analysis also does not mention whether information was available on previous pregnancy history. LBW due to growth retardation is more common for first pregnancies than subsequent pregnancies, and women with a previous pre-term birth are at higher risk for premature delivery in subsequent pregnancies. Inability to adjust for these factors may have influenced the results of the study.

It is normal practice to apply uniform definitions of LBW and VLBW to all births however the weight of healthy infants may be expected to vary between different ethnic and racial groups due to intrinsic genetic differences. In addition, rates of stillbirth, LBW and LVBW are elevated in socio-economically deprived groups (which in many instances disproportionately include ethnic and racial minority groups). The authors note that differences in the composition of populations with respect to ethnic minorities in the studied regions leading to different proportions of premature births versus LBW full term births, might be a possible explanation for the observed heterogeneity seen in the study results.

The strongest pattern of association between TTHM exposure and adverse pregnancy outcomes was seen in the United Utilities region, however this region also showed a strong association between socio-economic deprivation and TTHM levels in water. The authors comment that although adjustment for socio-economic deprivation (as measured by the Carstairs index) was included in the statistical analysis, there is still a possibility that residual confounding is influencing the result. Excess risks associated with high versus low levels of deprivation (after adjustment for other potential confounders and TTHM category) were 15 to 20 times stronger than those associated with high versus low TTHM exposure (after adjustment for deprivation and other potential confounders). Therefore inadequate control for socio-economic deprivation has the potential to strongly affect the estimated Odds Ratios.

Causation versus Association Trihalomethanes were used as the measure of exposure in this study as these DBPs are routinely monitored in the UK, and thus extensive databases were available. However the authors note that THMs are unlikely to have a causal relationship with adverse pregnancy outcomes. These compounds do not show significant reproductive or developmental toxicity in animal studies, and epidemiological studies which have examined THM exposure at the individual level have not shown an effect of swimming (an activity involving high inhalation and dermal exposure to THMs) on estimated risk levels.

Some other known classes of DBP, for example the haloacetic acids, exhibit a degree of reproductive or developmental toxicity in animals, but only at dose levels much higher than those found in drinking water supplies. There are few monitoring data available for DBPs other than THMs, therefore opportunities for retrospective epidemiological studies of possible associations with adverse health outcomes very are limited.

It is possible that the association observed between TTHM exposure and stillbirth in this study represents a cause and effect relationship due to some as yet unidentified DBP(s). The heterogeneity of results in different regions could be explained if this unknown compound had a variable relationship with TTHM levels, so that in some regions (eg United Utilities) high levels of this compound correlated with high TTHM levels, while in other regions it did not.

Alternatively, the observed associations may be due to some other factor not related to DBPs in the water supply. The authors suggest that further studies should examine subcategories of stillbirth, the effects of other DBPs, and the possible role of residual confounding at the individual level.

Committee on Toxicity Statement After publication of the research paper the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) released a statement on chlorinated water and reproductive outcomes [2]. COT is an independent scientific committee that provides advice to the Food Standards Agency, the Department of Health and other UK government departments and agencies on matters concerning the toxicity of chemicals.

The statement summarized past evaluations and statements on the issue by COT and concluded that:

- the data evaluated (including the SASHU study and other published literature) do not show a causal relationship between chlorinated drinking water and pregnancy outcomes (excluding congenital malformations, for which data have not yet been evaluated).
- COT recommends that further research be undertaken, specifically prospective studies with more precise assessment of individual exposures, allowance for seasonal variations in DBP levels, and more comprehensive analysis of other potential causative agents and confounding factors.
- COT considers that while such research is undertaken, efforts by water companies to minimise consumer's exposure to chlorination byproducts remain appropriate, providing that such measures do not compromise the efficiency of disinfection of drinking water.

SAHSU is currently finalizing a related study of congenital malformations and THM levels involving 14 UK water companies. The report on this study is

expected to be presented to COT in 2005. COT will then review and evaluate the scientific literature on chlorinated drinking water and congenital anomalies.

1) Relation of trihalomethane concentrations in public water supplies to stillbirth and birth weight in three water regions in England. Toledano MB, Nieuwenhuijsen MJ, Best N, Whitaker H, Hambly P, de Hoogh C, Fawell J, Jarup L, and Elliott P.
Environmental Health Perspectives, published online 21 October 2004
doi:10.1289/ehp.7111 (available at http://dx.doi.org/)

2) http://www.advisorybodies.doh.gov.uk /cotnonfood/ chlorination.htm

Giardia Outbreak In Norway

A waterborne outbreak of giardiasis with over 1,000 laboratory-confirmed cases has occurred in the town of Bergen, Norway. The outbreak appears to have begun in late August with case numbers gradually increasing over several weeks, but public health investigations did not identify the water supply as the probable source until early November. A boil water notice was then issued to the public and steps were taken to provide an alternative supply by diverting water from other sources to the area. Specific instructions were also issued to hotels, restaurants, other retail food outlets and institutions regarding water use. Water sampling after the outbreak was detected revealed *Giardia intestinalis* cysts (also known as *G. lamblia*) in treated water at concentrations of up to 5 cysts per 10 litres, however their viability was unknown.

Bergen has a population of 235,000 and the water supply in question serves about 60,000 people in the centre of the town. The water is drawn from a lake and is treated by chlorination but is not filtered. Norway has a number of similar high quality surface water supplies which are used without filtration although most serve smaller populations than the supply in Bergen. Chlorination is able to provide some degree of disinfection against *Giardia* cysts (up to 1.5 to 2-logs removal) provided appropriate CT values are used, however in countries such as Norway very cold water temperatures in winter may make this difficult to achieve.

This outbreak may have been triggered by heavy rainfall, with 120mm of rain recorded in the 2-week period before *Giardia* case numbers began to rise. Heavy rain then continued over several weeks. Levels of coliform bacteria in the raw water also peaked just after the initial rain event. Investigations into possible source of contamination are focusing on sewage contamination from homes and restaurants overlooking the lake.

Analysis of the age and gender distribution of cases has shown a predominance of adults in the 20 to 59-year age bracket with few cases in children or the elderly. This is an unusual distribution as waterborne disease outbreaks generally affect all age groups in a community. In this instance, it may be explained by the demographic characteristics of the affected area which includes businesses and rental accommodation for students. Therefore relatively few children or elderly people may have been exposed to the contaminated water.

A water treatment plant with filtration and UV disinfection had already been commissioned for the affected water supply before the outbreak occurred. A temporary UV plant has now been installed to provide additional disinfection capacity for the supply while the new plant is being built. At the time of going to press the boil water notice had been lifted except for an area of about 7,000 people for whom it is not possible to provide an alternative water supply.

