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In this Issue:

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US EPA To Withdraw Arsenic Rule

The US EPA has announced its intention to withdraw the revised Arsenic Rule only weeks after the Rule was published in the Federal Register on 22 January 2001. This decision follows a review of the legislation by the incoming Bush government, which had earlier announced its intention to scrutinise a number of decisions made in the last few weeks of the Clinton administration.

The US Congress had previously extended the deadline for promulgation of the Arsenic Rule to June 2001, in order to provide a full 12 months for review and debate as requested by the American Water Works Association (AWWA) and other stakeholders, however the EPA decided to press ahead with publication prior to the change of government.

The revised Rule lowered the arsenic standard for drinking water from 50 ppb (parts per billion or micrograms per litre) to 10 ppb, and was expected to affect about 3,000 community water systems and 1,100 nontransient, noncommunity water systems with arsenic concentrations exceeding the new limit. Most affected systems are located in the western states, and in parts of the mid-west and New England. About 97 percent are small systems, serving less than 10,000 people each.

The 10 ppb standard was chosen by the EPA after consideration of the potential health benefits, water treatment costs and technical feasibility for levels of 3, 5, 10 and 20 ppb. The formulation of the Rule was surrounded by controversy, with heavy criticism of the EPA's interpretation of the scientific evidence on health risks, and the validity of assumptions and lack of transparency of the economic calculations (1). While the EPA estimates that the maximum compliance cost will be about US$327 per year for

households in small communities, the AWWA believes the costs will be 3 to 4 fold higher.

Soon after the Arsenic Rule was promulgated, the cities of Albequerque (New Mexico) and El Paso (Texas), and the states of Nebraska and New Mexico filed notice of their intent to sue the EPA over the legislation. Law suits were also lodged by several organisations including the Western Coalition of Arid States (WESTCAS), the National Miners Association, and the Wood Preservers Institute. The legal actions challenge the Rule on the basis that the EPA has failed to follow the directive of the US Congress to base Safe Drinking Water Act regulations on the best available science.

The president of WESTCAS (representing water and wastewater agencies in seven western states) stated that "by using faulty science, EPA exaggerated the benefits and minimised the costs the new standard will impose on water customers throughout the country and particularly in the west". The law suits lodged by the National Miners Association and the Wood Preservers Institute also charge that the EPA failed to consider the implications of the new arsenic standard for their industries.

The American Water Works Association, also a strong critic of the EPA benefit-cost analysis, decided not to take legal action against the new Rule but called for the US Congress to ensure that adequate federal funds were available to assist small communities to comply with the new standard.

In the 20 March media release announcing its intention to withdraw the Arsenic Rule, the EPA stated that independent reviews would be commissioned of both the science underlying the 10 ppb standard, and the cost estimates for compliance with the new level.

(1) Refer to Health Stream Issues 19 and 20 for discussion of the benefit-cost analysis for the Arsenic Rule.

Cryptosporidium Genotyping

British researchers recently published the results of genotyping over 2,000 isolates of *Cryptosporidium parvum* from human and animal sources in the UK [(1)], which showed differences in the geographic and seasonal distribution of the two major genotypes of this pathogen. The isolates were genotyped by extracting DNA from oocysts and using PCR (polymerase chain reaction) to amplify several genes including two 18s ribosomal RNA fragments, the COWP gene (*Cryptosporidium* oocyst wall protein), and the TRAP-C1 and TRAP-C2 genes (thrombospondin-related adhesive proteins). The amplified DNA segments were then characterised by restriction enzyme digestion and/or DNA sequencing. This process permitted the identification of isolates of Type 1 (which infects only humans) and Type 2 (which infects both humans and other mammals including cattle and sheep)..

Characterisation of 71 isolates from calves and lambs showed that all belonged to Type 2, as expected. Analysis of 1,300 isolates from sporadic human infections (cases not related to known outbreaks) showed that 833 (64%) contained oocysts of Type 2, 442 (34%) contained Type 1, 13 (1%) had a mixture of Type 1 and Type 2, and 12 (1%) had a different genotype (designated as Type 3). Further characterisation of Type 3 isolates suggested that these were strongly related to *C. meleagridis*, a species previously isolated in turkeys.

When 706 isolates related to seven drinking water outbreaks were examined, the Type 1 genotype predominated in 4 outbreaks (indicating human faecal contamination of water), while Type 2 was predominant in the remaining three outbreaks (all with evidence of water contamination by sheep faeces during the spring lambing season). The results for 51 human isolates from 5 swimming pool outbreaks showed a mixture of Type 1 and Type 2 in three outbreaks, with one of the remaining outbreaks attributed to Type 1, and the other to Type 2.

Previous work by the same authors on a smaller collection of 978 sporadic cases collected in England between August 1998 and November 1999 showed marked differences in seasonal patterns between the two genotypes [(2)]. Type 1 was rare in the late-winter-spring season (Feb to May) and peaked in late-summer-autumn (Aug to Oct). In contrast, Type 2 was fairly common all year round, with a peak in spring and continuing high levels throughout summer and autumn.

There was also considerable geographic diversity when the distribution of the genotypes in different regional health areas was compared. In some areas, there was a heavy predominance of Type 2 (up to

87%) while others had equal amounts of Type 1 and Type 2. Overall, about 11% (103/978) of cases were associated with recent foreign travel, with about two-thirds of these being of Type 1. The authors suggest that introduction of Type 1 strains by foreign travellers and subsequent secondary spread from person-to-person and via drinking water, recreational water or food may be important factors in maintaining this genotype in the UK population. For Type 2 strains, livestock form a permanent reservoir from which infections may spread to humans by direct contact, or contamination of drinking water, recreational water or food. Infections of this genotype may also be maintained within the human population by person-to-person spread.

While a number of genetic markers exist which permit the distinction of Type 1 and Type 2 strains of *C. parvum* as described in the studies above, there are no established methods to differentiate isolates within each genotype. Such techniques to identify individual isolates are highly desirable to further understand the epidemiology of this pathogen and allow the importance of different routes of transmission to be better characterised. Researchers at the Centers for Disease Control and Prevention in the US have now identified a promising genetic marker which may fulfil this purpose [(3)].

The marker is a small segment of double stranded RNA which appears to be carried by all isolates of *C. parvum.* Two such double stranded RNAs were recently identified in *C. parvum.* These are not considered to be part of the normal genetic material (*C. parvum* chromosomes are made of DNA), but may be defective remnants of viruses which are still able to replicate and be inherited in a stable manner, but do not harm the cell.

A 173 nucleotide segment of the smaller double stranded RNA from 23 cattle isolates and 38 human isolates was sequenced and the results compared. All of the isolates had previously been classified as Type 1 or Type 2 using other genetic probes. Eighteen different RNA sequences were identified among the 61 isolates. The 38 Type 1 isolates could be grouped into 10 subgenotypes and the 23 Type 2 isolates could be grouped into 8 subgenotypes on this basis. Examination of groups of isolates from identified outbreaks showed that all isolates from an individual outbreak were of the same subgenotype. Some subgenotypes occurred in several geographically distinct isolates, indicating they had a widespread distribution in the environment.

These preliminary results suggest that this segment of the double stranded RNA fragment may be a useful marker to track individual *C. parvum* isolates, as it provides a higher level of discrimination than is currently available using other genetic markers. This would greatly facilitate outbreak investigations, and epidemiological studies seeking to clarify the importance of different transmission routes in human disease.

(1) Pedraz-Diaz S et al. (2001). Nested Polymerase chain reaction for amplification of the Cryptosporidium oocyst wall protein gene. Emerging Infectious Diseases **7**(1):49-56.

(2) McLauchlin J et al. (2000). Molecular epidemiological analysis of *Cryptosporidium* spp. in the United Kingdom: results of genotyping *Cryptosporidium* spp. in 1,705 fecal samples from humans and 105 fecal samples from livestock animals. Journal of Clinical Microbiology **38**(11):3984-3990.

(3) Xiao L et al. (2001). Tracking *Cryptosporidium parvum* by sequence analysis of small double-stranded RNA. Emerging Infectious Diseases **7**(1):141-145.

Legionella Monitoring

Legionella bacteria are naturally occurring inhabitants of moist environments, and are sometimes found in low numbers in drinking water supplies. Over 20 species of *Legionella* have been identified, with *Legionella pneumophila* being the most important human pathogen. Infection with *Legionella* species can result in either of two forms of illness; Pontiac fever, an acute flu-like illness which last about 1 week and has no long term effects, or Legionnaires' disease, a form of pneumonia which may be fatal particularly in the elderly or those with underlying illness.

