Health Stream

INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

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Distribution System Health Study

Researchers in Norway have conducted an epidemiological study suggesting that repairs and maintenance works in water distribution systems are associated with increased risks of gastroenteritis among residents in the area affected by the work (1). The outcome of the study once again raises questions about the role of tap water as a contributor to endemic gastrointestinal disease in developed nations. This study differed from previous investigations of endemic disease because it specifically targeted areas of the distribution system affected by low pressure events. Previous research has highlighted how even transient low pressure events may permit ingress of groundwater, potentially containing enteric pathogens, into water distribution systems (2).

The study was conducted over a 12 month interval in urban areas of Norway with a total population of about 1.1 million. Tap water was provided by seven waterworks which individually served between 35,000 and 460,000 people. During the study the water companies were asked to notify the researchers of low-pressure episodes affecting their service area. Such episodes were defined as events were a section of the water distribution system was closed off, with a presumed loss of water pressure. Episodes could be planned (eg scheduled maintenance) or unplanned (eg spontaneous pipe breaks or damage during construction work).

Each waterworks was asked to identify up to two episodes per month where at least 10 households were affected by low pressure; the first planned episode and the first unplanned episode during the month. When notifiable episodes occurred, the

researchers were contacted and supplied with information on the time and place of the event, the climatic conditions, the reason for the event, any measures taken to prevent contamination, and the location of sewage pipes in relation to water distribution pipes. The waterworks personnel also provided their assessment on the risk of contamination associated with the episode (low, medium or high risk). The waterworks company randomly selected 10 “exposed” households (affected by the low pressure episode) and 10 “unexposed” households (in the same general area but unaffected by the low pressure episode) from its customer register and provided their contact details to researchers. A letter was sent to these households advising that they would be contacted by telephone and asked to participate in the study. The letter requested that one person aged over 16 years be prepared to answer questions on behalf of all household members.

Telephone contact was made with households between 8 and 14 days after the low pressure episode, and a standard questionnaire was administered. Data collected included demographic details of household members, average tap water intake at home, any overseas travel in the last month, whether children attended a daycare centre, employment of household members in kindergartens, the presence of pets or regular contact with other animals. People were asked about gastroenteritis episodes in household members during the week following the low pressure event, and whether they had noticed discolouration or a strange taste in tap water in the last 14 days, or if they thought any work had been done on the water pipes. In order to avoid bias in data collection, the same preliminary letter was sent to both exposed and unexposed households, and interviewers were unaware of the exposure status of the households.

Data from 88 low pressure episodes were included in the statistical analysis, with the number of episodes for individual waterworks ranging from 2 to 24 during the 12 month study. It was estimated that 5,935 households had been exposed to low pressure conditions from these 88 episodes. Some reported low pressure episodes were not able to be included in the study due to lack of interviewing capacity. A total of 612 exposed households and 547 unexposed households were interviewed from a target of 880 households (88 episodes x 10 households in each group). Reasons for missing interviews included inability to establish telephone contact (37%), relocation or no phone number obtainable (21%), refusal to participate (20%) or unknown reasons (15%). Six households (4 exposed and 2 unexposed) were excluded as they were unable to specify the time of gastrointestinal illness in relation to the low pressure episode.

The majority (63%) of low pressure episodes were due to mains breaks or leaks, 26% were due to changes of equipment (valves, pipes), while 11% were due to various other causes (cleaning of pipes, construction near pipes, defective valves etc). Waterworks companies reported flushing pipes to eliminate contamination after 87% of episodes, but only one of the seven companies chlorinated after repair work (performed in 12 of the 14 episodes reported by this company). Water samples were obtained for only 18 low pressure episodes and one was positive for *E. coli*. Householders were not advised to boil water following any of the episodes.

There were no significant differences between exposed and unexposed households in terms of demographics or most non-water related risk factors (eg children were in childcare, overseas travel, animal contact etc). More unexposed households had a member who worked in a kindergarten (7% compared to 4% in the exposed group) and this was statistically significant. In both groups, 83% of households reported average water consumption was more than one glass per person per day. The analysis of gastrointestinal illness was performed at the household level with a case household defined as having at least one person experiencing gastrointestinal illness during the observation period (the week following the low pressure episode). Gastrointestinal illness was defined as an episode of vomiting and/or diarrhoea with at least 3 loose stools during a 24 hour period.

There was a significant difference in the reported rate of gastrointestinal illness by exposed households (12.7%) compared to unexposed households (8%).

The crude relative risk (RR) was 1.58 (95% CI 1.1-2.3). Stratified analysis for foreign travel or employment at a kindergarten did not change the RR estimate. Exposed households were significantly more likely to say they believed there had been work/repair of water mains in the last two weeks compared to unexposed households (75% vs 25%, p less than 0.001). Exposed households were also more likely to report they had noticed water discolouration (29% vs 7.3%), but reporting of bad tasting water was similar in both groups (3.8% vs 4.2%). To test the potential effect of bias due to participants being aware of some problem with the water supply, stratified analysis was carried out. Relative risks for "thought work/repair had been done", "noticed discolouration", or "bad taste of water" were 1.38 (95% CI 0.9-2.1), 1.37 (95% CI 0.9-2.0) and 1.54 (95% CI 1.1-2.2) respectively. These relatively small changes in RR suggest that awareness of a water problem did not have a large influence on the results of the analysis.

Among exposed households there was a significant difference in reported illness rates between households with higher average daily water consumption (more than 1 glass per person) and those with lower water consumption (RR=4.9 95% CI 1.6-15.2). However in unexposed households, illness risks did not differ significantly with reported average water consumption.

When individuals (n=3020) were considered instead of households, the attack rate for gastrointestinal illness was 7.5% in the exposed group compared to 3.9% in the unexposed group (Odds Ratio 2.0, 95% CI 1.3-3.2). Illness rates were similar in males and females. The highest illness rates were seen in children aged 5 years and less (17.7% in exposed households, 10.0% in unexposed households), however the greatest difference between exposed and unexposed groups occurred in adults aged 20-39 years (OR=7.2, 95% CI 2.8-18.7). Symptoms of illness were similar in the exposed and unexposed groups, and most episodes of illness were of short duration (median 2 days, range 1-14 days). Details of individual water consumption were not collected, so it was not possible to assess individual risk in relation to water intake.

When the data for each waterworks were separately analysed, relative risks varied from 0.9 to 2.2. The waterworks with the lowest RR reported only two low pressure episodes during the study so the RR estimate was very imprecise. The next lowest RR of 1.1 was for the waterworks which hyperchlorinated after most low pressure episodes. The remaining five waterworks had RRs ranging from 1.3 to 2.2.

Relative risks were also assessed for different kinds of work or repairs on the distribution system. On univariate analysis a significantly increased RR was observed for swabbing (4 episodes, RR=2.2, 95% CI 1.1-4.2), and a significantly decreased RR for hyperchlorination (12 episodes from one waterworks, RR=0.4, 95% CI 0.2-1.0). Non-significant increases in RR were seen for rain during repair work, prolonged water shut off (more than 6 hours), and water and sewage pipes being in the same ditch. A non-significant decrease in RR was seen for flushing of pipes after repairs. Analysis using a multivariate logistic regression model showed a significantly increased risk for prolonged water shut off (RR=1.9 95% CI 1.0-3.4) and a significantly decreased risk for flushing (RR=0.4 95% CI 0.2-0.8). Of the 88 low pressure episodes examined, none were considered high risk by waterworks personnel, seven were considered medium risk, and the remaining 81 episodes were considered low risk. Medium risk episodes were significantly associated with a higher rate of illness in affected households (RR=1.8 95% CI 1.0-3.2) compared to low risk episodes.

Although all of the water supplies were disinfected with chlorine at their respective water treatment plants, chlorine residual levels in the distribution systems were low and would have had little protective effect against significant contamination ingress. Previous research has shown that even when measurable free chlorine residual is present, inactivation of viral or protozoan pathogens is slow, although bacterial pathogens and indicators may be rapidly inactivated (3). This may explain why *E. coli* was detected only once among water samples from 18 low pressure events in the Norwegian study despite the increased risk of gastrointestinal illness observed in exposed households.