Health Stream thanks Professor Hallvard Ødegaard (Norwegian University of Science and Technology) and Dr Karin Nygard (Norwegian Institute of Public Health) for supplying information on this outbreak.

US Drinking Water Outbreaks

The Centers for Disease Control and Prevention recently released their biannual Surveillance Summary for drinking water-related disease outbreaks in the United States and its territories [(1)]. The report summarises 31 outbreaks in 19 states that occurred during 2001 and 2002. The outbreaks were associated with seven deaths and 1020 cases of illness. A causative agent was identified in 24 outbreaks (77%), with the majority being due to pathogens (19 outbreaks), while chemicals were

responsible for five outbreaks, and no cause was identified in seven outbreaks. The report also includes a previously unreported category of drinking water-related outbreaks of *Legionella* infection.

Information for the Surveillance Summary is contributed on a voluntary basis by state public health departments. An outbreak is defined as a similar illness affecting two or more people after exposure to a common water source, with water being implicated as the source of disease on the basis of epidemiological evidence. For instances of chemical poisoning supported by water quality data, and for primary amoebic meningoencephalitis, a single case is considered to represent an outbreak. Outbreaks associated with contamination of water at the point of use rather than at the water source or distribution system are excluded, as are outbreaks associated with cruise ships.

The causative agents, type of water source, the number of outbreaks and cases for drinking water outbreaks are summarised in the table in the next column (excluding *Legionella* outbreaks). The largest single outbreak was a Norovirus outbreak in a snowmobile lodge in Wyoming which affected 230 people. Norovirus was also the most frequently identified cause of outbreaks and was responsible for the majority of cases of gastroenteritis (727 of 938 cases, or 78%).

Three deaths were attributed to drinking water outbreaks (excluding *Legionella* outbreaks). Two of these were due to primary amoebic meningo-encephalitis caused by *Naegleria fowleri* which occurred in young children in Arizona [2]. This disease is rare but is invariably fatal. The remaining death was associated with Norovirus infection. In this instance a 15 year-old boy was one of 71 people who became ill after drinking from a water dispenser at a golf course. Two days later the boy was found unconscious on the bathroom floor of his home and could not be revived by paramedics. An autopsy showed the immediate cause of death to be asphyxiation due to inhalation of vomitus. Noro-viruses usually cause vomiting and diarrhoea lasting 24-48 hours, with a low rate of serious complications.

Drinking water-associated outbreaks in the US 2001-2002

	Surface water	**Ground water**
	Outbreaks (Cases)	
Protozoa		
Giardia	1 (6)	2 (12)
Cryptosporidium	0	1 (10)
Naegleria fowleri		1 (2)
Bacteria		
Campylobacter jejuni	0	1 (13)
E.coli O157:H7		1 (2)
Campylobacter jejuni + *Yersinia enterocolitica*		1 (12)
Viruses		
Norovirus	0	5 (727)
Chemical		
Copper	1 (28)	1 (2)
Copper + other minerals		1 (4)
Ethyl benzene, toluene, xylene		1 (2)
Ethylene glycol		1 (3)
Unknown cause		7 (117)
TOTAL	**2 (34)**	**23 (906)**

In the seven outbreaks where no causative agent was identified, the acute gastroenteritis symptoms experienced were consistent with a microbiological cause. Untreated groundwater was associated with 10 (40%) of the 24 non-*Legionella* outbreaks. Treatment deficiencies such as interruption of disinfection or inadequate filtration were identified in seven outbreaks (28%). Distribution system problems such as cross-connections and mains breaks were identified in five outbreaks (20%), and miscellaneous or unknown problems were associated with the remaining 3 outbreaks. Four of the five chemical-related outbreaks were associated with recent maintenance work or an improperly installed device.

Community systems (public supplies serving permanent populations) accounted for seven outbreaks (28%), Noncommunity systems (serving transient populations or institutions) for eight outbreaks (32%) and Individual systems (private supplies, bottled water) for 10 outbreaks (40%).

Six *Legionella* outbreaks were reported in 2001 and 2002 in situations where the primary water use at the outbreak site was for drinking purposes (ie including showering, bathing, cooking etc but not recreational, occupational or decorative uses). The sites comprised two hospitals, two nursing homes, a hotel and a government building complex. These outbreaks resulted in 80 cases of illness, 41 hospitalisations and four deaths. The predominant form of illness was Legionnaires disease, but cases of Pontiac fever also occurred in one outbreak.

Two additional outbreaks involving *Legionella* bacteria were also described in the report but not included in drinking water-related statistics as they related to occupational and decorative uses of water. In one of these 17 workers at an automotive plant developed Legionnaires disease over a one month period and two died. Illness was associated with the cleaning area of the plant. In the second outbreak 117 people developed Pontiac fever after dining in a restaurant with a fountain. Illness was associated with sitting near the fountain.

The authors of the report note that recognition and reporting of drinking water-associated outbreaks is variable from state to state, and differences in the frequency of reported outbreaks may not reflect the true pattern of disease in the community. The number of outbreaks reported here (31, excluding *Legionella* outbreaks) and the number of people affected (1020) are lower than for the 1999-2000 reporting period (39 outbreaks, 2068 people). Increasing detection of Norovirus is likely to reflect to improvements in laboratory diagnostic capability for this pathogen.

1) Surveillance for Waterborne-Disease Outbreaks Associated with Drinking Water – United States, 2001-2002. Blackburn BG et al. MMWR 22 October 2004 No. SS-8.
2) See Health Stream Issue 28 p4 for a report on these cases.

US Recreational Water Outbreaks

Surveillance for recreational waterborne disease is also carried out by the Centers for Disease Control and Prevention and reported for the same 2-yearly intervals. An outbreak is defined as a similar illness affecting two or more people after exposure to air or water in a recreational water setting, with water being implicated as the source of disease on the basis of epidemiological evidence. Single cases of primary amoebic meningoencephalitis, wound infection, or chemical poisoning supported by water quality data are also included.

During 2001 and 2002, 65 recreational water outbreaks were reported from 23 states [(1)]. These outbreaks caused an estimated 2536 cases of illness, 61 hospitalisations and eight deaths. Outbreaks due to infectious causes were classified into three categories; gastroenteritis (30 outbreaks, 1919 cases), dermatitis (21 outbreaks, 435 cases), and a miscellaneous group comprising meningoencephalitis (8 single cases), acute respiratory infections (1 outbreak, 4 cases) and Pontiac fever (1 outbreak, 68 cases). There were also four outbreaks associated with chemical exposures which affected 102 people.