Infection occurs by the inhalation of water aerosols containing the bacteria, and can not be acquired from drinking contaminated water or from person-to-person spread. Legionnaires' disease was first recognised in 1976, when an outbreak occurred at a convention of the American Legion in Philadelphia, however analysis of stored clinical samples from earlier outbreaks of pneumonia with unidentified causes suggest that the disease had been occurring as early as 1957.

Legionella bacteria can survive in water temperatures between 0°C and 63°C, and grow readily at temperatures between 32°C and 35°C. They are also harboured within intracellular vesicles in some amoeba species, and this is believed to contribute to their survival under adverse environmental conditions. Environments favourable to *Legionella* growth include cooling towers and evaporative condensers, hot water systems below 60°C and spa baths. Cooling towers, because of their potential to spread aerosols over extensive areas, generally tend to be associated with larger outbreaks than other sources. The public health management approach to this problem has been to require regular maintenance, cleaning and disinfection of towers.

The role of specific tests for *Legionella* in the management of cooling towers, rather than testing for general indicators of bacterial growth (such as heterotrophic plate count) is an area of controversy. A study of *Legionella* numbers in cooling towers suggested that those which had been linked to disease outbreaks were more likely to contain high numbers of *Legionella*, than those not linked to outbreaks, and suggested that high colony counts (>1,000 colony forming units /ml) be used as an indicator of high risk to trigger decontamination procedures [(1)].

Recently published Australian research has shown that numbers of *Legionella* bacteria in cooling towers vary markedly over short time intervals, and that in most cases there was no significant relationship between the colony counts obtained in water samples only one week apart [(2)] . About one third of towers had elevated counts (in the high risk category) at least once during the summer season, suggesting that classification on the basis of a single sample is unlikely to be a valid indication of risks.

The study was undertaken on 31 cooling towers over a 16-week period in the summer season. All towers were maintained in compliance with Australian Standard AS 3666:1989, and water samples were taken twice weekly at the same time of day and processed within 4 hours. Data from 3 towers was excluded because of variations from standard operating procedures or extended shut down periods.

The 28 towers showed wide variations in mean *Legionella* count from as low as 2 CFU (colony forming units)/ ml to as high as 2,031 CFU/ml. Counts for individual towers also varied greatly, with standard deviations generally three times as large as the mean. Time series correlograms were used to determine whether significant correlation existed between each sample and samples taken subsequently from the same tower.

Significant correlation between one sample and samples taken less than one week later, was observed for only 9 towers out of 28. After a 2 week interval, only 3 towers showed significant correlation between samples, and after 3 weeks, only one tower showed significant correlation. Therefore, given the time delay of 7-10 days to obtain a culture result, the number of *Legionella* present in a cooling tower will probably have changed significantly by the time the results of a sample are obtained.

Examination of the range of cell counts for individual towers showed that only 1 would have been classified as high risk on the basis of mean *Legionella* count (mean >1,000 CFU/ml), however 10 systems had individual counts in this range at least once during the 16-week sampling period. All systems showed *Legionella* counts in the low risk range (<100 CFU/ml) at some time during the study.

The results of this study demonstrate that single samples or infrequent sampling for *Legionella* in cooling towers is unlikely to provide a meaningful measure of the potential infection risk. The relationship between *Legionella* numbers and infection risks is also complicated by variations in the infectivity and virulence of different species and strains of the organism.

The practice of assigning the probable infection source on the basis of DNA fingerprinting of isolates has also been thrown into doubt by other recently published work on *Legionella* typing[(3)]. Outbreak investigation generally involves the comparison of human clinical isolates with those taken from environmental sources, using a variety of serological, biochemical or molecular genetic tests. Identical results in such tests are often interpreted as evidence that two or more isolates are the same, and that a particular environmental source is the likely origin of the outbreak.

Pulsed Field Gel Electrophoresis (PFGE) is one of the methods used in this kind of investigation. This molecular genetic technique involves the digestion of genetic material with restriction enzymes and

separation of the resultant fragments on agarose gels. Researchers from the US and Canada compared PFGE patterns from 62 *L. pneumophila* isolates collected over a 14 year period from 9 states, and found that common PFGE patterns occurred among a number of geographically and temporaly distinct isolates. This suggests that some strains are widely dispersed and persistent in the environment, and that the simplistic assumption that a particular cooling tower or other location is the source of an outbreak on the basis of limited characterisation is not valid. A combination of analytical techniques together with knowledge of the frequency and distribution of different strains is required to allow more certainty in assigning the source of outbreaks.

(1) Shelton BG et al (1994). Legionnaires disease outbreaks and cooling towers with amplified Legionella concentrations. Current Microbiology **2**(6):359-363.

(2) Bentham RH (2000). Routine sampling and the control of Legionella spp. in cooling tower water systems. Current Microbiology **41**:271-275.

(3) Drenning SD et al (2001) Unexpected similarity of pulsed field gel electrophoresis patterns of unrelated clinical isolates of *Legionella pneumophila*, serogroup 1.

Walkerton Inquiry Continues

The Walkerton Inquiry has completed the first phase of its investigation (Part Ia) into the waterborne outbreak of *E. coli* and *Campylobacter* infections that hit the small town of Walkerton, Ontario in May 2000. In the period from October 2000 to January 2001 the Inquiry heard testimony from 44 people and received over 1,300 documents in evidence regarding the circumstances of the outbreak in which 7 people died and over 2,300 became ill. Witnesses included the former Manager of the Public Utilities Commission, who admitted that he had frequently falsified chlorination readings, and that he and his staff had little training in drinking water quality management.

In a statement issued at the close of the first phase of the Inquiry, Commissioner Dennis R O'Connor said that he was pleased with the progress of the Inquiry, and satisfied that he had the necessary evidence to make the required findings in respect of the circumstances which caused the outbreak. The Commissioner also praised the conduct of the legal counsel for the various parties in avoiding procedural delays and arguments, and enabling the Inquiry to remain on schedule.

The second phase of the Inquiry (Part Ib) will examine the effect, if any, of government policies, practices and procedures on the events in Walkerton. This will commence with the review of over 100,000 documents from a wide range of government ministries and agencies, followed by more public hearings. The Inquiry will also receive advice from its Scientific Advisory Panel on the physical cause of the contamination in Walkerton.

Meanwhile, Part II of the Inquiry concerning the future management of Ontario's water supplies has already commenced, with the commissioning of a number of expert reports. The Inquiry will also hold public meetings in several towns across Ontario to facilitate input from a wide range of people and organisations. Part II is scheduled for completion in September 2001, with the final Report of the Inquiry to be delivered to the Ontario Attorney General by the end of the year.

Negotiations between the Ontario government and representatives of Walkerton residents have resulted in a "no-fault" settlement of the legal class action brought as a result of the outbreak. Under the terms of the Agreement, ratified by the Chief Justice of the Ontario Superior Court on 19 March, residents and visitors who suffered illness as a result of the water contamination will receive a minimum payout of $2,000. Additional claims may also be made for the illness or death of a relative, and for economic losses relating to the outbreak. Part of the costs for the compensation payments will be shared by the insurers of Walkerton's Public Utilities Commission, who will pay legal fees of $4 million for the plaintiff’s lawyers and the first $17 million of claims. The reminder of the compensation costs will be met by the Ontario provincial government.

Arrangements for meeting the $12 million costs of decontaminating the Walkerton water supply and leasing a temporary filtration system have not been finalised. A preliminary report from government appointed auditors has suggested that the Walkerton community meet $3 million of the cost plus a $1.5 million capital contribution to establishing a long term alternative water supply, however negotiations between the local council and the Department of

Municipal affairs are continuing. The council has also raised concerns that a planned health study of Walkerton residents has still not been funded some five months after it was announced by the Ontario Minister for Health.

News Items

E coli O157:H7 Genome Analysis

US researchers recently reported they had determined the sequence of most of the *E. coli* O157:H7 genome. This enterotoxin producing *E. coli* and other related strains have been the cause of a number of waterborne disease outbreaks (including the Walkerton outbreak in Canada last year). It is already known that toxin producing strains carry additional genes specifying their characteristic toxins and several virulence factors which are not possessed by the more common non-pathogenic *E. coli* strains, however the researchers were surprised to find the extent of genetic differences revealed by the genomic sequence comparison.

The *E. coli* O157:H7 type strain (originating from a 1982 ground beef food poisoning outbreak) contains an estimated 1,387 genes that are not carried by the non-pathogenic laboratory strain *E. coli* K-12, making its genome about 32% larger. The additional genetic material is interspersed in at least 177 positions around the single circular chromosome, suggesting that genetic material has been acquired or lost in many separate events since the two strains diverged an estimated 4.5 million years ago.