Overall, the results of the study are consistent with the hypothesis that low pressure episodes permit ingress of enteric pathogens into the distribution system, and that this may result in a subsequent increase in the risk of gastrointestinal infections in consumers in the affected area. The dose-response relationship observed with water consumption among exposed households, and the reduction in relative risk seen with decontamination procedures (hyper-chlorination or flushing after repair work) are also consistent with this model.

The authors note a number of limitations with the study. Firstly, it was carried out in urban areas and may not be applicable to other settings. However rural systems may be even more vulnerable than urban systems due to longer distribution systems. Secondly, water exposures other than drinking were not assessed. For example, the authors suggest that use of tap water to fill small swimming/paddling pools may represent another exposure route contributing to illness rates. The observation period in the study was limited to one week after the low pressure events, so illnesses caused by pathogens with longer incubation periods (such as *Cryptosporidium* and *Giardia*) would have been missed, however these organisms are less common causes of gastroenteritis than bacterial or viral pathogens. Households and interviewing staff were not informed of the exposure status in order to minimise the potential for recall bias (over-reporting of illness by exposed households). However, the nature of low pressure events means that many households in the exposed group would have been aware of a recent interruption or problem with the water supply. Stratified analysis suggested this had a relatively minor impact on risk estimates.

One previous study has reported an association between low pressure events and gastrointestinal illness among residents of affected areas (4). Data from the control group in a UK case-control study of cryptosporidiosis was analysed and it was found that households affected by low pressure events in the two weeks before interview had a significantly increased risk of illness in the same period compared to households not affected by such events. However due to the limitations of the study design, the low pressure events relied on reporting by participants without confirmation by water companies, and the time relationship between events and the onset of illness could not be established. Therefore the association between low pressure events and illness could only be regarded as tentative. Other studies of endemic waterborne illness in developed nations have used point-of-use interventions (such as comparison of households with real and sham water treatment devices) to assess the contribution of waterborne pathogens to community gastroenteritis, however the design of such studies means that they measure rates of illness in a relatively large area over a prolonged time period rather than targeting short potential exposure periods in localised areas. This new study establishes a novel approach for assessing the role of transient distribution system contamination in endemic gastrointestinal illness.

The results of the Norwegian study suggest that individuals exposed to low pressure events have an increased risk of illness (7.5% in the week following exposure vs 3.9% for individuals in unexposed households), however it is not possible to extrapolate this to an overall estimate of disease burden as the prevalence of exposure to such events across the whole population is not known. The authors speculate that if 20% of households are affected once per year, then an estimated 33,000 cases of acute gastrointestinal illness may be occurring among the 4.5 million residents of Norway due low pressure events in water distribution systems. The illness burden from distribution system contamination may be higher if transient low pressure events rather than the more prolonged events examined in this study also contribute significantly to ingress of contamination. Conversely, risks may be lowered if water companies routinely use decontamination practices such as hyperchlorination and flushing after repair and maintenance work. If the illness rate in unexposed households represents the "background" gastroenteritis rate from all causes in the general population then it can be estimated that the average rate would be about 2 episodes per person per year or a total of 9 million episodes for the whole population. This is reasonably similar to previous estimates for other developed nations (around 1 case of gastroenteritis per person per year).

(1) Breaks and maintenance work in the water distribution systems and gastrointestinal illness: a cohort study. Nygard K, Wahl E, Krogh T et al. (2007) International Journal of Epidemiology **36**:873–880.

Health Stream thanks Dr Nygard for additional information on disinfection practices in the study area.

(2) The potential for health risks from intrusion of contaminants into the distribution system from pressure transients. LeChevallier MW, Gullick RW, et al. (2003). Journal of Water and Health **1**(1): 3-14.

(3) Poor efficacy of residual chlorine disinfectant in drinking water systems to inactivate waterborne pathogens in distribution systems. Payment P (1999) Canadian J Microbiology **45** 709-715. (Reviewed in Health Stream Issue 16).

(4) Self-reported diarrhea in a control group: a strong association with reporting of low-pressure events in tap water. Hunter PR, Chalmers RM, Hughes S and Syed Q. (2005) Clinical Infectious Diseases **40**:e32-4. (Reviewed in Health Stream Issue 37).

NHMRC Fluoridation Report

The Australian National Health and Medical Research Council recently published a systematic review of fluoridation (1). The review, released on 14 November, examined English-language publications from 1996 to December 2006. The outcomes of other systematic reviews prior to 1996 were also considered. The aim of the review was to assess the evidence on the caries reducing benefits and associated potential health risks of providing fluoride systemically (via addition to water, milk and salt) and by use of topical fluoride agents (such as toothpaste, gel, varnish and mouthrinse). The potential adverse effects assessed included dental fluorosis, fractures, and cancer. The report also provides background information on environmental sources of fluoride, naturally occurring fluoride levels in water, and fluoride levels in air, soil and food.

An initial broad literature search identified 5418 publications potentially relevant to fluoride and fluoridation. Review of abstracts for these publications reduced this to 408 articles, which were then obtained and reviewed in detail. A total of 77 articles were found to meet the relevance criteria for the systematic review. Articles were classified according to a quality of evidence matrix and then the body of evidence was assessed taking into account the type of epidemiological study designs which could be feasibly applied to each clinical question. For example, although the randomised controlled trial is recognised as providing the highest level of evidence for a single study, this design cannot be applied to water fluoridation as the intervention is made at the population rather than the individual level. The characteristics of the studies examined and the quality of evidence is summarised in an Appendix to the report.

The main findings of the NHMRC review may be summarised as follows:

<u>Dental caries</u>

- there is strong evidence that water fluoridation is beneficial in reducing dental caries,
- fluoridation of milk is probably also beneficial in reducing dental caries, although the quality of evidence is weaker than for water fluoridation,
- the evidence on salt fluoridation is of poor quality and no conclusion can be made on caries prevention,
- topical fluoride products are beneficial in reducing dental caries. Combinations may be more effective than single products.

<u>Dental fluorosis</u>

- there is strong evidence that water fluoridation increases dental fluorosis, however the majority of cases are mild and not considered to be of aesthetic concern,
- there is some evidence that milk fluoridation and salt fluoridation increase dental fluorosis,
- there is some evidence that fluoridated toothpaste increases dental fluorosis. Advice to parents and use of low fluoride toothpaste in young children has reduced the incidence of dental fluorosis.

<u>Fractures</u>

- the evidence suggests either no effect or a slightly beneficial effect of water fluoridation at optimum levels (0.6 to 1 mg/L) on fractures,
- the evidence on milk or salt fluoridation, or topical fluoride products is insufficient to make any conclusions on fracture risks.

<u>Cancer</u>

- There is no clear association between water fluoridation and overall cancer incidence or mortality. Two recent studies showed significant effects on bone cancer, but one study suggested

an increased risk while the other suggested a decreased risk.

Other adverse effects

- A number of studies of lower quality have examined a diverse range of possible adverse effects, however there is insufficient evidence to draw conclusions on any relationship between water fluoridation or other means of fluoride supplementation and adverse health effects.

In a public statement accompanying the review the NHMRC again endorsed its current position that "fluoridation of drinking water remains the most effective and socially equitable means of achieving community-wide exposure to the caries prevention effects of fluoride. It is recommended that water be fluoridated in the target range of 0.6 to 1.1 mg/L, depending on climate, to balance reduction of dental caries and occurrence of dental fluorosis".

A few weeks after the release of the report, the Premier of Queensland announced that her government would act to fluoridate drinking water supplies in the state. Queensland has the lowest fluoridation coverage in Australia with less than 5% of the population having access to fluoridated water compared to at least 70% in other states and territories. The prevalence of tooth decay in Queensland children aged 5-12 year is double that of children living in the Australian Capital Territory, which has 100% access to fluoridated water. Within Queensland, tooth decay rates are noticeably lower in Townsville, the only major population centre with fluoridated water.