Among the gastroenteritis outbreaks, *Cryptosporidium* was the most commonly identified pathogen (11 outbreaks), followed by Norovirus (5), pathogenic *E.coli* (4), *Shigella* species (2) and *Giardia intestinalis* (1). In seven gastroenteritis outbreaks, no pathogen was identified. Treated (disinfected) water venues accounted for slightly more than half (52.5%) of all gastroenteritis outbreaks, with *Cryptosporidium* species being responsible for 65.6% of outbreaks in these venues.

The majority of gastroenteritis outbreaks (21 of 30) were associated with artificial water bodies (swimming and wading pools), with nine outbreaks occurring in lakes. *Cryptosporidium* species were responsible for the three largest outbreaks; affecting 767, 358 and 157 people respectively. Most (10/11) of the outbreaks associated with this organism were associated with pools, while outbreaks due to Norovirus or pathogenic *E.coli* occurred mainly in natural water bodies. One outbreak of *Shigella sonnei*

involving 33 people was associated with an interactive fountain, and 33 children became ill from unidentified causes after playing in large puddle of water from a septic tank overflow.

Pseudomonas aeruginosa was the most common cause of pool and spa dermatitis outbreaks, (18/20 outbreaks). One spa outbreak was attributed to *Bacillus* species and one to *Staphylococcus* species. The remaining dermatitis outbreak was attributed to avian schistosomes in a lake causing "swimmers itch" in 19 people.

Eight unrelated cases of meningoencephalitis attributable to *Naegleria fowleri* were reported, and all were fatal. All were associated with natural freshwater bodies. An outbreak of Pontiac fever attributable to *Legionella* species affected 68 people who used a hotel spa, and four people developed acute respiratory infection from unidentified causes after using a spa in a private home. Two of four chemical-related outbreaks were attributed to build up of chloramines leading to acute respiratory and skin irritation in pool users. There were also two outbreaks involving accidental exposure to chlorine gas due to errors in chemical mixing or maintenance procedures. A total of 50 people were affected by severe respiratory symptoms and 17 were hospitalised in these two incidents.

The authors note that the number of reported recreational water-associated outbreaks has risen markedly in the last decade but it is not possible to determine to what extent this reflects an increasing number of outbreaks in the community perhaps due to greater use of recreational water venues, or improved recognition and reporting. In several of the reported gastroenteritis outbreaks there was evidence of pathogen spread and secondary outbreaks at other recreational water venues and childcare settings. Thus efforts to reduce infection risks from recreational water exposure are an important public health priority.

1) Surveillance for Waterborne-Disease Outbreaks Associated with Recreational Water – United States, 2001-2002. Yoder JS et al. MMWR 22 October 2004 No. SS-8.

News Items

Release of Australian Drinking Water Guidelines

The long-awaited new edition of the Australian Drinking Water Guidelines (ADWG) was published on 10 December by the National Health and Medical Research Council. The revisions to this edition involved restructuring the entire document to incorporate the Framework for Management of Drinking Water Quality, placing preventive risk management as the central focus of water quality management in Australia.

The release of the ADWG follows a protracted delay in obtaining approval for publication from the Natural Resource Management Ministerial Council. While NHMRC has primary responsibility for the development of the ADWG, this document and others which form part of the National Water Quality Management Strategy are also subject to approval of the NRMMC. Such approval normally requires the unanimous agreement of all states and territories, however in view of the failure of the state of New South Wales to approve the document after more than 19 months, the NRMMC agreed to publication and public release of the ADWG without this approval.

NHMRC have also released a companion document entitled *Water Made Clear* which provides information on drinking water quality and safety for consumers. Both documents are available in PDF format from the NHMRC website, and print copies will be available for purchase early in 2005.

www.health.gov.au/nhmrc/publications/synopses/eh19syn.htm

New Microbiological Media Guidelines

The Culture Media Special Interest Group of the Australian Society for Microbiology (ASM) has released *'Guidelines for Assuring Quality of Food and Water Microbiological Culture Media'*. The Guidelines have gone through extensive local, national and international review, and incorporate cross-references to Australian Standards for food microbiology (including recent updates of AS1766 series to AS5013 series), AS4276 series for water microbiology, and appropriate ISO standards. The

document is intended to offer guidance to food and water microbiology laboratories of any size, whether they prepare media in-house, purchase it commercially, or obtain it from a central facility within their greater organisation. The Guidelines can be obtained from:

Peter Traynor MASM, Hon Sec Culture Media SIG, Australian Society for Microbiology
Ph 1800 33 1163
Email peter.traynor@oxoid.com.au

Leptospirosis in Ireland

Health authorities in Dublin recently reported three cases of leptospirosis in people who had taken part in canoeing activities on the River Liffey. The three were part of a group of about 30 who canoed on the river during a holiday weekend in late October. One person developed severe symptoms of jaundice, renal dysfunction and haemolytic anaemia requiring intensive care in hospital. The others also spent several days in hospital with flu-like illness. Leptospirosis is caused by bacteria of the Leptospira genus which may be carried by a range of animals including cattle, pigs, horses, dogs, rodents. The organism is excreted in urine and may infect humans through cuts and scratches on the skin or via the mucous membranes of the eyes, nose or gastrointestinal tract. Infection is often associated with recreational activities in natural water bodies, but can also be acquired from contaminated soil, food or contact with animals. Leptospirosis is relatively rare in developed countries, with fewer than 10 cases reported annually in Ireland over the last 3 years.

Walkerton Guilty Pleas

The two brothers who operated the Walkerton water supply, Stan and Frank Koebel, have pleaded guilty to charges of common nuisance endangering the lives, safety and health of the public. The charges carry a maximum sentence of two years imprisonment. Prosecutors have asked for a near-maximum sentence for Stan Koebel and house-arrest for his younger brother. Defence lawyers have argued that the men did not understand the risks associated with water contamination, and have already suffered greatly since the tragic outbreak that claimed seven lives in 2000. Sentencing is expected to occur in the Ontario Superior Court on 17 December.

From the Literature

Web-bonus articles

Summaries of these articles are available in the web page version of Health Stream and included in the searchable archive at:
www.waterquality.crc.org.au/pubs

Nutritional factors and susceptibility to arsenic-caused skin lesions in West Bengal, India.
Mitra SR, Mazumder GDN, Basu A, et al. (2004) Environmental Health Perspectives **112**(10):1104-1109.

Magnesium and calcium in drinking water and risk of death from ovarian cancer.
Chiu HF, Chang CC and Yang CY. (2004) Magnesium Research **17** (1):28-34.