The additional material is far in excess of that required to encode the known virulence determinants of the pathogenic strain, and may contain genes for as yet unidentified virulence characteristicss, additional metabolic capabilities or latent bacteriophages.

UK Study of Radon Risks

The UK Department of Environment, Transport and Regions has announced the result of an 18-month study of radon levels in 116 private water supplies in the west Devon region. About 18% of homes in this area use private wells or bores for drinking water. The study showed that about 1 in 7 homes had radon levels above the draft European Union Commission Recommendation action level of 1000Bq/l, and 1 in 14 had uranium levels above the WHO provisional guideline of 2 microgram/L.

The study also included laboratory studies of radon loss during the preparation of hot and cold drinks, and found that losses were less than previously reported in the literature. Estimates of individual ingested doses of radon showed that some people might receive an exposure of over 13 mSv per annum. Exposure from inhalation may be higher than that from ingestion. Current regulations governing radiation workers require safety monitoring, protective equipment and medical checks for those receiving doses of 6 mSv or more.

The local council has called for a larger study in all radon affected areas of Britain, while public health authorities have advised consumers not to be unnecessarily concerned as guideline levels include wide safety margins.

China Pipeline Plan

The Prime Minister of China recently announced that plans to build a major pipeline to transport water from the rivers and lakes in southern China to the arid north would be accelerated. It is estimated that two-thirds of China's 600 cities suffer from water shortages, and limitations in supply are seen as a significant obstacle to further economic development. The pipeline project involves three networks of aqueducts, canals and pipes with a combined length of over 2,1000 miles which are designed to carry 1.87 trillion cubic feet of water per year.

While the latest 5-year plan for economic development calls for more emphasis on sustainable development strategies, environmental advocates still fear that inadequate government controls and entrenched corruption will see continuation of widespread ecological destruction. They warn that the pipeline plan may result in southern rivers running dry.

Jail for Selling Tap Water

A British business man was recently jailed for 6 months for selling bottled tap water as spring water. The former winner of a Businessman of the Year Award pleaded guilty to fraudulent trading and acting as a company director while being an undischarged bankrupt. His company, which operated for only 9 months, initially bottled genuine spring water from rural Cumbria, but when the supply became inadequate he ordered employees to use water from a number of different sources including the ordinary tap water supply.

From the Literature

Aluminium

Aluminum form in drinking water and risk of Alzheimer's Disease.
Gauthier E, Fortier I, Courchesne F, Pepin P, Mortimer J, Gauvreau D. Environ Res (2000) 84 p234-46.

This study examined the relationship between long-term exposure to aluminium (Al) forms in drinking water and Alzheimer's disease (AD). Study participants were randomly selected from files of the provincial health plan of Quebec in 1984. Eligible participants resided in the region of Saguenay-Lac-Saint-Jean and were 70 years or older. Initially 3826 names were selected, and 1924 (50.2%) agreed to participate in the study. Of the remainder, 473 were found to be deceased, 1037 refused to participate, and 118 had moved away from the area.

Participants were initially examined for signs of Alzheimer's disease using a cognitive impairment screening test. Those scoring 78 or less from a possible score of 100 were then further examined by a 2 stage process to determine whether they were demented and, if so, whether the form of dementia was probable or possible AD. Family history of AD and/or dementia was also recorded.

There were 86 cases of AD diagnosed among participants according to these criteria. Eighty-six non-demented controls were matched to the cases of the same age (±2 years) and sex. Both cases and controls were tested for their ApoE genotype (a gene known to be associated with AD risk). Water samples were collected for speciation of Al from 54 municipalities of the Saguenay-Lac-Saint-Jean region during 1995-1996, at four different periods. Individual long-term exposure to Al forms in drinking water was assessed by combining the subject's residential history with physicochemical data of the municipality. Eighteen pairs of cases and controls were excluded from analysis due to absence of data for one or both of the pair (mainly due to refusal of blood sampling for genotyping tests), leaving 68 pairs for analysis.

A significantly increased risk of AD was found to be associated with the presence of AD or other dementia in first-degree relatives (OR=6.15, 95%CI 2.70-14.00) and with the presence of the ApoE epsilon-4 allele (OR=4.96, 95%CI 2.35-10.36). AD was significantly less common in those with levels of education beyond 7th grade (OR=0.46, 95%CI 0.23-0.91). There was no significant association with occupational exposure to neurotoxins or occupational exposure to aluminium.

There was no significant association between long-term exposure to total Al or individual Al forms in drinking water and AD development. The forms of Al assessed were total aluminium, total dissolved aluminium, monomeric organic aluminium, monomeric inorganic aluminium, and polymeric aluminium. However when the results were adjusted for other factors significantly influencing risk (education level, AD/dementia in relatives, Apo genotype) a significant association was seen with monomeric organic aluminium exposure at the time of AD onset (OR 2.67, 95%CI 1.04-6.90 for exposure above 4.53×10^{-7} M, corresponding to the upper quartile).

For long term exposure to monomeric aluminium (1945 to onset date of AD), the OR remained non-significant even after adjustment for other risk factors. In discussion the authors suggest this may be due to decreased accuracy of exposure information over the long time frame. There was no significant association between AD and concentrations of iron, silicon, dissolved organic carbon or pH levels over the long term or at time of onset of AD after adjustment for other risk factors.

The authors suggest that these results reveal a possible association between exposure to monomeric organic aluminium and AD development, which may explain why previous studies considering only total aluminium levels in drinking water have given inconsistent results. This study involved a geographic environment with low Al concentrations and high pH values, which is also in contrast to earlier studies. Further investigation in different geochemical contexts in necessary to confirm the results and further studies should also include information on Al speciation in water and the genetic characteristics of the subjects.

Comment Only 4 of the water supplies in the study were subjected to conventional water treatment (including alum flocculation). These 4 supplies had a mean total dissolved Al concentration of 1.36

microM, slightly lower than that in 14 river water supplies (mean of 2.51 microM) and 17 lake water supplies (mean of 1.50 microM). Total dissolved aluminium levels in 19 groundwater supplies were lower (mean of 0.33 microM). The 4 treated water supplies had lower percentages of monomeric organic aluminium (mean of 22.6% of total dissolved aluminium) than the untreated river water supplies (35.97%), lake water supplies (36.50%) and groundwater supplies (54.00%).

If the observations reported here reflect a real association between monomeric organic aluminium and AD risk, then conventional alum treatment of surface water supplies would tend to decrease risks as treatment removes some organic aluminium from solution.

Arsenic

Lung cancer and arsenic concentrations in drinking water in Chile.
Ferreccio C, Gonzalez C, Milosavjlevic V, Marshall G, Sancha AM, Smith AH. Epidemiology (2000) **11**(6) p673-679.

This case-control study involved three regions in northern Chile. Regions I and III contained relatively little arsenic in water supplies. Region II had had high exposure to inorganic arsenic in past years due to natural contamination of drinking water originating in the Andes Mountains.

Cases were all those who were admitted to public hospitals in the study region between November 1994 and July 1996 with confirmed lung cancer. Two different control groups were used. One group was patients admitted to hospital with cancers not known or suspected to be associated with arsenic exposure (ie excluding people with cancer of the liver, skin, kidney, bladder or prostate). The second group of controls were hospital patients admitted with non-cancer diseases excluding cardiovascular, skin or neurological diseases. A structured questionnaire was administered to all participants including questions on socioeconomic status, lifetime residential history, occupation and smoking. A total of 151 cases agreed to participate and 419 controls, including 167 cancer controls and 252 non-cancer controls.

Data on drinking water arsenic levels from 1950 through to 1994 for the study area was collected from water companies. Arsenic levels in water were not measured in the period from 1930 to 1949, but were estimated from knowledge of the water sources. Each participant's exposure was estimated from the average water arsenic concentration for the county in which he or she resided for each year.

There was a definite trend of increasing lung cancer odds ratios (OR) and 95% confidence intervals (CI) with increasing arsenic concentrations. For an average water arsenic concentration of <10 µg/l, 10-29 µg/l, 30-49 µg/l, 50-199 µg/l and 200-400 µg/l the ORs were 1, 1.6 (95% CI 0.5-5.3), 3.9 (95% CI 1.2-12.3), 5.2 (95% CI 2.3-11.7) and 8.9 (95% CI 4.0-19.6) respectively. There was evidence for a synergistic action between cigarette smoking and ingestion of arsenic in drinking water with an OR for lung cancer of 32.0 (95% CI 7.2-198.0) among smokers exposed to > 200 µg/l of arsenic in drinking water compared with non-smokers exposed to < 50 µg/l. Overall this study supports an association between human lung cancer and ingestion of inorganic arsenic.