According to media reports, the state government will provide an estimated $35 million in capital costs for installation of fluoridation equipment while operating costs will be funded by an increase in water prices. The government has set a target of providing fluoridated water to 90% of Queensland residents by the year 2012. The fluoridation program will begin with water treatment plants serving the state capital Brisbane and larger water treatment plants in southeast Queensland.

(1) A systematic review of the efficacy and safety of fluoridation (2007). Available from: www.nhmrc.gov.au/publications/synopses/eh41syn.htm

Waterborne Outbreak In Finland

The town of Nokia in western Finland has been hit by a large waterborne disease outbreak. According to media reports, up to half of the town's 30,000 residents may have been exposed to contaminated drinking water after a cross-connection resulted in sewage effluent entering the distribution system. The contamination apparently began on 28 November when a worker carrying out repairs opened a valve which separated drinking water from water used to clean the sewage treatment plant. A pressure differential between the systems caused sewage effluent to enter the drinking water supply.

The contamination was not discovered until two days later, around the same time that cases of severe gastroenteritis began to be reported by residents. During the interval an estimated 450,000 litres of filtered sewage effluent had entered the drinking water system. Local police investigating the incident are reported to have said they believe the contamination was accidental, however they are investigating if the pipe which permitted the cross-connection to occur was illegally installed.

Over a thousand cases of gastroenteritis are estimated to have been caused by the contamination, at least 250 people sought medical care and a number have been diagnosed with *Campylobacter* and *Salmonella* infections. A boil water alert was issued on 2 December, and the water company began a program of hyperchlorination and flushing to clear the contamination from the distribution system. An extended program of air scouring is also planned, although this will take several months to complete. The Finnish Defence Forces were called in to supply water tankers and assist with door-to-door deliveries of bottled water to residents, and schools were closed for a week. In an effort to limit secondary transmission of infections, health authorities have urged ill people not to return to work or school for at least two days after symptoms have resolved.

The Health ministry admitted that the outbreak had highlighted deficiencies in emergency response procedures, particularly in relation to communication with the public during the crisis. A spokesman for the

National Public Health Institute also said that hospitals and local governments had trouble coping with the outbreak and more resources were needed for outbreak and emergency response programs. The Accident Investigation Board of Finland has appointed a committee to examine the causes of the incident and the subsequent response by relevant authorities. Nokia was the home of the Nokia Corporation in the days when the main products of the company were paper, rubber and cables, however the current Nokia telecommunications company does not have any operations in the town.

News Items

Water Quality Research Australia Established

Australia's new national water research centre, Water Quality Research Australia Limited (WQRA) was established as a legal entity on 12 October 2007 with the signing of an agreement between three founding members. Membership now stands at 40 organisations with a diverse mix of industry, research and government agencies. WQRA has been set up to succeed the CRC for Water Quality and Treatment (CRC) when the CRC terminates on 30 June 2008. WQRA is currently seeking a Chief Executive Officer and also invites Expressions of Interest for the position of Chair of the Board of Directors. Information on WQRA can be found at: www.waterquality.org.au

WHO Chemical Safety Guidance

The World Health Organisation has released a guidance document to assist policy-makers, regulators, managers and public health practitioners to evaluate and manage chemical risks in drinking water supplies. The document "Chemical safety of drinking-water: Assessing priorities for risk management" comprises three sections; Part A provides information on assessing priorities and developing and implementing risk management strategies, Part B gives guidance on identifying chemicals of concern for individual water supplies including both natural contaminants and those arising from human activities, and Part C provides more detailed information in a set of appendices.

www.who.int/water_sanitation_health/dwq/en/index.html

Naegleria Found in Arizona Wells

A survey of wells operated by the Tucson Water company has found *Naegleria fowleri* present in 12 of 35 wells tested. The "brain-eating amoeba" (as dubbed in local newspaper headlines) has become an issue of concern in the area following the deaths of two young boys in 2002 (See Health Stream Issue 28 p4). Researcher suspect the organism may have colonised the wells as a result of using biodegradable oil in pumps, with the oil providing a food source for bacteria which are in turn consumed by the amoeba. Tucson Water is developing risk management procedures including 3-yearly sampling of wells with water temperatures above 77 degrees F, chlorinating any positive wells, and chlorinating wells before use if they have been offline for 6 months or more. Employees will also be warned to avoid inhalation of water before chlorination.

Bacillus Prompts Bottled Water Warning

The California Department of Public Health issued a warning to consumers on 5 December warning them not drink a particular brand of flavoured water produced in the state and sold nationwide. The warning follows detection of the bacterium *Bacillus cereus* in samples of the water, and one reported case of illness in Illinois possibly associated with the contaminated water. Four flavours of water are affected by the warning. Many toxigenic *B. cereus* strains are capable of producing two types of toxin, each causing distinct symptoms of either vomiting or diarrhoea.

PET Myth Returns

The urban myth that re-filling plastic drink bottles poses a risk of exposure to cancer-causing chemicals has been revived by an email circulating in Australia. According to media reports the email cites a US singer who said on a celebrity chat show that she attributes her breast cancer to drinking water from plastic bottles left sitting in the sun. The email has caused the Plastics and Chemicals Industries Association (PACIA) to once again issue a statement about the safety of PET bottles, and refer to a previous statement by Food Standards Australia New Zealand. (See Health Stream Issue 32 p5 for a report on the PET urban myth).

From the Literature

Web-bonus articles

Summaries of these additional articles are available in the web page version of Health Stream and are included in the searchable archive at:

www.waterquality.crc.org.au/pubs

Drinking water arsenic exposure and blood pressure in healthy women of reproductive age in Inner Mongolia, China.
Kwok RK, Mendola P, Yi Liu Z, et al. (2007) Toxicology and Applied Pharmacology, **222**(3); 337-43.

Workshop overview: arsenic research and risk assessment.
Sams R, 2nd, Wolf DC, Ramasamy S et al. (2007) Toxicology & Applied Pharmacology, **222**(3); 245-51.

Implications of biofilm-associated waterborne Cryptosporidium oocysts for the water industry.
Angles ML, Chandy JP, Cox PT et al. (2007) Trends in Parasitology, **23**(8); 352-6.

Gastroenteritis associated with accidental contamination of drinking water with partially treated water.
Fernandes TM, Schout C, De Roda Husman AM et al. (2007) Epidemiology & Infection, **135**(5); 818-26.

Intake and risk assessment of nitrate and nitrite from New Zealand foods and drinking water.
Thomson BM, Nokes CJ and Cressey PJ. (2007) Food Additives & Contaminants, **24**(2); 113-21.

Domestic rainwater harvesting to improve water supply in rural South Africa.
Mwenge Kahinda J-m, Taigbenu AE and Boroto JR. (2007) Physics and Chemisty of the Earth, **32**(15-18); 1050-7.

Impact of bathers on levels of Cryptosporidium parvum oocysts and Giardia lamblia cysts in recreational beach waters.
Sunderland D, Graczyk TK, Tamang L and Breysse PN. (2007) Water Research, **41**(15); 3483-9.

Grand rounds: nephrotoxicity in a young child exposed to uranium from contaminated well water
Magdo HS, Forman J, Graber N et al. (2007) Environmental Health Perspectives, **115**(8); 1237-41.

Problems with provision: barriers to drinking water quality and public health in rural Tasmania, Australia.
Whelan JJ and Willis K. (2007) Rural & Remote Health, 7(3); 627.

Comparing serologic response against enteric pathogens with reported diarrhea to assess the impact of improved household drinking water quality.
Crump JA, Mendoza CE, Priest JW et al. (2007) American Journal of Tropical Medicine & Hygiene, **77**(1); 136-41.

Arsenic

Comparison of health effects between individuals with and without skin lesions in the population exposed to arsenic through drinking water in West Bengal, India.
Ghosh P, Banerjee M, De Chaudhuri S, et al. (2007) Journal of Exposure Science & Environmental Epidemiology, **17**(3); 215-23.