Prospective study of swimmer's itch incidence and severity.
Verbrugge LM, Rainey JJ Reimink RL and Blankespoor HD (2004) J Parasitology **90**(4):697-704.

Disinfection byproducts and bladder cancer: A pooled analysis.
Villaneuva CM, Cantor KP, Codier S et al. (2004) Epidemiology **15**(3):357-367.

Biofilms, thermophilic amoeba and *Legionella pneumophila* – a quantitative risk assessment for distributed water.
Storey MV, Ashbolt NJ and Stenstrom TA. (2004) Water Science and Technology **150**(1) 77-82.

Arsenic

Arsenic toxicity at low doses: epidemiological and mode of action considerations.
Schoen A, Beck B, Sharma R, Dubé E (2004) Toxicology and Applied Pharmacology **198**; 253-267.

This paper examines key scientific issues in evaluating arsenic carcinogenicity. Current US cancer risk assessments for arsenic are based on a linear dose-response model. The authors suggest that alternative methods such as biologically-based

modeling or a "margin of exposure (MOE)" analysis are more appropriate given consideration of plausible modes of action and epidemiological evidence. They review of the current literature on arsenic-related cancers; and conclude that none of these current studies provide convincing evidence that typical US exposures of ingested arsenic increase bladder, lung or skin cancer. The available evidence suggests that arsenic does not act directly on DNA to cause mutations. Several modes of action have been proposed to explain mutagenic effects, including generation of oxidative stress, perturbation of DNA methylation patterns, inhibition of DNA repair, and modulation of signal transduction pathways. All of these modes of action may contribute to arsenic-induced carcinogenesis.

Studies of populations exposed to arsenic drinking water show increases in cancer only at relatively high concentrations (ie concentrations in drinking water of several hundred micrograms per litre). Studies in the US of populations exposed to average concentrations in drinking water up to about 190 micrograms per litre do not provide evidence of increased cancer.

The understanding of arsenic-induced carcinogenesis has advanced in recent years with appreciation that the metabolism of inorganic arsenic results in the generation of free-radicals, providing a source of oxidative stress. There is evidence which suggests that arsenic may also inhibit DNA repair systems. Disruption of these systems and other mechanisms to ensure damaged cells do not proliferate has significant implications for carcinogenesis. A recent study in humans suggests that exposure to low levels of arsenic in drinking water (ranging from non-detectable to 75 micrograms per litre) resulted in the inhibition of enzymes critical to nucleotide excision repair. Further study would be necessary to confirm the observed relationship because the study cohort was small (n=16). The authors also hypothesized that inhibition of DNA repair enzymes would result in increased bladder cancer incidence.

Chromosomal damage from arsenic exposure is a well-established feature of arsenic toxicity. Epidemiological studies in highly exposed populations demonstrate that arsenic exposure results in increased micro-nuclei incidence and sister chromatid exchanges in bladder cells. Further recent investigations suggest that arsenic-induced cell transformation may result from the perturbation of the signal transduction pathways. Of particular interest is that such cell-binding becomes enhanced in mouse bladder cells in vivo following exposure to arsenic levels greater than 20 mg/L in drinking water. The biological significance of this finding however remains to be elucidated since such levels of arsenic concentration are significantly higher than concentrations found in even the most arsenic-contaminated environments.

A further review of recent research evidence shows that nutritional status may modify the toxicity of arsenic, and that dietary deficiencies (including specific studies which looked at deficiencies in selenium, choline, and methionine) may contribute to arsenic-induced cancer risk. Conversely, diets enriched with antioxidants can also limit arsenic's toxicity. A mixture of folic acid, zinc, selenium, and various vitamins protected against arsenic-induced oxidative injury in animal studies.

Ischemic Heart Disease Mortality Reduction in an Arseniasis-Endemic Area in Southwestern Taiwan After a Switch in the Tap-Water Supply System.
Chang CC, Ho SC, Tsai SS, Yang CY (2004) Journal of Toxicology and Environmental Health, Part A, **67**; 1353-1361.

An area along the southwestern coast of Taiwan is known for the endemic occurrence of an endemic peripheral vascular disease known as blackfoot disease (BFD). The occurrence of this disease has been attributed to drinking water containing arsenic derived from artesian wells in endemic areas, although the mechanisms have not been established. Research on arsenic has concentrated on cancer risks, however there are also a number of reports that exposure to inorganic arsenic is associated with increased risks of mortality from cardiovascular disease. This paper describes a retrospective case-control study in Taiwan to determine whether a reduction in population arsenic exposure by changing to a low arsenic tap water supply had any effect on mortality from coronary heart disease (CHD).

The study used mortality data from the national death registration system. Four townships in the arsenic endemic area were included. Residents had used high-arsenic well water (0.35 to 1.14 ppm) for drinking and cooking until the early 1970s, then switched to a low-arsenic tap water supply (0.01 ppm). Records of deaths attributed to CHD between 1971 and 2000 were analysed. 3-year moving averages for the standardised mortality ratios were calculated and cumulative sum techniques were used to detect significant changes in mortality rates. No information was available on risk factors such as smoking, diet or occupation.

Large changes in CHD mortality occurred in both men and women over the 30 year period examined. The authors note a significant change in cumulative-sum for CHD in men in 1991-1993 and for women in 1995-1997. CHD mortality in both sexes has declined markedly since this period. The authors attribute this to a reduction in arsenic exposure beginning 17 to 21 years earlier when the water supply was changed, and state that the reversibility of the relationship between arsenic exposure and CHD mortality indicates this is likely to be a causal relationship.

Comment *The plot of cumulative sums for CHD mortality also show a marked change in 1978-1980 for men and a lesser change in 1977-1979 for women, however the authors do not comment on this.*

Campylobacter

Swimming and *Campylobacter* Infections.
Schoenberg-Norio D, Takkinen J, Hanninen MJ, et al. (2004) Emerging Infectious Diseases, **10**(8); 1474-1477.

Campylobacter jejuni and *C. coli* are common causes of bacterial gastroenteritis in developed countries, sometimes exceeding *Salmonella* species in frequency. The infection is usually more frequent in summer, and most cases appear to be sporadic rather than associated with recognised outbreaks. This paper describes a matched case-control study to investigate risk factors for domestically acquired sporadic *Campylobacter* infections in Finland. The study included cases diagnosed by three participating laboratories from July to September 2002 in three geographic areas. Two controls drawn from a national population register were matched to each case by age, sex and municipality. Cases with international travel in the 2 weeks before symptoms developed and controls with international travel in the 2 weeks before interview were excluded.