Comment In this study arsenic exposure was classified according to the estimated mean exposure over a 65 year period, however data are also presented showing that the differential exposure of cases and controls was mainly confined to a period of 20 years from 1955 to 1975. During this 20 year interval, median arsenic concentrations in drinking water were about 0.270 mg/l (270ppb) among cases and 0.070 mg/l (70ppb) among controls. The association between arsenic exposure and lung cancer may therefore be related to peak exposures in this high exposure period, rather than the average exposure over the entire study period.

Arsenic in drinking water and the prevalence of respiratory effects in West Bengal, India.
Mazumder DNG, Haque R, Ghosh N, De BK, Santra A, Chakraborti D, et al. Int J Epidemiol (2000) **29**(6) p1047-52.

A cross-sectional survey was undertaken in West Bengal, India in an arsenic-affected region between April 1995 and March 1996. The aim of the survey was to determine the prevalence of various health effects associated with arsenic. This paper considers respiratory effects, including cough, chest sounds, and shortness of breath.

Two areas were selected in one of the arsenic-affected districts south of Calcutta. The first included 25 villages with high levels of arsenic in some of the tubewells, the second area included the remaining part of the district where people were drinking from shallow tubewells. The study population included 6864 participants for which arsenic levels in drinking water sources were measured and excluded those who were smokers. Participants were clinically examined and interviewed.

The arsenic concentration in the tubewell water ranged from <3 micrograms per litre to 3400 micrograms per litre. In females the overall age-adjusted prevalence for each respiratory outcome (cough, chest sounds and shortness of breath) was about to 2.5 per 100. There was an increasing prevalence of cough and chest sounds with increasing arsenic concentrations. For shortness of breath there was a markedly non-linear relationship with arsenic concentration. In males the overall age-adjusted prevalence of cough was 5.2 per 100 and chest sounds was 4.4 per 100. For these two outcomes there was a trend of increasing prevalence by water arsenic concentration.

For shortness of breath in males the prevalence was 3.6 per 100, the highest prevalence in the 200-499 micrograms per litre range. In children the prevalence of cough and chest sounds increased with higher arsenic concentrations. The age-adjusted prevalence of weakness in both sexes increased strongly with arsenic water concentrations. When the highest exposure category (≥500 micrograms per litre) was compared with the lowest exposure category (<50 micrograms per litre) the prevalence odds ratios (POR) were all elevated, in particular for shortness of breath among females and weakness in both sexes. There were marked increases in POR for participants with arsenic-induced skin lesions who were in the high exposure category. When outcomes were jointly considered for those with skin lesions and current drinking water containing ≥500 micrograms per litre, 5 of the 7 females reporting cough were also found to have lung chest sounds as was the case in 6 of the 14 men reporting cough.

This study found that ingestion of inorganic arsenic in drinking water resulted in pulmonary effects such as cough, chest sounds in lungs and shortness of breath. The prevalence of each outcome was seen to rise with increasing arsenic concentrations except for shortness of breath in females. The occurrence of respiratory effects was also mostly confined to those with arsenic induced skin lesions.

Arsenic methylation capacity and skin cancer.
Yu RC, Hsu KH, Chen CJ, Froines JR. Cancer Epidemiol Biomarkers Prev (2000) **9**(11) p1259-62.

An epidemiological case-control study was conducted in a blackfoot disease endemic area in the southwestern region to Taiwan to clarify the role of arsenic methylation capacity in the development of arsenic-associated skin lesions.

Twenty-six skin disorder patients were each matched by age (+/- 3 years) and gender with one control. Twenty-four hour urine samples were collected, questionnaires were administered and medical records obtained from local hospitals.

Cases and controls both had ingested similar high concentrations of arsenic in drinking water for about 30 years, and had switched to arsenic-free tap water at least 10 years ago. Skin lesion cases had a statistically significant higher percentage of total urinary metabolites of inorganic arsenic and methylarsonic acid (MMA) and a lower percentage of dimethylarsinic acid (DMA) than matched controls. The mean of the ratios of MMA to DMA of cases was significantly higher than that of controls. Subjects with a higher percentage of MMA (>15.5%) were more likely to develop arsenic-associated skin lesions than those with a low percentage (OR 5.5, 95% CI 1.22-24.81). The association was still found when confounders such as gender, age, hepatitis B surface antigen, smoking, alcohol consumption or tea intake were taken into account. This study demonstrated that arsenic biotransformation including methylation capacity may be associated with risks for developing of arsenic-induced skin lesions.

Cancer

Drinking water contaminants and childhood leukemia.
Infante-Rivard C, Olson E, Jacques L, Ayotte P. Epidemiology (2001) **12**(1) p13-19.

The aim of this study was to evaluate the relationship between exposure to drinking water contaminants and childhood acute lymphoblastic leukemia. The

drinking water contaminants considered were trihalomethanes (THMs), arsenic, cadmium, chromium, lead, zinc, and nitrates.

Cases were children from 0 to 9 years of age diagnosed between 1980 and 1993 in the Province of Quebec. Cases were identified from computerised hospitalisation data, hospitalisation censuses, lists maintained by hematology-oncology laboratories of histologic data, and special medical records from the largest paediatric centre in the province. For each case one control was chosen from government records (family allowance files) and matched by age (within 24 months), sex and region of residence. A total of 510 eligible cases were identified and 491 took part in the study. Due to the young age of the cases and controls, interviews were conducted with parents.

A municipality exposure matrix for total and specific THMs, metals, and nitrates was built using information from interviews of the parents of study subjects, historical data provided by municipalities and the Ministry of Environment and a tapwater survey of 227 homes of cases and controls carried out in 1995 and 1996. Exposure indices used were the average level of exposure and the cumulative average over the period. Risk was measured for the prenatal and postnatal periods up to the time of leukemia diagnosis.

No statistically significant associations were seen between any of the exposures assessed and the risk of childhood leukemia.

Cardiovascular disease

Geographic variation of the mortality from cardiovascular disease and drinking water in a French small area (Puy de Dome).
Sauvant MP, Pepin D. Environ Res (2000) **84**(3) p219-227.

France has relatively low rates of cardiovascular disease (CVD) compared to other industrialised nations and within the country a decrease in gradient of CVD mortality is seen from the north to the south. The Puy de Dome area in central France has a CVD mortality rate that does not match with this overall gradient, and a significantly higher mortality from ischaemic heart disease and cerebrovascular diseases has been found particularly in the middle-aged male population in this area. Past research in a number of countries has shown an inverse relationship between CVD mortality and the hardness of drinking water. In Puy de Dome, drinking water is supplied mainly from ground water and has a high stability of mineral content over time and a low hardness.

An ecological study was performed in this area to test the relationship between mortality from cardiovascular disease and hardness of drinking water. The national service of medical statistics of France provided information on all deaths with cardiovascular causes in Puy de Dome between 1988 and 1992. The average hardness of drinking water for each of the 52 cantons in the Puy de Dome area was calculated.

The mortality rates from CVD appear to be higher in Puy de Dome than the rest of France for these years. In females mortality rates of 354.8 versus 327.3 per 100,000 persons/year and for males 335.7 versus 287.9 per 100,00 persons/year were estimated. Standardized mortality ratios (SMR) were calculated at the canton level to examine the spacial variation of mortality from CDV. For both sexes a significant excess of mortality from all CVD was found in several cantons at the periphery (rural area) of Puy de Dome and a significant decrease of mortality in the middle (urban area). This was particularly apparent for ischemic heart diseases and cerebrovascular diseases. A slight but statistically significant inverse relationship was found for hardness of water and “all diseases of the cardiovascular system” for males and females, for ischaemic heart disease in males and cerebrovascular disease in males and females.

These results however must be interpreted cautiously and need to be confirmed using data at the individual level. Also other risk factors of CVD such as lifestyle and dietary habits have not been taken in to account in this study and may act as confounders to the results.

Copper

Determination of the taste threshold of copper in water.
Zacarias I, Yanez CG, Araya M, Oraka C, Olivares M, Uauy R. Chem Senses (2001) **26**(1) p85-89.

Copper is an essential nutrient but is toxic when ingested in large amounts. Studies have suggested

that copper concentrations above 3 mg/L Cu in drinking water produce changes in taste and colour. At this level toxic effects are not observed and therefore it is assumed that changes in taste and colour would be noticed before the level of copper is high enough to produce toxic effects in humans. Recently however interest in the early adverse effects of copper such as mild and transient nausea has led to questioning to what extent colour or taste in drinking water may be sufficient to protect from early toxic effects. This study was carried out to determine the taste threshold of copper in different types of water using some copper salts found commonly in drinking water.