In West Bengal, India there are more than 7 million people exposed to arsenic through drinking water at levels much higher than the World Health Organisation (WHO) acceptable limit of 10 micro g/l. Associations have been found between arsenic ingestion and hyper-pigmentation, keratosis of skin, anaemia, burning sensation of the eyes, solid edema of the legs, liver fibrosis, chronic lung disease, gangrene of the toes and neuropathy as well as cancers of skin, lung, liver, bladder, kidney and prostate. Skin lesions generally develop more than 10 years after first exposure and are recognised as the most sensitive end points of chronic arsenicism. However, only 15% to 20% of those exposed to arsenic contaminated water develop skin lesions. This study assessed the prevalence of neuropathy, respiratory illness and eye problems in those with and without skin lesions as a result of arsenic exposure, and compared them with a group of unexposed individuals from an area not affected by arsenic.

This cross-sectional study was conducted between January 2003 and May 2005 and included individuals from five villages exposed to arsenic in West Bengal. There were 373 individuals with skin lesions and 352 without skin lesions from the arsenic exposed area recruited. These individuals ranged from 15 to 70 years of age and had at least 10 years of exposure. Also 389 unexposed subjects aged between 15 and 70 were recruited from a different area. Participants were interviewed using a structured questionnaire which recorded information on lifetime residential history, occupation, diet, and smoking habits. A team of expert physicians with at least 15 years of experience interviewed and examined each participant. Water, urine, nail, hair and blood samples were collected from participants and arsenic concentrations measured.

There were no significant differences between the three groups in terms of age distribution, smoking habits and occupation types. For those in the exposed population (with and without skin lesions) the arsenic content in drinking water and other biological samples was significantly higher ($P<0.001$) when compared with the unexposed group. The difference in arsenic concentration in the drinking water of the exposed group with skin lesions and the exposed group without skin lesions was not significant. However, a significantly higher amount of urinary arsenic was detected in the group without skin lesions, and a significant retention of arsenic in nail and hair was found in the skin lesion group. The arsenic concentration in the drinking water of the exposed study area ranged from 50 to 1188 micro g/l, while that of the unexposed area ranged from 0 to 10 micro g/L. Among the exposed group, those with skin lesions had a higher risk for conjunctivitis ((odds ratio) OR: 7.33, 95% CI: 5.05-10.59), peripheral neuropathy (OR: 3.95, 95% CI: 2.61-5.93) and respiratory illness (OR: 4.86, 95% CI: 3.16-7.48) compared to those without any skin lesion. Those without skin lesions in the exposed group showed a higher risk for conjunctivitis (OR: 4.66, 95% CI: 2.45-8.85), neuropathy (OR: 3.99, 95% CI 1.95-8.09) and respiratory illness (OR: 3.21, 95% CI: 1.65-6.26) when compared to arsenic unexposed individuals. The trend test for OR of the three diseases in the three groups was found to be statistically significant.

There was no significant difference in the level of arsenic in drinking water in the groups with and without skin lesions, and this suggests the possibility that genetic variation may be a strong factor in susceptibility to arsenic toxicity. This study provides considerable evidence that ingestion of inorganic arsenic through drinking water is a risk factor for peripheral neuropathy, conjunctivitis and respiratory illness even in exposed individuals who remain lesion free. Those with skin lesions were found to retain much higher levels of arsenic in their nail and hair and excrete much lowers amounts of arsenic through urine compared to those without skin lesions. A higher retention of arsenic would be expected to cause more damage to the cells resulting in skin lesions. The authors suggest that those with lower capacity to methylate the inorganic arsenic (which is necessary before it can be excreted in urine) might retain it in the body and as a result develop skin lesions. Comparison of genotyping information between the groups would be required to confirm this hypothesis.

Arsenic, internal cancers, and issues in inference from studies of low-level exposures in human populations.

Cantor KP and Lubin JH. (2007) Toxicology & Applied Pharmacology, **222**(3); 252-7.

Most of the evidence showing an association between inorganic arsenic in drinking water and elevated cancer risk for internal organs comes from studies of populations with high exposure levels above 150-200 micro g/L. Findings from epidemiological studies in populations with lower levels of exposure to arsenic in drinking water (below 100 micro g/L) are varied and in general do not show levels of cancer risk that would be expected from linear extrapolation of finding from high exposure studies. This paper discusses statistical aspects of these studies, particularly the effects of exposure misclassification and small study size.

Relatively small errors in assessment of historical exposure to arsenic during relevant exposure periods may have a great effect on the risk that is observed in epidemiological studies. Misclassification can be expressed in terms of specificity (probability that an exposed individual is classified as exposed) and sensitivity (probability that a non-exposed person is classified as non-exposed). Some error in estimating past exposures is unavoidable and when a true risk exists and the misclassification of exposure is non-differential (i.e. similar among cases and non-cases), the risk estimate is typically biased toward the null (no effect). The greater the exposure mis-classification, the greater the decrease in the observed risk. This limitation is of particular concern in low-exposure situations where expected excess risk is relatively small and the error in exposure estimates can be of such degree that detection of this small excess is difficult. Many of the low-exposure studies also are small in size which limits their statistical power to detect lower levels of risk.

The authors illustrate the effects of exposure misclassification and sample size using graphs which show the Odds Ratios (ORs) estimated for 2000 computer simulated case-control studies with sample sizes of either 100 cases + 100 controls, or 1000 cases +1000 controls, and sensitivity and specificity levels of 1.0 (no misclassification), 0.9 or 0.7. Simulations were run assuming a true OR of 1.0 (no increase in risk associated with exposure) or 2.0 (a doubling of risk associated with exposure). Each individual case-control study produces an estimate of the true OR (either 1.0 or 2.0), but for small studies there is a considerable overlap in the two OR distributions even when no misclassification occurs. Larger studies produce narrower distributions with little overlap when misclassification is absent, however overlap increases (and ability to distinguish low risk from no risk decreases) as misclassification increases. These factors suggest that estimation of risks for low level arsenic exposure requires studies with large samples size and improved accuracy of exposure assessment. The authors note that such a study is currently underway in the US.

<u>Bacteriophage</u>

Simple and rapid F+ coliphage culture, latex agglutination, and typing assay to detect and source track fecal contamination.

Love DC and Sobsey MD. (2007) Applied & Environmental Microbiology, **73**(13); 4110-8.

Coliphages are bacterial viruses that infect enteric bacterial species, and have been suggested as a possible alternative to faecal bacterial indicators of water quality, particularly as their properties may more closely resemble those of human viruses. F + coliphages can be divided into two families, those containing RNA genomes (F+ RNA coliphages) and those containing DNA genomes (F+ DNA coliphages). The F+ RNA coliphages can be serotyped into distinct groups present in human faecal waste (groups II and III) or animal faecal waste (groups I and IV). Current coliphage recovery and detection assays are time consuming, and the aim of this study was to develop, optimize and validate a same-day microbial water quality monitoring assay using F+ coliphages.

The latex agglutination method used involves particles coated with antibodies (or antigens) and visual detection of the binding and clumping of target antigens (or antibodies) with adjacent detector particles. Latex agglutination assays are generally rapid, specific, uncomplicated and inexpensive making them suited for field or laboratory diagnostic kits such are those used to detect adenovirus and rotavirus in stools. Environmental samples generally have low levels of coliphage antigens which means a culture step needs to be used before coliphage detection by particle agglutination. A 180 minute F+ coliphage culture enrichment was developed as a modified version of the 16- to 24-h culture step of EPA method 1601, to rapidly enrich both F+ RNA and DNA coliphages to levels amenable to particle agglutination. Preliminary trials showed that rapid F+ coliphage cultures gave equivalent results to those from EPA method 1601 with overnight enrichment. The enriched F+ coliphage culture is able to be assayed directly by typing, with no plaque purification or centrifugation. Typing was performed on a cardboard card by mixing a drop of coliphage enrichment culture with a drop of antibody-coated polymeric beads as detection reagent. Visual agglutination or clumping of positive samples was found to occur in less than 60 seconds. The CLAT (culture, latex agglutination and typing) assay was found to have sensitivities of 96.4% (185/192 samples) and 98.2% (161/164 samples) and specificities of 100% (34/34 samples) and 97.7% (129/132 samples) for F+ RNA and DNA coliphages, respectively. CLAT accurately detected and subtyped prototype F+ RNA coliphage strains into serogroups I, II, III and IV and did not react with F+ DNA coliphage prototype strains or controls. Using the same panel of F+ coliphage field strains, the CLAT assay had a similar performance and typing alibility as an RT-PCR-probe hybridization assay.