Risk factors assessed included travel, food items, drinking water, contact with pets and other animals, and swimming. A total of 151 cases (73% of eligible cases) and 309 controls (49%) completed the questionnaire, however some were later excluded for various reasons leaving 100 cases and 139 controls for statistical analysis.

Four significant risk factors were identified in the initial univariate analysis; tasting or eating uncooked or raw meat, drinking untreated dug well water, swimming in natural sources of water, and eating strawberries. In multivariate analysis, eating strawberries was not significant, but the other three risk factors remained statistically significant. At least one of these three epidemiologically associated risk factors was found in 67% of the patients.

Undercooked poultry and untreated drinking water have been associated with outbreaks of *Campylobacter* gastroenteritis, however swimming in natural waters has not previously been reported as a risk. A recent Norwegian study reported the opposite effect, with swimming in the sea, lakes, and swimming pools being associated with a reduced risk of *Campylobacter* infection.

This result indicates that private water supplies in Finland may be a significant source of sporadic *Campylobacter* infection, at least for the time of year covered by the study.

Cryptosporidium

Detection of infectious *Cryptosporidium* in filtered drinking water.
Aboytes R, Di Giovanni GD, Abrams FA, et al. (2004) J AWWA **96**(9) 88-98.

This paper describes the results of a 3-year study (1999-2001) which screened finished water samples

from 82 conventional water treatment plants with surface water sources in the US. Plants were located in 14 states and all were members of the Partnership for Safe Water (a joint US EPA-industry scheme for optimising treatment plant performance). A total of 1690 x 100 litre finished water samples were tested. Oocysts were concentrated using a modified version of US EPA Method 1622, and potential human infectivity was determined using cell culture-PCR on human cell layers. This method has previously been shown to correlate well with infectivity of *C. parvum* as measured by mouse bioassay. The recovery efficiency of the overall concentration and assay method was estimated using 203 x 100 litre samples spiked with 1,000 fresh oocysts of the Iowa Harvey Moon *C. parvum* strain. Average recovery efficiency was 32.3% over the time period of the study.

Viable infectious oocysts were detected in 24 of the 1690 samples (1.4%) by CC-PCR. This method gives a presence/absence result so it is not known how many oocysts were present in each positive sample. Positive samples were detected from 22 treatment plants (26.8%). The occurrence of positive samples was not associated with the type of water source (flow stream, lake or reservoir), microbial indicators, plant capacity, level of automation, frequency of backwash, or historical detection of oocysts in raw water. The majority of positive samples (70%) occurred in samples with turbidity less than 0.1 NTU, and 20% in water of less than 0.05 NTU. Smaller systems (serving fewer than 25,000 people), older plants (more than 75 years) and suburban plants were at slightly increased risk of having oocysts in filtered water. However there was no clear distinction between plants where oocysts were detected and those with no positive samples. The authors conclude that nearly all conventional surface water treatment plants may occasionally allow low numbers of oocysts to pass into filtered water.

The potential number of human infections resulting from oocysts in filtered water was estimated by assuming each positive sample represented one recovered viable oocyst. This was corrected for recovery efficiency and percentage of positive samples to give an average of 0.00044 oocysts /litre of filtered water. The estimated annual risk of infection was then calculated assuming a daily ingestion of 1.2 litres of water per person per day and a risk of infection from ingesting a single viable oocyst of 0.028. This figure comes from an earlier statistical modelling paper which analysed data from human volunteer studies on three *Cryptosporidium* parvum strains to derive an estimate of infection risk for a single oocyst of any hypothetical *Cryptosporidium* strain selected from the unknown mixture of strains that exists in nature.

The calculation resulted in an estimated risk of 1.5 x 10^{-5} infections per person per day or and annual risk of 52 infections per 10,000 people per year, with an 80% credible interval for the infection risk is 9-119 infections per 10,000 people per year. This risk estimate is greater that the US EPA target of 1 infection in 10,000 people per year. The authors concluded that additional treatment steps such as UV treatment would be needed for surface water treatment plants to meet the US EPA target.

<u>Comment</u> *The assumed daily ingestion figure (1.2 litres) may be an overestimate given that only unboiled water would be a risk for Cryptosporidium infection. The figure used for infection risk from a single oocyst is derived from a published paper on a meta-analysis of data for three C. parvum strains (IOWA strain, UCP strain and TAMU strain). The validity of the derived figure therefore depends on whether these three strains are truly representative of the total range of strains that exist in the environment and find their way into water supplies. The TAMU has a very low infectious dose and this strongly influences the overall figure for infection risk.*

The authors note that EPA targets refer to cases of infection not illness. Serological studies suggest that exposure to Cryptosporidium is common in the US. Some of these studies, but not all, suggest a substantial fraction of exposure may come from drinking surface water supplies. However the same studies also indicate that most cases of infection do not lead to illness. This suggests that most Cryptosporidium strains in the environment are unable to cause illness (although they presumably can cause a low grade infection sufficient to provoke an immune response), and/or that most strains cause illness only in a very small percentage of infected people. Outbreak strains (which by definition are detected because they cause illness in a high percentage of infected people) may therefore be atypical.

Cyclospora

Human Challenge Pilot Study with *Cyclospora cayetanensis*.
Alfano-Sobsey EM, Eberhard ML, Seed JR et al. 2004) Emerging Infectious Diseases; **10**(4); 726-728.

Little is understood about cyclosporiasis, an emerging infectious disease, because the dose-response relationship and other host-parasite factors for infection with *Cyclospora* are unknown. It appears that *Cyclospora* oocysts may survive for extended periods in the environment, given the marked seasonality of infection in areas where the disease is endemic. The freshly excreted oocysts are not infectious, but over a period of days to weeks they mature to the infectious sporocyst form. However, the triggers and conditions necessary for this change are not well understood. The species that infects humans, *Cyclospora cayetanensis*, is not known to have natural animal hosts, and attempts to establish an animal model for the infection have been unsuccessful. *Cyclospora* infection causes gastroenteritis, sometimes with prolonged intermittent diarrhoea.

The authors describe a pilot study that attempted to infect human volunteers with *Cyclospora cayetanensis*. Oocysts were harvested from the faeces of people with symptomatic infection and batches were subjected seven different chemical treatment and storage regimes in an attempt to induce change to the sporocyst form. Seven healthy volunteers ingested an inoculum of *Cyclospora* oocysts (approx 200-49,000 oocysts). The volunteers were requested to collect all stool samples for a period of 4 weeks after exposure, and also to provide specimens at 5, 6, 8 and 16 weeks. None of the volunteers experienced symptoms of gastroenteritis, and no oocysts were detected in any stool samples examined.