Sixty-one volunteers aged 18-60 years participated in the study. Volunteers received copper concentrations ranging from 1.0 to 8.0 mg/L Cu as copper sulfate or copper chloride prepared in tap water, distilled deionised water and uncarbonated mineral water. A screening test was performed where copper concentrations were presented in ascending order from 0 to 8 mg/L Cu of copper sulphate as copper salt until a distinct taste sensation was perceived. This value and those near it represented the threshold zone for that person. A modified triangle test was performed where each subject was presented with five samples, four identical ones and one containing the test solution. Subjects were asked to identify the odd samples and indicate the perceived taste. A subgroup of 15 individuals underwent a triangle test with nose clamped and nose open to evaluate the effect of olfactory input on taste threshold and the capacity to confirm the taste threshold. Distilled water with copper sulfate at a concentration corresponding to the individual's threshold was used.

The results of the screening test showed that of the volunteers, 43 and 77% perceived the copper taste at concentrations of 2 and 3 mg/L Cu respectively. The modified triangle test found that 50% of the subjects reported taste perception at a concentration of 2.6 mg/L Cu for both copper salts in tap water. In distilled deionized water 50% of subjects perceived taste at 2.4 and 2.5 mg/L Cu for copper sulphate and copper chloride respectively. In uncarbonated mineral water 50% of subjects perceived taste at concentrations of 3.5 and 3.8 mg/L for copper sulphate and copper chloride respectively. The results for uncarbonated mineral water gave significantly higher threshold values (P<0.01) than for tap water and distilled deionized water. When the nose was clamped the taste threshold did not change significantly.

This study found the median values for copper taste threshold were low and ranged from 2.4 and 3.8 mg/L Cu depending on which type of water was used. The type of copper salt used had very little influence on the capacity to taste copper.

Cryptosporidium

Detection of infectious *Cryptosporidium parvum* oocysts in environmental water samples using an integrated cell culture-PCR (CC-PCR) system.
Lechevallier MW, Abbaszadegan M, Di Giovanni GD. Water, Air, & Soil Pollution (2000) **123**(1-4) p53-65.

In assessing human health risk of *Cryptosporidium* it is necessary to have a method to determine the viability and infectivity of oocysts in drinking water. Previously investigations of naturally occurring *C. parvum* oocysts from environmental water samples has been restricted by the inability to determine the public health significance of detected organisms.

This study presents the development of a method that incorporates immunomagnetic separation (IMS) and an infectivity determination using an integrated cell culture-PCR (CC-PCR) assay. This method concentrates water samples by filtration or centrifugation and separates oocysts from other particles by IMS. To dissociate captured oocysts from IMS beads an acidified Hank's balanced salt solution containing 1% trypsin was used. In 96-well microtiter plates *in vitro* HCT-8 cell culture of purified oocysts was performed and infected cells were detected using PCR primers specific for *C. parvum.* To validate this procedure, 242 raw source water samples or filter backwash water samples from 25 sites in the US were analysed. To evaluate recovery efficiencies and performance of CC-PCR protocol, oocyst seeded in raw and filter backwash water samples were used with different water quality matrices.

The recovery of oocysts from 20 spiked 100L samples (1080 to 3612 oocysts per spike) of finished water averaged 37% (range 15 to 41%). CC-PCR detected infectious *C. parvum* in 5.0% of the 121 raw water samples, compared to 13.2% detected positive (viable and inviable oocysts) by conventional

floatation-immunofluorescent assay microscopy (IFA). Viable oocysts were found in 7.4% of the 122 filter backwash water samples, compared to 5.7% positive by IFA. Cloning and DNA sequence analysis of PCR products was used to confirm all CC-PCR positive samples as *C. parvum.*

In April 1999, testing of filtered drinking water from conventional surface water treatment plants for the presence of infectious *C. parvum* commenced at plants operated by the company sponsoring this research. Of the 50 samples from 26 sites analysed, infectious *C. parvum* has not been detected in drinking water samples. All 80 treatment plants are eventually to be tested monthly for 24 months to provide an extensive data set. The results of this study support the use of IMS as a sample purification method and the use of the sensitive and specific CC-PCR assay for water samples of diverse quality.

Cyanobacteria

Health risks caused by freshwater cyanobacteria in recreational waters.
Chorus I, Falconer IR, Salas HJ, Bartram J. Toxicol Environ Health. Part B, Crit Rev (2000) **3**(4) p323-347.

This article gives an overview of the currently known cyanotoxins and considers documented cases of human illness which have been attributed to toxin exposure. The routes of exposure which pose a hazard to human health are examined. Risk management including surveillance and risk minimisation is discussed in relation to the WHO guidelines. Methods of monitoring the occurrence of cyanobacteria and of cyanotoxin analysis are considered. Short and long-term measures to minimise risk due to toxic cyanobacteria are explored.

Research into cyanobacterial toxicity has increased in the past two to three decades due to cases of livestock poisoning and adverse human health effects resulting from drinking contaminated water. Cyanobacterial blooms and toxins have increased in recreation waters due to increased fertilization of many water bodies with nutrients from agriculture and domestic wastewater. Guidelines are now being developed in several countries for exposure to toxic cyanobacteria through recreational water use.

Humans may become ill from cyanobacterial exposure through direct contact of exposed parts of the body, including the ears, eyes, mouth and throat, accidental ingestion of water containing cells by swallowing and uptake of water containing cells by aspiration (inhalation). The international developments on guidelines for cyanotoxins are focusing on microcystins due to the widespread nature of *Microcystis* species, and the potential chronic effects of exposure. The World Health Organisation (WHO) has a provisional drinking water guideline value of 1 μg/L for microcystin-LR designated as being safe for life-long consumption.

In recognition of the differing health impacts of transient irritative symptoms and chronic toxicity, the WHO recommends that a three levels of guidelines be adopted comprising: relatively mild and/or low probabilities of adverse health effects, moderate probability of adverse health effects, and high risk of adverse health effects. The WHO approach to monitoring and surveillance for toxic cyanobacteria aims at narrowing regular surveillance efforts down to those sites that are likely to present a risk. This approach is supplemented by a scheme for immediate temporary assessment and action.

To assess health risks of cyanobacteria, dense blooms and surface scums should be sought and sampled. Sampling is usually undertaken fortnightly in countries following the European Union directive, however as soon as cyanobacterial population growth begins, sampling frequency should be increased. The most important short-term measure when risk due to toxic cyanobacteria is perceived is to adequately inform the public on the risk. Long-term measures to minimise risk may not be to close bathing sites but to restore bathing water quality. This may be achieved through catchment management programs to limit nutrient runoff.

Disinfection by-products

Evaluation of the health risk associated with exposure to chloroform in indoor swimming pools.
Levesque B, Ayotte P, Tardif R, Charest-Tardif G, Dewailly E, Prud'Homme D, et al. J Toxicol Environ Health. Part A (2000) **61**(4) p225-243.

This study examined the potential heath risk associated with exposure to chloroform in indoor swimming pools. Chloroform is the most abundant

trihalomethane in chlorine treated waters and can be absorbed by inhalation and dermal exposure. At high concentrations, chloroform has been shown to cause liver cancers in animals. The authors used physiological measurements and pharmacokinetic modelling to estimate the amount of chloroform reaching the liver tissues in indoor swimmers.

This study was undertaken in Quebec City region in the autumn of 1995 and the winter of 1996. Swimmers were recruited into two study groups. The first group consisted of 52 young people aged 11 to 20 yrs who were members of a competitive swimming club, this group represented young swimmers who regularly used pools and exercised strenuously. The second group consisted of 12 adult volunteers who represented those who swam in pools as part of their leisure activities. For the competitive swimmers there were 6 sample collection sessions at 3 different pools and for the leisure swimmers there were 5 sampling sessions each at a different pool. Water samples were collected at a depth of 20cm and air samples were collected in the swimmers breathing zone. Both were used to estimate external exposure. Internal dose was estimated by measuring concentration in alveolar air samples (exhaled air) collected from swimmers before entering the pool premises and after 15, 30 and 60 minutes of swimming.

Chloroform concentrations in the water from the 8 pools varied from 18 to 80 μg/L. Chloroform concentrations in air varied in most cases between 100 and 200 $\mu g/m^3$. Mean chloroform alveolar air levels after 60 minutes of exposure varied from 72 to 376 $\mu g/m^3$ for competition swimmers and from 64 to 124 $\mu g/m^3$ for leisure swimmers. Simple correlation analysis of data collected during the six training sessions showed that chloroform concentrations in water were strongly associated with chloroform concentrations in air. Multiple linear regression analyses revealed that chloroform alveolar values in competition swimmers were strongly correlated to ambient air and water levels, and to intensity of training to a lesser degree. In the leisure group, only ambient air concentration was positively associated with chloroform alveolar levels.