This F+ coliphage CLAT method was found to be simple, rapid and inexpensive and is a novel tool for monitoring the microbiological quality of water and other environmental media. It could be used in developed and developing countries and for identifying and tracking human and animal faecal waste sources.

Biofilms

Prevalence of bacterial pathogens in biofilms of drinking water distribution systems.
September SM, Els FA, Venter SN and Brozel VS. (2007) Journal of Water & Health, **5**(2); 219-227.

Water is normally disinfected prior to being distributed to the consumers and the microbial levels of the water are required to be within set limits when leaving the treatment plant. However, by the time the water reaches the consumers tap the quality may be very different from the quality at the time of treatment. This can often be due to recontamination after treatment as a result of regrowth of sub-lethally damaged bacteria or contamination from bacteria living in biofilms. This study was undertaken to determine the prevalence of *Aeromonas*, *E. coli*, *Pseudomonas*, *Salmonella*, *Shigella* and *Vibrio* in biofilms in drinking water distribution systems in large and small towns and home storage systems in South Africa.

Biofilm samples were collected from September 2001 to August 2002. There were 95 samples collected from two well-serviced urban areas (31 from Pretoria and 30 from Pietermaritzburg), a semi-urban developing community (Botshabelo five tap and 17 bucket samples) as well as other towns with small distribution networks (22 samples). The water from the two urban areas had been treated with chlorination and chloramination whereas the rest of the water was only chlorinated. Biofilm samples (*c.* 1cm^2) were taken using a sterile swab from the inner surface of the service pipe and in the case of the buckets an equivalent sized area was swabbed. Water from the systems was tested for the presence of faecal coliforms. The heterotrophic culturable count was determined for both the water and biofilm phases of the samples. Biofilm samples were analysed to determine the number of potential pathogens (*Aeromonas*, *E. coli*, *Pseudomonas*, *Salmonella*, *Shigella* and *Vibrio*). These pathogens were quantified by the three-tube most probable number (MPN) method using enrichment broths and plating on selective agars.

The heterotrophic culturable counts in the water samples ranged from 1.0 x 10^{-1} to 1.9 x 10^9 colony forming units (cfu) per ml and for the biofilms analysis of the same samples between 1.0 x 10^1 and more than 1.9 x 10^9 cfu cm^{-2}. Bacterial biofilms were present on the walls of all of the surfaces tested. Faecal coliforms were found in 7.7% of the tap samples and 23.5% of the buckets. These waters were not in compliance with the South African National Standard. Some sampling points had a variety of potential pathogens isolated at densities up to 10^4 cfu cm^{-2}. Pathogens isolated included *Aeromonas*, *E. coli*, *Pseudomonas*, *Salmonella*, *Shigella* and *Vibrio.* Samples from the larger distribution networks of Pretoria and Pietermaritzberg in general had much lower incidence of pathogens than those from the small towns and Botshabelo. The containers in Botshabelo in general harboured a higher number of pathogens than the tap except for *Salmonella*.

The partial sequences of the 16S rDNA genes of 74 randomly selected isolates were determined and revealed 5 *Acinetobacter*, 15 *Aeromonas*, 4 *Enterobacter*, 6 *Klebsiella*, 6 *Pantoea* and 34 *Pseudomonas* along with one or two representatives of various other genera. There were no putative *Salmonella* or *Shigella* confirmed however, indicating that none of these virulent pathogens could be detected in the drinking water-associated biofilms tested. The *Pseudomonas* isolates were all very similar to each other, and none of those isolated belonged to the nosocomial pathogens *P. aeruginosa* or *P. mendocina*. The selective culture media was found to be not as selective as reported when used for analysis of non-medical samples with a high incidence of false positives. Therefore, bacterial analyses of water based on selective isolation and culturing techniques should be interpreted cautiously. Water needs to be protected from the source to the tap using a comprehensive safety plan. Such a plan should address multi-barrier treatment and integrity of the water distribution systems to avoid pathogens entering the system.

Comment *Exposure to the opportunistic pathogens detected in this study also occurs through other routes including food, and may be of public health significance.*

Copper

Case study of complaints on drinking water quality: relationship to copper content?
Pizarro F, Araya M, Vasquez M et al. (2007) Biological Trace Element Research, **116**(2); 131-45.

In November 2001, an investigation was undertaken of the origin of health complaints relating to drinking water quality reported by consumers in specific districts of Talca (a city of 175,000 inhabitants located 450km south of Santiago), Chile. Complaints included gastrointestinal (GI) symptoms including vomiting, diarrhoea, abdominal pain and other non-specific subjective symptoms. Drinking water consumed in Talca comes from suppliers who obtain water from local wells. This report tested the hypothesis of a potential association between symptoms and copper (Cu) exposure from drinking water by examining the prevalence of GI symptoms by level of exposure to Cu in drinking water.

Households were grouped into three categories: category 1, two districts with Cu plumbing for tap water where residents reported health complaints; category 2, two districts with Cu plumbing for tap water where residents reported no health complaints and category 3, a district with plastic (PVC) plumbing for tap water where residents reported no health complaints. The final study population consisted of 1778 families: 682 category 1, 700 category 2 and 396 category 3. Participants answered a questionnaire about characteristics of the home (year of construction, years living in the home, type of tap water piping, change of piping system within recent years, etc), demographic data (sex, age and time spent at home), presence of chronic diseases and information on self-perception of symptoms experienced during the last 3 months. A subsample of 80 homes with Cu pipes was randomly selected for water sampling which included 40 homes from areas where GI symptoms were frequently reported and 40 homes of families reporting no GI symptoms. Water samples were taken from the cold water kitchen tap in the early morning at least 8 h after the last use (stagnant water) and after running water for 2 minutes and analysed for Cu concentrations, pH, alkalinity and temperature.

Men in category 1 had significantly higher percentages of GI symptoms than those in category 3. Women in category 1 had significantly higher percentages of GI symptoms than women in other categories. When category 3 was compared to categories 1 and 2, GI symptom reports in category 3 were twofold less than in the other categories (6.6% vs 12.3%, $x^2 = 41.7$, *p* less than 0.0001). There was a significantly greater prevalence of GI complaints reported by the mothers of children less than 12 years in category 1 than in categories 2 (*p* less than 0.006) and 3 (*p* less than 0.001). Subjects who lived in homes with Cu pipes reported a significantly higher percentage of abdominal pain and diarrhoea than subjects living in households with PVC piping. Subjects living in homes with Cu piping also had a higher frequency of episodes of allergies, bronchitis and emotional stress. A univariate analysis found that age (x^2 test, p less than 0.001), sex (x^2 test, p less than 0.03), category (x^2 test, p less than 0.001), presence of Cu pipes for the cold water kitchen tap (Fisher test, p less than 0.001), consumption of bottled water (Fisher test, p less than 0.001), and year of construction of home (Fisher test, p less than 0.0001) were all related to GI symptoms. Backward stepwise multiple logistic regression model analysis of the significant variables found in the univariate assessment identified less than 12 years living in the house, female sex, home built during or after 1996 and consumption of less than 200 mL of bottled water were risk factors for GI.