The authors concluded that given the results of their study, the conditions necessary for *Cyclospora* to become infectious were probably not achieved in preparing and storing the oocysts. They recommended future studies in order to examine individual and combined effects of temperature, humidity, storage media, and disinfection on the survival, viability and infectivity of stored *Cyclospora* oocysts.

Comment *This organism is believed to be relatively resistant to water chlorination based on the occurrence of a waterborne outbreak among British troops stationed in Nepal, where residual chlorine levels in the camp water supply were monitored daily.*

Gastroenteritis

Did A Severe Flood in the Midwest Cause an Increase in the Incidence of Gastrointestinal Symptoms?
Wade TJ, Sandhu SK, Levy D et al. (2004) American Journal of Epidemiology. **159**(4); 398-405.

It is evident that severe flooding has the potential to increase the rates of infectious gastrointestinal illness in a community through a number of mechanisms including deterioration of drinking water quality, contact with faecally contaminated flood waters, environmental contamination and disruption of usual sanitary practices. However there is little direct epidemiological evidence to quantify the overall risk or the contribution of different components.

This paper describes the impact of severe flooding in the town of Davenport, Iowa on the Mississippi river during April and May of 2001. At the time of the flooding, a randomised trial of in-home drinking water treatment (Water Evaluation Trial or “WET” Study) was being conducted. As part of this study, household members completed daily diaries of their incidence of gastrointestinal symptoms. This allowed the authors to evaluate the impact of flooding on the incidence of gastrointestinal symptoms.

A total of 456 households (1296 persons) were enrolled in the study and the follow-up period was one year. Each household was randomly assigned to receive either an active water treatment device or an outwardly identical inactive (placebo) device installed at the kitchen tap. After 6 months, the devices were removed, and after a 1-week washout period, the devices were replaced with a device of the alternate type. Subjects maintained a daily health

diary and recorded any occurrence of gastrointestinal symptoms (diarrhoea, vomiting, nausea, or abdominal cramps). The WET cohort was restricted to persons without serious immune-compromising conditions (eg HIV) and residents whose source of home tap water was municipal water.

A separate random-digit dialing telephone survey of the Davenport population was also undertaken concurrently with the WET Study to obtain community estimates of home water treatments, water consumption, and the monthly occurrence of gastrointestinal illnesses. Immediately following the flood, subjects in the WET Study were sent a questionnaire on their contact with floodwater or flood-contaminated items, and equivalent questions were also added to the community telephone survey.

The primary symptom outcome, "highly credible gastrointestinal symptoms", was defined as the occurrence of any of the following during a single 24-hour period: vomiting, liquid diarrhea, diarrhea (not liquid) with cramps, or nausea with cramps. This definition is consistent with previously published work.

Rates of highly credible gastrointestinal symptoms and diarrhea episodes among the WET participants were higher in winter than in any of the other seasons. Crude rates of both highly credible gastrointestinal symptoms and diarrhea were higher during the flood than in any other season, including winter. Rates of highly credible gastrointestinal symptom episodes were 1.29 times higher during the flood than during the rest of the WET cohort follow-up period (95% CI 1.06-1.58). The risk during the flood period was higher among people classified as more sensitive to gastrointestinal illness (with a chronic gastrointestinal condition, or self reported frequent gastrointestinal symptoms prior to the study, or age 12 years and less or 50 years and over).

When the groups with real and sham water treatment devices were compared, no significant differences in gastrointestinal illness rates were found during the flood (or any other period), indicating that drinking tap water was not contributing to illness. The strongest risk factor for illness was having the house or yard flooded (IRR 2.36, 95% CI 1.37-4.07).

The authors concluded that there was a measurable increase in gastrointestinal symptoms during a severe flood in the Midwest US in 2001. This effect was greater among persons who were susceptible to gastrointestinal illness. There was no evidence for transmission of gastrointestinal symptoms through the public water supply during the flood.

<u>Comment</u> *A report on the WET Study can be found in Health Stream Issue 31 p1.*

Predictors of Infectious-Disease Symptoms in Inner-City Households.

Larson EL, Lin SX, Gomez-Pichardo C (2004) Nursing Research, **53**(3); 190-197.

This prospective study monitored cleaning and hygiene practices in 238 inner-city households in Manhattan USA over a period of 48 months and looked for correlations with reported symptoms of infectious disease symptoms. The study was conducted in an area with a mostly Hispanic population, and households with three or more individuals including at least one pre-school child were eligible to take part. Data were collected by means of monthly home visits, weekly telephone interviews and extensive home interviews every 3 months. The health outcomes recorded were gastrointestinal and respiratory symptoms, fever, skin boils and conjunctivitis. Potential risk factors examined included drinking water supplies, food handling, laundry facilities and practices, general cleaning habits, personal hygiene, and beliefs about where 'germs' were most likely to be acquired.

Monthly rates for occurrence of any symptom ranged from 8.9% to 12.4% for individuals, and 32% to 39.7% for households. Three factors showed a statistically significant association with symptom incidence in a logistic regression model; drinking only bottled water was associated with an increased relative risk (RR) (RR=2.1, 95% CI 1.2-3.7), while using hot water (RR=0.7, 95% CI 0.5-0.9) and bleach (RR=0.5, 95% CI 0.23-0.66) for laundry were protective. People who stated that germs were more

likely to be picked up in the kitchen as opposed to other people, toys, soiled laundry or the bathroom were significantly less likely to report symptoms (RR=0.5, 95% CI 0.3-0.8). No other hygiene practices, including hand-washing, were associated with infection risk.

On the basis of these data, the authors conclude that further studies investigating a potential role of bottled water in infections are warranted, as is a renewed appreciation of the potential protective role of laundry practices such as using bleach and hot water.

Melioidosis

Preliminary Report on the Northern Australian Melioidosis Environmental Surveillance Project.
Inglis TJJ, Foster NF, Gal D, et al. (2004) Epidemiology and Infection. **132**; 813-820.

Melioidosis is a potentially fatal bacterial infection endemic in northern Australia and Southeast Asia. The disease is caused by the soil organism *Burkholderia pseudomallei* and the majority of infections occur during the tropical ‘wet season’. The disease may manifest as septicaemia (generalised infection in the bloodstream) or pulmonary infection (localised to the lungs). It is believed that infections arise most commonly from mud or water contamination of cuts and scratches. However two case clusters have been associated with unchlorinated drinking water supplies in northern Australia.
This paper describes the first two years of an environmental surveillance project that was set up to investigate the occurrence of *B. pseudomallei* in soil and water samples in three northern Australian states (Western Australia, Northern Territory and Queensland). Sampling was targeted to communities where culture-confirmed cases of septicaemic melioidosis had occurred during the dry season, and nearby communities (controls) without cases. A total of 48 sites were included. Environmental isolates were also compared to clinical isolates by molecular typing using PFGE and ribotyping, and a dendogram was generated to examine the genetic relatedness of isolates.