A physiologically based pharmacokinetic mode (PBPK) was used in this study for modelling chloroform alveolar values in alveolar air of swimmers. This model took into account the several physiological parameters at two levels of work intensity (100 and 150W). Concentrations of chloroform metabolites bound to hepatic and renal macromolecules estimated using this model were 1.6 and 1.9 times higher for competition swimmers than for leisure swimmers respectively. The highest hepatic concentration predicted in competition swimmers using this model was 0.22 μg chloroform equivalents/kg of tissue which, even using worst case assumptions, is at least 10,000 times lower than the smallest no observed effect level for liver tumours in laboratory animals.

The results indicate that the level of chloroform that competitive swimmers are exposed to represents a very large safety margin, and for leisure swimmers who are exposed to lower levels of chloroform an even larger safety margin exists.

Modeling the susceptibility of drinking water utilities to form high concentrations of trihalomethanes.
Milot J, Rodriguez MJ, Serodes JB. J Environ Manage (2000) **60**(2) p155-71.

Chlorine is frequently used to disinfect water to make it microbiologically safe for drinking. In Quebec, more than 5,550,000 people are supplied with water that has been disinfected with chlorine. The chlorine disinfection process can produce chlorination by-products if there is natural organic matter present in the water. Exposure to these by-products including trihalomethanes (THMs) may constitute a health risk as they are potentially carcinogenic.

This paper puts forward models developed to estimate the propensity for drinking water systems in Quebec to form high concentrations of THMs. These models are based on information on general utility characteristics (type of water source, type of water treatment, geographical location) as well as information on water quality and other operational conditions. Using models is beneficial in determining strategies for decreasing THM concentration and therefore reducing potential risks of exposure. To estimate the likelihood of systems forming high concentrations of THMs the models were based on logistic regression analysis, which involved establishing the probability that a threshold of THM concentration will be exceeded. Five different threshold concentrations of THMs were used (40, 50, 60, 80, 100 μg/l).

These models produced satisfactory results for the 50, 60, 80 and 100 µg/l thresholds and allowed for the identification of the largest problems concerning the presence of THMs in drinking water systems in Region 1. Also the models showed that most of Quebec's water utilities would be able to comply with a 100 µg/l standard during the summer period which is proposed by the government of Quebec. These models are useful in helping public health officials to evaluate the feasibility of more rigorous regulations governing THMs and they may assist in epidemiological investigations concerning exposure to THMs.

Nitrate

A case-control study of nitrate in drinking water and non-Hodgkin's lymphoma in Minnesota.
Freedman DM, Cantor KP, Ward MH, Helzlsouer KJ. Arch Environ Health (2000) **55**(5) p326-329.

It has been hypothesised that nitrate may be a risk factor for cancer with a recent study in Nebraska suggesting long-term consumption of nitrate in drinking water may contribute to non-Hodgkin's lymphoma (NHL) risk. This study further examines the association between nitrate in drinking water and non-Hodgkin's lymphoma (NHL) in Minnesota; a state with heavy nitrogen fertiliser use. The present study is a supplement to data collected in 1980 in Minnesota. The original study included 329 cases of NHL (all white males aged 30 years or older who had been diagnosed between 1980 and 1982) and 642 population-based white male controls.

The present study restricted cases and controls to only those who had reported using Minnesota community water supplies or bottled water for at least 90% of the years between 1947 and 1980. The study population included 73 cases and 147 controls, and excluded those who had mainly used private well water for which nitrate concentrations were unknown. Participants reported residential histories were linked with estimated nitrate level by year in each community of residence for the period 1947 to 1975.

No association was found between NHL and long-term average nitrate exposure from community water supplies within the exposure range of this study (ie 0.1-7.2 mg/l). Age-adjusted odds ratios were calculated and the OR was 0.3 in the highest category (>1.5 mg/l) with a median nitrate average of 2.4 mg/l. NHL was not associated with the maximum nitrate exposure. The results of this study suggest that water with 2.4 mg/l of nitrate or less does not pose a risk of NHL.

Excretion of volatile nitrosamines in a rural population in relation to food and drinking water consumption.
Levallois P, Ayotte P, Van Maanen JMS, Desrosiers T, Gingras S, Dallinga JW, et al. Food Chem Toxicol (2000) **38**(11) p1013-1019.

It has been hypothesised that drinking water or foods containing nitrate may act as carcinogens via the formation of *N*-nitroso compounds in the stomach. This study was undertaken to examine this hypothesis in a real-life setting by looking at the relationship between drinking water nitrate and the urinary excretion of volatile nitrosamines, for which carcinogenic properties have been established.

Non-smoking well water users from the Portneuf County of the province of Quebec in Canada were recruited for the study. In this region nitrate concentrates above 7 mg nitrate-N/L have been observed. Participants were between 20 and 74 years old, drank only tap water, and ate mostly at home.

There were a total of 59 participants recruited. Participants were visited by a research assistant who collected a tap water sample and explained the 24-hr urinary collection procedure. A nutritionist using a 24-hr dietary recall evaluated food and water consumption of each participant. Urine was analysed for nitrates by hydrazine reduction and for volatile nitrosamines by gas-chromatography/mass spectrometry. Tap water was analysed for nitrate and nitrite concentrations and dietary intakes of nitrate and vitamins C and E were estimated using a validated Canadian food database.

A moderate correlation was observed between total nitrate intake and urinary excretion ($r=0.71$, $P<0.001$). The correlation of urinary nitrate excretion with nitrate intake was stronger for dietary nitrate intake ($r=0.54$, $P<0.001$) than for water nitrate intake ($r=0.38$, $P=0.003$). For 52 of the 59 subjects *N*-nitrosopiperdine (NPIP) was found in urine samples. No other nitrosamine was detected in urine samples. NPIP excretion was not related to total nitrate intake, urinary nitrate excretion nor to vitamin

C or E intake. However, coffee intake was significantly correlated with NPIP excretion. Coffee is known to contain piperidine, the precursor of NPIP.

The authors comment that the proposed use of urinary nitrosamine excretion as a biomarker of exposure to nitrosamines needs further study to elucidate the metabolism of these compounds.

Nitrate concentration in private rural drinking water supplies in Saskatchewan, Canada.
Thompson TS. Bull Environ Contam Toxicol (2001) **66** p64-70.

The province of Saskatchewan in Canada has a population of about 1 million, with about half living in cities and the remainder in rural towns, villages, hamlets, rural municipalities and Indian reserves. Many of these individuals use privately maintained wells and some farm families use shallow surface water (dug outs) as their only source of potable water. Most of these private drinking water supplies are not treated. The presence of elevated concentrations of nitrate in rural drinking water supplies is of public health concern with studies linking high nitrate concentrations to methaemoglobinemia in infants and possibly various forms of cancer. This study examined nitrate concentrations in private wells and dugouts in Saskatchewan. The drinking water quality guideline for nitrate established by Health Canada is 45 mg/L nitrate.

Water samples from private wells and dugouts were collected and analysed for nitrate using an automated hydrazine reduction method performed on a continuous-flow analyser system. There were 3425 private wells tested over a 12-month period. Nitrate concentrations ranged from undetectable (less than1 mg/L) to 957 mg/L. Nitrate concentrations exceeded the Canadian drinking water guideline in 483 (14.1%) of the well samples. Samples from 150 dugouts had nitrate concentrations ranging from undetectable to 27 mg/L, with a median of 1 mg/L.

The authors conclude that the range of nitrate concentrations found in these well water samples is typical of levels reported from other rural areas of Canada and the United States. Nitrate contamination in dugouts tested does not seem to be a problem, however the sample number in this study was relatively small.

Selenium

Mortality in a population with long-term exposure to inorganic selenium via drinking water.
Vinceti M, Nacci G, Rocchi E, Cassinadri T, Vivoli R, Marchesi C, et al. J Clin Epidemiol (2000) **53**(10) p1062-1068.

A cohort of 2065 residents of the Italian municipality of Reggio Emilia (Emilia Romagna region, northern Italy) with long-term exposure to inorganic selenium via drinking water were analysed for mortality from cancer, cardiovascular disease and neurological disease. Exposure to selenium levels of 7-9 microgram/L in municipal tap water had occurred from September 1972 to September 1988. Based on a survey of 176 households, of which 88 responded, about 97% of residents in the area drank municipal tap water during this time.

The study period was from January 1, 1986 to December 31, 1997 with vital status at the end of this period determined from a national health database. Causes of death were obtained from review of death certificates. Mortality of this cohort was compared with that of the rest of the municipal population, who had received tap water with less than 1 microgram/L selenium and were considered the unexposed cohort. The number of deaths in the exposed cohort was divided by the expected number of deaths to calculate the standardised mortality ratios (SMRs) relative to the unexposed cohort. Age specific mortality rates in three age groups (30-49, 50-69, 70-84 years) were also calculated.