The stagnant Cu concentrations in the drinking water of the households studied were below the US EPA Maximum Contaminant Level Goal (less than 1.3 mg Cu/L). The mean stagnant water Cu concentration was 0.50 ± 0.32 mg/L and running water Cu was 0.06 ± 0.05 mg/L. The mean pH in stagnant water in category 1 was significantly lower than in those from category 2 (6.64 ± 0.11 vs 6.92 ± 0.26 respectively, *p* less than 0.01). The Cu concentration in stagnant tap water samples was significantly lower in category 2 than in category 1 (0.16 ± 0.13 vs 0.68 ± 0.36, respectively, *p* less than 0.01). There were 33% and 100% of homes from category 1 and 2 that had less than 0.5 mg Cu/L, respectively.

The data obtained from interviews in Talca suggests that Cu exposure was related to the GI complaints, however measurements of Cu concentration from stagnant tap water samples were below the No Observed Effects Level (NOEL) for acute GI responses to Cu of 2 mg Cu/L determined from human studies. The limitations of this investigation are that participants were aware of the potential Cu problems with local newspapers and television reporting on these matters and public discussion leading to a consensus that symptoms were due to the high Cu exposure from drinking water. Also the health survey was performed about 8 months after the complaints had occurred and the water sampling 6 months after the survey. A second water survey conducted a further 6 months later to check for seasonal differences found similar copper levels. Laboratory studies mimicking the most aggressive water composition found in Talca suggested that stagnant copper levels in new homes might reach 2-3 mg/L, but this would rapidly fall within a few weeks due to natural ageing processes. All homes assessed in the health study were built greater than two years earlier which would make Cu leaching from pipes less likely to contribute to the Cu in drinking water. In addition individuals with Cu piping in their home reported significantly more symptoms not likely to be Cu intake (eg allergies, bronchitis), as well as reporting symptoms plausibly related to copper exposure (eg nausea, vomiting, diarrhoea).

Comment *Overall these results suggest the association between copper exposure and illness may have been due to reporting bias as participants were aware of their exposure status and had been influenced by the widespread publicity of the problem. The paper makes no mention of any changes of water source or treatment that may have affected water quality during the relevant period. There is no information on microbial water quality or whether this was investigated and ruled out as a possible reason for the apparent outbreak.*

Fluoridation

Socio-economic differences in public opinion regarding water fluoridation in Queensland.

Mummery WK, Duncan M and Kift R. (2007) Australian and New Zealand Journal of Public Health, **31**(4); 336-9.

Fluoride added to drinking water is effective in the prevention and reversal of dental caries and is a cost-effective public health intervention. There have been concerns raised about the safety of fluoridation however there is no clear evidence of the negative health effects apart from concerns regarding dental fluorosis. More than 70% of Australians have fluoridated drinking water however in Queensland less than 5% of the population has access to fluoridated drinking water. There is evidence that poor oral health is associated with relatively low socio-economic status (SES) and also that water fluoridation reduces oral health disparities between SES groups. The aim of this study was to measure public opinion about fluoridation of drinking-water supply and to examine associations between support for fluoridation and socio-economic status.

Data was collected in Queensland in July and August 2006 as part of the annual Queensland Social Survey. A representative sample of the Queensland population was surveyed using a computer-assisted telephone interview (CATI) survey. Those interviewed were 18 years or older who at the time of the survey were living in a dwelling unit in Queensland and could be directly contacted on a land-based telephone service. There were three questions in the survey relating to the public's opinion of water fluoridation which required a "Yes", "No", and "Don't know" response. These questions were: 1. Do you support the idea of adding fluoride to your local drinking water? 2. Do you believe that fluoridation of the water supply is safe? 3. Do you believe that fluoridation of drinking water is effective in the prevention of tooth decay? A range of demographic data was also collected including age, gender, presence of children in the household and the postcode of residence. Residential postcode was used to determine the Socio-Economic Indices For Areas (SEIFA) to investigate the socio-demographic relationships (expressed as quartiles) with public opinion about water fluoridation.

There were 1,220 completed telephone interviews, and 70% of respondents supported water fluoridation of their local supply. There was lower agreement in the 55 year and older age group (63.6%) and higher agreement in the 35-44 year-old age group (77.0%). More than 71% of the total sample agreed that water fluoridation was safe. The lowest agreement was in the 18-34 age group (64.4%) and the highest in the 35-44 year age group (80.4%). The highest percentage of agreement about the effectiveness of fluoridation of drinking water in preventing tooth decay was in the 35-44 year age group with more than 80% agreeing. Logistical regression analysis for each question found that there was a significant association between the SEIFA quartile and response opinion. The top two quartiles were significantly more likely to agree with the statement relating to the support of adding fluoride to local drinking water than the lowest SEIFA quartile. The top two SEIFA quartiles were also significantly more likely to agree with the statement on safety than the lowest quartile. There were age and socioeconomic differences found on the question relating to the effectiveness of fluoride in the prevention of dental decay with 35-44 year olds (OR 1.78; 95% CI 1.15-2.76) and 45-54 year olds (OR: 1.50; 95% CI 1.01-2.22) being more likely to agree with the statement than 18-34 year olds. The two top SEIFA quartiles were more likely to agree with this statement than those in the lowest SEIFA.

There was general support found in this sample of the Queensland population for fluoridation, including its safety and its benefits in the prevention of dental decay. There were significant differences between SES categories for all of the questions asked, with the two highest SEIFA quartiles being more likely to agree with the statements relating to implementation, safety and effectiveness of water fluoridation than the lowest quartile. Those demographic groups that may benefit the most from water fluoridation are the least likely to favour it. Accurate, easy to understand scientific information about water fluoridation needs to be provided to those groups that may benefit the most from its implementation. This paper suggests that the addition of fluoride to public drinking water would be supported by most of the population 18 years and over in Queensland.

Gastroenteritis

Large outbreak of viral gastroenteritis caused by contaminated drinking water in Apulia, Italy, May-October 2006.

Martinelli D, Prato R, Chironna M et al. (2007) Eurosurveillance Weekly **12**(4); 19 April E070419 1.

An unusually high number of patients with acute diarrhoea were reported by the accident and emergency departments in Taranto, Apuila, Italy at the end of July 2006. A field investigation was conducted and included case ascertainment and descriptive epidemiology, microbiological investigation of stool samples and environmental samples and a case-control study. The outbreak investigation was conducted between July and October 2006 and included hospitals in the entire province of Taranto. A case was defined as a patient with diarrhoea (at least three loose or liquid stools in a day) and one or more of the following symptoms: fever greater than or equal to 38 degrees C, headache, vomiting, abdominal pain and nausea. Of the six hospitals in Taranto, five provided information on patients with acute gastroenteritis. Data was collected retrospectively between May and July and prospectively for August and September 2006. Cases were also reported by the special medical facilities set up for tourists in the summer season.

There were 2,860 patients with gastroenteritis symptoms from 1 May to 30 September 2006 which were either admitted to hospital or seen by the hospitals' outpatient accident and emergency units. For the same period in 2005 there were only 586 patents with gastroenteritis treated by the same hospitals. The first peak in incidence was seen at the end of June and the second peak at the end of July. By mid-September the number of cases per week was similar to that seen during the same period in 2005. The mean age of cases was 25 years. The highest incidence by town was in the city of Taranto with 9.5 cases per 1,000 inhabitants. There were 361 cases reported by the tourist medical facilities which was significantly more than a year before.

Stool samples were collected from patients and tested for gastrointestinal bacteria and parasites.

Environmental samples were collected and included: tap water from the water distribution system across the whole area affected by the outbreak, sea water and shellfish. The water samples were collected at the local waterworks from major water pipelines and wells, and from tap water in pubs.

A case-control study was conducted to see if there was an association between the occurrence of gastroenteritis and the exposure to one or more risk factors. The case group included 166 gastroenteritis patients treated at the accident and emergency departments of the hospitals in Taranto province between 1 August and 15 September 2006. The control group included 146 non-hospitalised healthy individuals who were resident in the same area as case patients during the study period. Cases were matched by age to controls. Study subjects were interviewed using a standard questionnaire.