There were 41 human cases of culture-confirmed cases of melioidosis in northern Australia during 2001 and 43 in 2002. This is fewer than for 2000, and may have been attributable to lower than average rainfall in all three states. 62% of cases were from the Northern Territory, 30% from Queensland and 8% from Western Australia.

A total of 385 water samples and 360 soil samples were examined. Eleven water samples from 6 sites, and 11 soil samples from 5 different sites in the NT were found to be culture-positive for *B. pseudomallei*. No positive samples were detected from Western Australia or Queensland. None of the sites were positive for both soil and water, and none of the positive water sources were chlorinated. Three of the positive sites were associated with human cases, four were associated with animal infections, and four were sites where no disease was known to have occurred. Genetic analysis showed that human clinical isolates did not exactly match environmental isolates from the site where the case patient lived, however the strains were closely related. In sites where more than one environmental sample had tested positive, a similar situation was found in that the isolates were very similar but not identical.

The study identified 6 isolates from animal infections (5 strains from pigs at one location, one strain a dog at another location) which were closely related to water isolates from the same sites. One human clinical isolate and one goat isolate from separate locations were closely related to soil isolates from the same sites.

These results support the hypothesis that undisinfected drinking water supplies may be a potential source of *B. pseudomallei* infection in addition to soil. Testing locations in this study were limited by the practical difficulties of transporting samples from remote locations to the three specialised testing laboratories. However this is the most extensive survey to date in Australia, and it failed to support the common assertion that *B. pseudomallei* is widely distributed in the environment. This may reflect a patchy environmental distribution, the existence of a viable

but non-culturable form, or sequestration of the organism in specialised habitats.

Nitrate

Nitrate and human health.
Addiscott TM, Benjamin N (2004) Soil Use and Management, **20**; 98-104.

This article examines the supposed health risks attributed to nitrogen and the role of nitrate and nitrite metabolism in humans. The environmental impacts of nitrate in terms of eutrophication and effects on the atmosphere are not discussed. The authors review the published research on nitrate in water supplies and methaemoglobinaemia (blue baby syndrome) and conclude that the evidence does not support a causative role for nitrate in the absence of bacterial pollution. While there is some theoretical basis to the expectation that nitrate might increase risks of stomach cancer by formation of *N*-nitroso compounds by reaction with acid in the stomach, a number of epidemiological studies have failed to find an association between nitrate exposure and stomach cancer risks.
The authors note that in 1985 the UK government formally accepted that no link existed between nitrate exposure and stomach cancer, leaving the supposed risk of methaemoglobinaemia as the sole reason for imposing nitrate limits on potable water sources. However critical assessment of the historical literature from which the current European Union nitrate limits is derived suggests it is not justified by the evidence. Thus the current limit may impose unnecessary costs on water suppliers without producing a public health benefit.

Recent research on nitrate and nitrite metabolism in humans has led some scientists to propose that nitrite and its acidification products (in particular nitric oxide) play an important role in defense mechanisms against microbial infection of the skin and gastrointestinal tract. The authors suggest that a simple method to increase levels of acidified nitrate in the stomach may provide a significant protection against bacterial gastroenteritis, and potentially save many lives in developing countries.

Comment *See Health Stream Issue 25 March 2002 for a review of a book on this topic 'Nitrate and Man: toxic, harmless or beneficial?' By J L'hirondel and J-L L'hirondel.*

Rainwater

Rainwater First Flush Devices – Are They Effective?
Gardner T, Baisden J and Millar G (2004) 'Sustainable Water in the Urban Environment, 2004 Conference', Brisbane, Australia. August 30-31, 2004.

Over 11% of Australians use rainwater as their primary source of drinking water. To date the installation of rainwater tanks has been a matter of choice for the householder, however such tanks have recently been factored in as a key component of Australian urban water supply planning for new suburbs. In such areas, where disinfected tap water supplies are available, rainwater tanks are not intended for potable use. However the integration of rainwater tanks into urban design increases the likelihood of accidental or deliberate ingestion by residents. A major concern with the official endorsement of rainwater tanks is that the water quality may be substantially inferior to that specified under the Australian Drinking Water Guidelines especially on microbiological criteria.

This paper reports on a study which examined rainfall runoff from three locations in south east Queensland. Faecal coliforms and suspended solids were measured at the Healthy Home on the Gold Coast. Trace metal runoff (Cu, Pb, Zn) was monitored at two houses in Brisbane in areas with evidence of high atmospheric deposition. Rainfall catch efficiency was also predictively modelled and compared to recorded volumes.

There is reasonably strong evidence to show that organic and trace metal contaminants are concentrated in the first flush of water entering the rainwater tank, especially in highly urbanised areas. One widely-recommended treatment method is that the "first-flush" of roof water is discarded via a passive diversion device, on the basis that this

volume is likely to contain high levels of microbiological and chemical contaminants. The researchers sought to resolve the question of whether the "first-flush" system was a) effective in reducing the total contaminant load entering a rainwater tank, and b) an efficient enough system for improving tank water quality to warrant official endorsement.

The chemistry of roof runoff of the three homes was monitored for one year. Faecal coliform data levels in runoff from the Healthy Home showed erratic first flush behaviour over 11 measured rain events, and discarding the first 1mm of runoff reduced the bacterial load entering the tank by between 9% and 62% for individual rain events. Reductions in suspended solids ranged from 20% to 50%. However the water collected in the tank did not comply with ADWG microbiological guidelines with 55% of 40 samples from the outlet tap being positive for faecal coliforms, at concentrations up to 480 cfu/mL.

Runoff of metals from the other two locations also showed considerable variation for different rainfall events, although the behaviour of particulate forms was more consistent than for soluble forms. At the Healthy Home, the measured tank inflow correlated strongly with the modelled volume. The amount of rainfall lost through initial wetting of the roof surface, filling of the first flush device, and continuing drainage from the first flush device during a rain event was also investigated. It was found that 38% of rainfall was lost, with the major loss component (29%) being due to continuing drainage from the first flush device during rain events. It appears this loss could be easily minimised by reducing the size of the continuous drainage hole in the device.