During this 12-year follow-up, deaths occurred in 156 men and 127 women of the exposed population. When observed deaths were compared with expected deaths, mortality from all causes was similar to the expected figure in women (SMR1.02), and was higher among men (SMR=1.12) but not statistically significant. When specific causes of death were considered, men showed significantly higher SMRs for melanoma (SMR=10.98), cancer of the kidney (SMR=3.30), and Parkinson's disease (SMR=6.54). For women, significantly increased SMRs were seen for multiple myeloma (SMR=6.75) and motor neurone diseases (SMR=19.97).

For cardiovascular disease overall mortality was slightly higher both in men and women (SMR 1.05, 95% CI 0.89-1.23). Mortality from coronary disease was similar to that expected in men, but lower in women which led to an overall slight decrease (SMR 0.87, 95% CI 0/63-1.16). Cerebrovascular mortality was higher in both men and women (SMR 1.43, 96% CI 1.03-1.93).

During the entire follow-up period an increase in the rate ratios for malignant neoplasms and for cerebrovascular disease was found in the 70-84 age group. Rate ratios for coronary disease were inconsistent in women with an excess mortality in the 50-69 age group and a lower mortality in the older group. Over the study period in the 70-84 age group mortality from cancer increased in men, and mortality from cerebrovascular disease increased in women but decreased in men.

The authors comment that the inconsistency of findings between the sexes, and the fact that statistically significant findings were based on small case numbers (2-4 individuals) and are thus statistically unstable tends to suggest no adverse effects of prolonged selenium exposure at these levels.

Comment The effect of important confounders could not be ruled out in this study as data about smoking and alcohol consumption was not obtained. However the exposed cohort and the surrounding community had similar socioeconomic characteristics and were assumed to be similar in lifestyle habits.

Water Reuse

Risk factors for Giardia intestinalis infection in agricultural villages practicing wastewater irrigation in Mexico.

Cifuentes E, Gomez M, Blumenthal U, Tellez-Rojo MM, Romieu I, Ruiz-Palacios G, et al. Am J Trop Med Hyg (2000) **62**(3) p388-92.

This study looks at the risk factor for *Giardia intestinalis* infection in the Mezquital Valley Mexico, where one of the largest wastewater reuse systems in the world is located. Currently in Mexico cropland irrigation with untreated wastewater is only permitted on fodder and maize and growing vegetables for consumption without cooking is not allowed.

Storm water run off and untreated wastewater from Mexico City flows 70km north through metropolitan outlets and irrigates 90,000 hectares of farmland. The first group of villages receives untreated wastewater (UW group), with the excess being transported further north and retained in interconnected reservoirs. Effluent from these reservoirs flows towards another group of villages (RW group). Also many communities practicing rain fed agriculture (control group) are scatted around the Mezquital valley.

A cross-sectional survey was carried out during the rainy months where 11,357 dwellings were visited, and those with one or more people involved in agriculture with a single identifiable water source were included. About 75% of households actively participated, contributing stool samples and answering questionnaires. Participants comprised 2,257 individuals from the UW group, 2,147 from the RW group and 2,344 from the control group. Data were gathered on agricultural profile, hygienic and sanitation characteristics, socioeconomic variables and other potential confounders. Stool samples were also collected from 6,748 participants. Samples of water were collected monthly from selected sites. Wastewater samples were tested for faecal coliforms and *Giardia sp.* cysts; these were used as water quality indicators.

Untreated wastewater contained high concentrations of faecal coliforms (10^8/100 ml) and *Giardia sp.* cysts (125-300 cysts/L). Lower concentrations of these water quality indicators were found in samples from the effluent of the reservoirs (10^1 - 10^4 faecal coliforms/100ml and 5 or less Giardia cysts /L). Retention time in reservoirs ranged from 2 to 6 months.

The prevalence of *G. intestinalis* infection differed significantly in different age groups, being highest in children aged 1-4 years of age (about 20%) and decreasing in older subjects. Individuals in the RW group had the highest prevalence of infection followed by those in the UW and control groups although these differences were not statistically significant. Individuals with the longest time of exposure to agricultural activities (5 years or more) tended to have lower prevalence of infection compared with those who had 1-4 years of exposure time. People involved in grazing and weeding had a higher prevalence of infection than those involved in

seeding and planting. Higher rates of infection were seen in those who bought vegetables at the city market compared to those buying at the village shop. Prevalence was also higher in households with unprotected tanks and buckets to store drinking water and in households without basic sanitation.

In conclusion, the study found no increased risk of infection with *G. intestinalis* in those who used untreated wastewater compared to the other groups.

Comment Almost 50% of the RW group households were considered to be extremely poor, compared with 9.3% of the UW group and 17.5% of the control group. More than half the households in all groups had no sanitary facilities, and fewer than 12% had water piped into the house. It is possible that Giardia transmission via routes other than agricultural exposure was high in all groups, thus masking any differences due to water quality used for irrigation.

Water Quality

The effect of residential development on ground-water quality near Detroit, Michigan.
Thomas MA. J AWWA (2000) **36**(5) p1023-1038.

This study was undertaken to determine how recent residential development in the outskirts of the Detroit metropolitan area has affected ground-water quality. The development mainly consists of upper-middle class homes on large lots with most homes having private wells, septic systems and water softeners.

During the summer of 1996, 30 monitor wells were installed in the area and sampled once between November 1996 and early January 1997 to assess the quality of the shallow ground water. Samples were analysed for major ions, nutrients, pesticides, volatile organic compounds (VOCs), dissolved organic carbon, trace elements, radon and tritium. The same area was revisited in 1997 to assess the quality of ground water used for domestic supply. This drinking-water study involved the sampling of 28 wells; each located near one of the monitor wells. These domestic wells were sampled once between May and July 1997. Samples were analysed for concentrations of major ions, nutrients, tritium, radon, pesticides and VOCs. The age of the groundwater was estimated using tritium age-dating. Water with tritium concentration (TU) less than 1.1 tritium units was interpreted to have been recharged before 1953 and referred to as "old water" and water with tritium concentrations greater than or equal to 1.1 TU was referred to as "young water".

Results of the water analysis indicated that almost 20% of water supplies were old water that appeared to be minimally affected by human activities. Such supplies were mainly from wells that were 68 to 264 feet in depth. The young and shallow waters had a significantly higher median concentration of nitrate, chloride, dissolved solids, sodium, calcium and potassium than the old deeper water. The shallow high-salinity water was concluded to be the result of human activity based on the chloride/bromide ratios.

One or more VOCs were detected in 97 % of the samples from monitor wells, although concentrations were several orders of magnitude below US EPA MCL concentrations. Pesticides were detected in 7 % of the samples from monitor wells. The co-occurrence of nitrate, VOCs and pesticides with halite suggests that septic-system effluent is the likely sources of contamination and infiltration of storm water runoff from roads. No enforceable health-related drinking water standards were exceeded in samples from domestic wells, however standards do not exists for all constituents measured and not all contaminants were tested for.

In the study area it was shown that residential development during the past 25-30 years had widely influenced the groundwater quality. The effects of human activity are apparent in 76% of young waters and at depths well below 25 feet, which is the current minimum depth required for domestic wells by state regulations.

Safety of community drinking-water and outbreaks of waterborne enteric disease: Israel, 1976-97.
Tulchinsky TH, Burla E, Clayman M, Sadik C, Brown A, Goldberger S. Bull WHO (2000) **78**(12) p1466-73.

This paper reviews the microbiological quality of Israel's water supplies and outbreaks of waterborne disease, and describes changes in the total burden of enteric diseases in the country.

In Israel the Ministry of Health regulates community water supplies, and non-community sources of water

such as springs, rivers or wells only receive attention when outbreaks occur. Surveillance and investigation of outbreaks is based on mandatory reporting of enteric disease by physicians to local public health officers who in turn report their findings to the Epidemiology Department of the Ministry of Health. Diseases that must be reported include salmonellosis, shigellosis, hepatitis, campylobacteriosis and other enteric disease.

Between 1975 and 1992 high rates of waterborne enteric disease and many reports of water not meeting the current quality standards were documented in Israel. In March 1989 new stricter regulations were introduced as a result of water quality problems in the 1980s. Under the new regulations continuous chlorination of all community water supplies for both surface and groundwater sources became mandatory. Also the minimum acceptable quality standard for drinking water was made more stringent (from less than 10 coliforms/100ml to less than 4 coliforms/100ml). Changes in regulations governing turbidity and groundwater protection have also been phased in over the last decade.