Of the 70 stool samples, 34 (48%) were positive for rotavirus and 28 (40%) were positive for norovirus. Of the environmental samples of tap water collected in Taranto city, no faecal indicator bacteria or endotoxins were detected. Of the 44 samples tested, 4 (9%) were positive for norovirus and 11 (25%) for rotavirus. The molecular profiles identified in some tap water samples of rotavirus and norovirus were the same as the ones found in some patients' stool samples. Sequence analysis showed the new norovirus strain GGII.4 2006a and rotavirus genotype G9. Of the 12 sea water samples, four (33%) were positive for norovirus and one (8.3%) for rotavirus. None of the shell fish samples were positive for bacteria or viruses. The risk factors found to be significantly associated with the onset of acute diarrhoea/gastroenteritis were the use of tap water (OR = 2; 95% CI: 1.23-3.36) and the use of water of uncertain origin in the 72 hours before the onset of symptoms (OR = 3.9; 95% CI: 1.41-10.54).

The epidemiological investigation and the laboratory tests found that the possible source of infection was the drinkable tap water which was contaminated with at least rotaviruses and noroviruses. An extra chlorination treatment of household water supplies was performed starting from the 34th week of 2006 to stop possible contamination of the water. The systematic technical and microbiological investigations of the pipelines and wells of the water distribution systems did not show the source of contamination however technical problems at the local chlorination treatment facilities could not be excluded. This outbreak of viral gastroenteritis is probably the largest one to date associated with drinking tap water in Italy.

Household Interventions

The effectiveness of large household water storage tanks for protecting the quality of drinking water.
Graham JP and VanDerslice J. (2007) Journal of Water & Health, **5**(2); 307-13.

In El Paso County, Texas there are an estimated 3,500 people living in *colonias* (unincorporated neighbourhoods) who do not have piped water who have poor living conditions and substandard housing. Colonia residents either collect water themselves using available containers or rely on water delivery trucks to fill large open containers outside the home such as discarded 55-gallon drums. A project was conducted to improve the water supply available to households in colonias by providing a 2,500-gallon water storage tank to homes lacking piped water. The tanks were filled by a water delivery truck and pipes were connected to homes so that each household could have running water. The aims of this study were to: evaluate water quality from different drinking water sources used by colonia residents; to evaluate how the intervention (the installation of the large storage tanks) affected drinking water quality; and study how delivery of water affects the quality at various points during the transport of water.

Four contiguous communities of El Paso County, Texas were studied between September 1998 and December 1999 where funding was received to install 102 x 2,500-gallon water storage tanks. Interviews were conducted and data was gathered on water collection, use and storage practices. Data was collected before installation of the intervention, one month after the intervention and nine months after the intervention. Drinking water samples were analysed for residual chlorine, turbidity, total coliforms and *Escherichia coli*. A series of water

samples were collected between collection and delivery of water by the delivery trucks to examine changes in water quality. Samples were taken from the distribution standpipe where the tanker trucks fill up, the tanker truck once it arrived at the home, and the household's large storage tank before it was filled with water and after being filled.

Results of questionnaires and drinking water analysis were completed for 35 households before the intervention, 59 households one month after intervention and 34 households nine months after intervention. After the tanks were installed many of the households did not change the source of their drinking water to the large storage tanks. Therefore, the drinking water quality results were combined from the three collection times and compared on the basis of where the household's drinking water came from. There were 37 samples analysed from households that purchased their drinking water and stored it in a small container (29 from a vending machine and 8 from a store). All of the samples from stores were positive for total coliforms (38% greater than 10 CFU/100ml) and 59% of the samples from vending machines were positive for total coliforms (38% greater than 10 CFU/100ml). There were 43 samples from households that collected drinking water from a municipal supply and stored it in small containers (less than 10gal.). There were 26 (60%) of these samples from small containers that tested positive for total coliforms (35% greater than 10 CFU/100ml). There were 48 samples from households that received their drinking water from delivery trucks with 71% of these samples with total coliform levels greater than 10 CFU/100ml.

Data were compared from 35 households prior to installation of the water storage tanks and 34 households nine months after tank installation to compare pre-intervention and post-intervention drinking water quality. The percentage of samples with total coliforms was found to be higher for the samples collected at the 9-month follow-up visit and the geometric mean of total coliforms was also higher. The percentage of households with adequate free chlorine was equal for samples from baseline and the 9-month follow-up. There were 3 samples positive for *E. coli* prior to the intervention and one positive sample after the intervention. It was generally found that having adequate residual chlorine resulted in very low total coliform levels. The water quality during transport and delivery by tanker trucks was assessed and water quality generally worsened as the water was taken from the standpipe and delivered to the storage tank. There were 30% of samples taken immediately after water delivery to the home that had high total coliforms (more than 10 CFU/100ml). Mean free chlorine levels were found to drop from 0.43 mg/l, where the trucks filled their tanks, to 0.20 mg/l inside the household's tank immediately after delivery.

Education of families on safe water treatment and storage in the home, especially for homes not connected to a public water distribution system is recommended. The use of small-mouthed container should be promoted as they allow for easy fill-up and dispensing and prevent people from contaminating the drinking water during storage. It is recommended that households do not drink water directly from large water storage tanks unless chlorine levels are adequately maintained. Where water must be delivered in trucks, the amount of chlorine added to the water should be adjusted to a level that will protect the water quality during storage.

<u>NDMA</u>

Estimation of the total daily oral intake of NDMA attributable to drinking water.

Fristachi A and Rice G. (2007) Journal of Water & Health, **5**(3); 341-55.

Changes in US EPS regulations on disinfection by-products are causing some United States drinking water suppliers to switch from free-chlorine to alternative disinfectants such as chloramine. Chloramination may reduce total DBP levels however it may result in the formation of nitrosamines such as N-Nitrosodimethylamine (NDMA). Some early studies have indicated that chloramination may lead to higher levels of NDMA than chlorination. NDMA been classified as a probable human carcinogen. This paper estimates NDMA concentrations in drinking water and food and calculates the average daily dose (ADD) for

ingestion route exposures for the U.S. population. It also estimates the proportional oral intake (POI) of NDMA attributable to the ingestion of drinking water relative to that of NDMA present in food and formed endogenously in the human body. Three age groups were examined: bottle-fed infants (less than 6 months), children (6 months to 17 years) and adults (greater than or equal to 18 years). An exposure model was developed that used NDMA concentration point estimates for each source and parametric distributions of averaging times, exposure duration, intake rates and body weight under the assumption of independence of the parameters.

Food ingestion rates were developed for cereal, dairy, fish, meat, vegetables, beer, powered infant formula and foods high in nitrite and nitrate levels including beets, lettuce, spinach and pork. Drinking water ingestion rates were developed for adults and children and for infants (not accounting for water used to reconstitute powered formula) using mean and standard deviation values. NDMA concentrations in drinking water were estimated from a 2001-02 survey of 21 U.S. and Canadian drinking water treatment plants that reported a range of NDMA levels from below the minimum reporting level (MRL) of 6×10^{-4} micro g/L to 2.3×10^{-2} micro g/L. A point estimate for NDMA in reconstituted infant formula was calculated to be 8.3×10^{-2}micro g/L. The distribution of NDMA concentrations in meat, fish, diary, cereal and vegetables were based on results of European studies conducted between 1987 and 1992. Distributions of NDMA concentrations in beer were developed from values reported in two surveys of North American beers. NDMA concentrations from endogenous formation from the nitrosation of ingested secondary and tertiary amines were estimated from an in vitro study resulting in an estimation of 0.37 micro g NDMA formed endogenously per gram of nitrate/nitrite-rich food.