The authors concluded that:
- there is no doubt that a first flush effect occurred at all three monitored roof sites, although the response was not consistent from storm to storm.
- in terms of microbiological quality, diversion of the first flush will not provide rainwater in compliance with the ADWG, even though discarding the first 1 mm will reduce the load of bacteria entering the tank.
- in highly urbanized areas, particulate concentrations of Pb and Zn were often above potable water standards even after the first 1 mm runoff, but are unlikely to pose a health hazard if allowed to settle to the tank sludge layer, and remain undisturbed (ie install household water intake pipe not less than 150mm-200mm above tank base).
- fitting first flush devices with low self-draining rates should readily achieve a 90% catch efficiency.
- some form of disinfection should be applied to tank water if used inside the home (other than for toilet flushing), such as hot water sterilization or UV disinfection, especially for consumptive uses.

<u>Viruses</u>

Vulnerability of Drinking Water Wells in Lacrosse, Wisconsin, to Enteric-Virus Contamination From Surface Water Contributions.

Borchardt MA, Haas NL, Hunt RJ (2004) Applied and Environmental Microbiology, **70** (10); 5937-5946.

Contamination of municipal drinking-water wells by human enteric viruses has been the cause of a number of gastroenteritis outbreaks, and screening surveys in the US have indicated that virus contamination appears to be frequent. However there has been little research on the routes by which viruses enter wells. This study describes a one year monitoring study of four wells and one surface water (river) site in La Crosse, Wisconsin which used measurement of oxygen and hydrogen isotopes to determine the contribution of surface water to the wells, and looked for correlations with viral contamination.

The four wells were chosen to have differing levels of expected surface water contribution. All wells were conventionally drilled in an alluvial sand-gravel aquifer, and all were currently in service as municipal water supplies. Untreated water samples (100ml) were collected monthly and tested for somatic and male-specific coliphages, total coliforms, *E. coli* and faecal enterococci.

Viruses were concentrated from 1500 litre samples by filtration, eluted and concentrated by acid or PEG flocculation. Reverse transcription-PCR was carried out to detect enteroviruses, rotaviruses, hepatitis A

virus (HAV), and Norovirus genotypes G1 and G2. Samples were also tested for culturable enteroviruses using three different cell lines, and any which tested positive for HAV by RT-PCR were also tested for infectivity by culture. Control experiments were carried out to determine limits of detection, efficiency of virus recovery and occurrence of PCR inhibition. Ratios of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ were measured.

In RT-PCR tests 50% of the 48 well water samples examined were positive for at least one virus group and 23% were positive for 2 or more virus groups. For enterovirus 20/48 samples were positive, for rotavirus 10/48 were positive, for Hepatitis A 4/48 were positive, for Norovirus genogroup G1 3/48 were positive and none were positive for Norovirus genogroup 2. For river water samples, 10 of 12 samples (83%) were positive for one or more viruses, and all types except Norovirus genogroup 2 were detected. None of the well water samples were positive for enterovirus by culture, but 9 of 12 river water samples were positive. DNA sequencing showed 5 of the 9 enterovirus-positive samples to be bovine strains; the remaining 4 were human strains comprising Coxsackie virus A3, B1, B5 and Echovirus 30. Of the 4 samples which were positive for HAV by RT-PCR, 3 were also positive by culture.

Two of the four wells contained appreciable amounts of surface water as determined by examination of isotope ratios. However no correlation was evident between surface water contribution and occurrence of viruses in well water. None of the well water samples were positive for sanitary water quality indicators (somatic and male-specific coliphages, total coliforms, *E. coli*, fecal enterococci), however all 12 river water samples were positive for total coliforms and somatic coliphages. 11 of 12 river water samples were positive for *E.coli* and fecal enterococci, and 4 were positive for male-specific coli-phages.

The authors note that the results were unexpected and suggest that factors other than surface water ingress must be the main determinants of virus contamination. Three of the wells examined here were located in residential areas and may be subject to contamination from leaking sewers, while the fourth well was close to the Mississippi river. The results also suggest that fecal indicators do not have good predictive value for the presence of viruses. The public health implications of the virus contamination are not clear, since comparison of RT-PCR and culture results for enteroviruses indicates the viruses were not infectious. However the sensitivity of cell culture is 10 to 100-fold less than RT-PCR detection. While three well water samples were positive for infectious hepatitis A virus, only one case of this notifiable disease was recorded in the area during the year of the study. Well water in La Crosse is chlorinated before distribution, which would reduce viral infection risks, however not all public groundwater supplies in the US are disinfected.

The La Crosse aquifer is typical of one-third of groundwater aquifers in the US, and these findings may be broadly applicable. While quantitative risk assessment modelling by the US EPA has suggested substantial numbers of infections may be caused by undisinfected well water, the authors suggest that the presence of viruses (as detected by RT-PCR) is not in itself a sufficient indicator of disease risks. They advocate an epidemiological study to determine whether the presence of viruses in well water is associated with adverse health outcomes.

Water Quality

Water quality deterioration: A study of household drinking water quality in rural Honduras.
Trevett AF, Carter RC and Tyrrel SF. *International Journal of Environmental Health Research* 2004;14(**4**):273-283.

This paper investigates levels of post-collection contamination of drinking water in a village in rural Honduras. It aims to identify if drinking water collected from a communal source is contaminated by handling and storage in the home to identify frameworks for further research to develop practical guidelines to prevent such contamination in the future. While much research and effort goes into providing safe collection points for drinking water, safe storage and handling practices should improve public health outcomes for villagers.

The three villages used in the study collected their drinking water from community wells fitted with hand pumps. The wells were either hand-dug or bores. Samples were collected in both wet and dry seasons. The study included microbiological analysis of water quality and detailed observations of water handling. The microbiological parameters measured were thermotolerant coliforms to indicate faecal contamination, pH and temperature. Researchers noted the type of storage vessel, if it was covered, how the water was served, and the time since collection, hygienic behaviour and water usage. Water storages in 43 households were tested at least bi-monthly.

Analysis of the microbiological samples showed that water collected from the bores were or better initial quality than that collected from hand dug wells. However, water collected from both sources showed post-collection deterioration as expected. Household water quality varied from day to day, suggesting direct handling caused the contamination, rather than any environmental factors consistent across the villages. No significant differences were found in the quality of water stored covered or uncovered or if it was stored in clay or plastic containers. Similarly, the length of time that the water had been stored had no significant impact on water quality.

All of the observed practices for collection, transport and storage of water were essentially uniform across all households tested. Many possible points of contamination were identified in the procedures observed. Similarly, the houses had animal faeces commonly observed inside and no soap was used for washing hands.

This study concludes that there is substantial post collection contamination of drinking water in households that seem to be due to handling and not currently used storage methods. Hypotheses can be drawn to enable further research with the aim of developing better guidelines and methods to improve the health of the 1.5 billion people worldwide who use drinking water in this manner.

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