Over the period from 1976 to 1980 there was an obvious decline in outbreaks of waterborne disease from community water supplies; the last outbreak was reported in 1991. There was also a decline in outbreaks from non-community sources, from foodborne diseases and for outbreaks where the source was unknown.

From 1976 to 1980 there were 25 outbreaks of waterborne disease from community water sources, which resulted in 7,619 reported cases of illness. From 1981 to 1985 there were 27 outbreaks from community water sources with 10,880 cases of illness. Most cases were associated with a major outbreak in 1985 caused by a construction accident which resulted in heavy sewage contamination of an unchlorinated ground water source and resulted in about 9,000 cases of shigellosis. A secondary outbreak of *Salmonella typhi* occurred a week later and included 77 cases and 75 hospitalisations. There were 9 outbreaks of waterborne disease from community sources between 1986 and 1990 with a total of 1779 cases. In 1991 one outbreak was reported with both *Salmonella* and *Shigella* identified.

From 1976 to 1980, cases of waterborne disease constituted 17.6% of all reported cases of enteric diseases. This increased to 18.2% for 1976 to 1980, then decreased to 3.8% for 1986 to 1990, and 0.9% in 1991 to 1995. No waterborne outbreaks were detected from 1996 to 1997.

The authors conclude that changes in water management and regulation since 1989, have produced substantial improvement in water quality supplied to communities. There has been an overall reduction in the burden of enteric disease in Israel, the exceptions being salmonellosis (primarily foodborne) and shigellosis (person-to-person).

Development of California public health goals (PHGs) for chemicals in drinking water.
Howd RA, Brown JP, Morry DW, Wang YY, Bankowska J, Budroe JD, et al. J Appl Toxicol (2000) **20**(5) p365-80.

The California Safe Drinking Water Act of 1996 mandated the development of Public Health Goals (PHGs) for over 80 chemicals in drinking water by the 31 December 1999. These PHGs were to be set at levels that would not pose any significant risk to the health of those consuming the water over a lifetime and were to be purely based on public health considerations not feasibility or cost impact. The values obtained were then to be used by the California Department of Health services as one consideration in setting new maximum contaminant levels (MCLs) for substances in drinking water. This paper describes the estimated safe levels and toxicological rationale for the first 26 of these chemicals.

Twelve of the PHGs were lower than the USEPA MCLs, seven were higher and six were the same and for two (Freons 11 and 13) there were no comparable federal standards. A similar pattern of difference was also seen when PHGs were compared with the State of California MCLs. The differences seen were due to changes in risk assessment methodology, consideration of new studies and reinterpretation of earlier studies or evaluations. The Office of Environmental Health Hazard Assessment in December 1997 adopted these PHGs. As these guidelines were developed as health protective guidance values, economic and practicality issues need to be considered in the implementation of these suggested limits as actual drinking water standards.

Contamination of potable roof-collected rainwater in Auckland, New Zealand.
Simmons, G., V. Hope, et al. (2001). Wat Res **35**(6): 1518-24.

This paper reports on a survey of microbiological and chemical water quality in 125 rainwater tanks in homes in rural areas near the city of Auckland, New Zealand (NZ). Four districts not served by a reticulated water supply were selected for the study, and 166 households were randomly selected from census records and invited to participate.

The 125 participating households completed an interviewer-administered questionnaire covering demographics and health, and information about the history of the water supply and maintenance practices. Each rainwater supply system was visually inspected and cold tap water samples were collected from the kitchen tap. First draw samples were used for metals analysis, and fully flushed samples (after tap was running for 4 minutes) were used for microbiological analysis.

Parameters assayed were turbidity, pH, lead, copper, zinc, arsenic (only for 14 households with unpainted tanalised wood in the water collection system), heterotrophic plate count, total coliforms, faecal coliforms, and enterococci. Pathogenic bacteria (*Salmonella* spp., *Campylobacter* spp., *Aeromonas* spp. and *Legionella* spp.) were tested in every 4th household, and protozoa (*Cryptosporidium* and *Giardia* in 500 litre sample) only in households with 30 or more faecal coliforms/100ml or 60 or more enterococci /100ml.

The percentages of tank water samples not in compliance with NZ Drinking Water Standards for physicochemical parameters were 4% for turbidity, 40.8% for pH, 14.4% for lead, 2.4% for copper, 0.8% for zinc and 7.1% (1 of 14 sampled) for arsenic. Bacterial indicator organisms showed strong correlation with each other, and 56% of tanks were positive for faecal coliforms in a 100ml sample. *Aeromonas* spp. were detected in 20 (16%) of 125 tanks, *Salmonella* spp were detected in 1 (0.9%) of 115 tanks, and *Cryptosporidium* in 2 (4%) of 50 tanks. *Campylobacter* spp. (115 tanks tested), *Legionella* spp. (23 tanks) and *Giardia* (50 tanks) were not detected.

Households which had one or more members with gastrointestinal symptoms in the month prior to water sampling were significantly more likely to have *Aeromonas* spp. detected in their water supply (OR 3.22, 95%CI 1.15-9.01). The authors comment that the absence of *Campylobacter* spp. is surprising given the likelihood that rooftops would be contaminated by bird droppings. The levels of lead contamination observed here are likely to be due to rooftop materials and paint, rather than atmospheric lead pollution as these areas had low traffic density and predominantly unleaded petrol has been used for some years in New Zealand.

Brass corrosion and the LCR monitoring program.
Kimbrough DE (2001). Journal of the American water Works Association Vol **93**(2): 81-91.

The Lead and Copper Rule (LCR) promulgated by the US EPA requires water utilities to carry out first draw sampling programs in "high risk" houses to determine whether action is needed to reduce the corrosivity of water and reduce exposures to lead and copper through drinking water supplies. At the time the Rule was formulated, there was little information on the possible contribution of brass fixtures to lead and copper leaching into first draw samples. Thus the Rule and its specified remedial measures focus on other components of household plumbing (lead supply lines, copper pipes with lead solder, and internal lead pipes), with the implicit assumption that brass fittings are a minor concern.

This paper decribes the results of four different surveys:

- LCR sampling programs undertaken by several Californian water utilities with analyses for lead, copper, zinc and nickel.
- samples from households complaining of blue water.
- long term trends in LCR samples in teh ciy of Santa Monica.
- a small survey of mostly low risk houses.

Overall, the results suggest that corrosion of brass fittings is an important source of lead, copper and zinc in household first draw tap water, and that the criteria used to target high risk homes under the LCR may be of limited relevance.

List of Articles

Uptake of chlorination disinfection by-products; a review and a discussion of its implications for exposure assessment in epidemiological studies.
Nieuwenhuijsen MJ, Toledano MB, Elliott P. J Exp Anal Environ Epidemiol (2000) **10**(6 Part 1) p586-599.

Inflammatory activity as an indicator of water quality: The use of human whole blood cultures.
Pool EJ. van Wyk JH. Leslie AJ. J Immunoassay (2000) **21**(4) p387-99.

Uncertainties in risk assessment for the determination of drinking water pollutant concentrations: Cryptosporidium case study.
Fewtrell, L., S. M. Macgill, et al. (2001). Water Research **35**(2): 441-447.

Norwalk-like virus sequences detected by reverse transcription-polymerase chain reaction in mineral waters imported into or bottled in Switzerland.
Beuret, C., D. Kohler, et al. (2000). Journal of Food Protection **63**(11): 1576-1582.

Understanding the fate of Cryptosporidium and Giardia in storage reservoirs: a legacy of Sydney's water contamination incident.
Hawkins, P. R., P. Swanson, et al. (2000). Aqua (Oxford) **49**(6): 289-306.

Helicobacter sp. recovered from drinking water biofilm samples from a distribution system.
Park Sr, MacKay WG and Reid DC. (2001) Wat Res 35(6): 1624-1626.

Cyanobacterial toxins, the perception of water quality, and the prioritisation of eutrophication control.
Codd, G. A. (2000). Ecological Engineering **16**(1): 51-60.

Recommendations for water supply in arsenic mitigation: A case study from Bangladesh.
Hoque, B. A., A. A. Mahmood, et al. (2000). Public Health **114**(6): 488-494.

Outbreak of Legionnaires' disease associated with a display whirlpool spa.
Benkel, D. H., E. M. McClure, et al. (2000). International Journal of Epidemiology **29**(6): 1092-1098.

Bromate formation during ozonation of bromide containing drinking water - a pilot scale study.
Myllykangas, T., T. Nissinen, et al. (2000). Ozone-Science & Engineering **22**(5): 487-499.

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The CRC for Water Quality and Treatment also produces the quarterly newsletter **Water Quality News** featuring current affairs, highlights from all four research programs of the CRCWQT, and information about other CRCWQT activities.

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