Bottle-fed infants were found to receive their largest NDMA exposure doses from powdered infant formation reconstituted with drinking water contributing 0.07 micro g/day or 98% of total intake. The largest source of NDMA intake for children (9.96 micro g/day) and adults (23.1 micro g/day) is predicted to be from endogenous formation, contributing 99% of total intake for both age groups. The next largest source of daily NDMA intake for children and adults on average was from meat (0.04 micro g/day), contributing 0.30% of total intake. A sensitivity analysis was performed to measure the potential importance of the model inputs to the variance of the ADD estimates. Results indicated that endogenous nitrosation contributed over 99% to the variance and dominated the overall uncertainty and obscured the contributions of other model parameters. Therefore endogenously formed NDMA was excluded from the final sensitivity analysis.

The estimated Lifetime average daily dose (LADD) of NDMA in drinking water over a 75 year lifespan was estimated at 7.3×10^{-7} micro/kg-day. This represented 0.02% to 0.003% of total LADD from all sources depending on whether *in vitro* or *in vivo* estimates of endogenous NDMA formation were used in models. Exogenous sources were found to contribute about 2.8% of total exposure, with the remainder due to endogenous production of NMDA. The results from this study suggest that the occurrence of NDMA in finished drinking water for the US population leads to low exposures relative to other ingestion route NDMA sources. The mean concentration of NDMA in drinking water would have to increase about 47-fold for the POI to reach 1% relative to all sources of NDMA included in the model studied here. The NDMA contribution from food is small however it is relatively high compared to NDMA in drinking water. The contribution of NDMA formed endogenously greatly increases the total NDMA encountered and reduces the contribution of contaminated drinking water ingestion to total NDMA exposure.

<u>Comment</u> *This study considered only ingested NDMA and thus excluded cigarette smoke which is a significant exposure route in smokers and others exposed to cigarette smoke. The authors note that their estimates are based on limited data but are largely consistent with an independent estimate of NDMA intake performed recently by WHO. NDMA is only one of many nitrosamine compounds that may be present in drinking water or food or produced by endogenous formation.*

Nitrate

Nitrate in drinking water and risk of death from colon cancer in Taiwan
Yang, C.Y., Wu, D.C. and Chang, C.C. (2007) Environment International, **33**(5); 649-53.

Nitrate in drinking water comes from a variety of natural and man-made sources. Several studies have shown a direct relationship between nitrate intake and endogenous formation of *N*-nitroso compounds (NOCs). Most of these NOC compounds are potent animal carcinogens. This study was undertaken to assess whether $N0_3$-N levels in drinking water correlates with colon cancer.

There were 322 municipalities in Taiwan examined in the study. Data on all deaths of Taiwan residents was obtained from 1999 through 2003. The case group included all eligible colon cancer deaths occurring in those between 50 and 69 years. The control group included all other deaths excluding those deaths associated with gastrointestinal disease. Control subjects were pair matched to cases by sex, year of birth and year of death. Information was obtained on $N0_3$-N levels in each municipality's treated drinking water supply. Four finished water samples were collected, one for each season. The municipality of residence for cases and controls, identified from death certificates was assumed to be their source of exposure to nitrate via drinking water.

The final data included 252 municipalities and 2234 colon cancer cases with complete records for 1999-2003. The mean $N0_3$-N level in drinking water of colon cancer cases was 0.43 mg/L (SD=0.44) and controls has a mean $N0_3$-N level 0.44 mg/L (SD=0.44). Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for colon cancer death were 0.98 (0.84-1.14) for the group with water $N0_3$-N levels between 0.23 and 0.45 mg/L and 0.98 (0.83-1.16) for the group with $N0_3$-N levels of 0.48 mg/L or more. The results of this study show no statistically significant association between $N0_3$-N levels in drinking water and risk of death from colon cancer. Future studies need more precise individual intake estimates of nitrate through food and water and need to control for personal risk factors such as physical activity and meat and fat consumption.

Comment *This ecological study was unable to assess whether people drank tap water or differed in other habits that may have affected cancer risks.*

Pesticides

Pesticides in surface drinking-water supplies of the northern Great Plains
Donald, D.B., Cessna, A.J., Sverko, E. and Glozier, N.E. (2007) Environmental Health Perspectives, **115**(8); 1183-91.

In the northern Great Plains of the United States and Canada, pesticides have been found in atmospheric samples, in surface and groundwater and in a variety of food products. Some studies have shown an association between environmental exposure to agricultural chemicals and a number of adverse health outcomes. In this study the potential for occurrence of pesticides in drinking water of residents of 15 rural communities in the northern Great Plans in Canada was assessed.

The drinking water reservoirs and water treatment plants associated with the 15 communities studied were in Manitoba, Saskatchewan and Alberta. Communities were selected where the source of drinking water in reservoirs was mainly from snowmelt and rainfall runoff from agricultural crop lands. Reservoir water samples were collected in 2003 every 2 weeks from early May through mid-August to coincide with the spring application of herbicides and organophosphorus insecticides. Water samples were also collected once before ice formation (October 2003), through the ice in mid-winter (January 2004) and after spring snowmelt runoff (April 2004 and 2005). Simultaneous reservoir and treated drinking water samples were collected in early July 2004 and 2005. Drinking water samples were collected after water treatment at the beginning of each distribution system where water was first accessed for drinking by the community.

Assays were carried out for 45 pesticides and degradation products during the study. Two

insecticides, 27 herbicides and two degradation products were detected in reservoirs used as sources for drinking water. Insecticides were detected infrequently and at concentrations less than 20 ng/L. There were 7 herbicides consistently present in water samples from the 15 drinking water reservoirs. There appeared to be no distinct geographic pattern of herbicide concentration, and detection rates were similar for all three provinces. For six herbicides, concentrations were significantly greater in July sampling than in early spring. Up to 15 herbicides were detected in single reservoir water samples.

On average, water treatment reduced herbicide concentrations in drinking water by 14-86% of those in reservoir water. After treatment there were still 3-15 herbicides remaining in potable water supplies at a combined concentration of less than 2,500 ng/L. Herbicide reduction was highly variable from one site to another and often from one year to another. There appeared to be no apparent differences in herbicide reduction for different water treatment procedures. The single facility with membrane filtration however had the highest average percent reduction for three of the five herbicides found in drinking water at that facility. Drinking water guidelines have been established for only seven of the herbicides commonly found in drinking water. The individual herbicide concentrations found here were mostly one to three orders of magnitude lower than established guidelines. Drinking water guidelines however have not been established for exposure to mixtures of pesticides. The toxicity of mixtures of pesticides in water may be different from the sum of the toxicities of the single compounds if synergistic effects occur.

Management practices could be implemented in small reservoirs to reduce concentrations of pesticides. This would require cooperation of the land owners who farm the catchments surrounding reservoirs. To reduce deposition of application drift to reservoirs, decreased aerial application of pesticides near drinking water reservoirs is required along with spraying when wind speeds are optimal and use of precision applicators. Concentrations in runoff to reservoirs could be reduced through use of pesticides with lower water solubility.

Public Perception

A qualitative exploration of the public perception of municipal drinking water.

Jones, A.Q., Dewey, C.E., Dore, K., Majowicz, S.E., McEwen, S.A., Waltner-Toews, D., Henson, S.J. and Mathews, E. (2007) Water Policy, **9**(4); 425-38.

In Canada and the USA use of alternative water sources including bottled water and water treatment devices is commonplace and sales continue to rise. In Canada there have been a number of epidemics of waterborne gastrointestinal illness and boil water advisories in recent years. Several studies have suggested that alternative water is being used as it has perceived improvements in sensory quality and safety over regular tap water. A more detailed understanding of alternative water use and the perceptions of municipal drinking water is needed. The purpose of this study was to explore the drinking water perceptions and self-described behaviour and needs of participants served by municipal water systems in the City of Hamilton, Ontario, Canada.

Three focus groups were conducted in September 2003 with English-speaking adult residents of the City of Hamilton who were supplied by a municipal system. Two focus groups were conducted with men and women between 36 and 65 years of age (n=7 for each group) and one with men and women between 20 and 35 years of age (n=6). The focus groups were moderated by a trained facilitator and gathered data regarding participant perceptions of water quality, alternative water sources and their self-identified need for information regarding drinking water.

Convenience was the most common reason cited for bottled water use, but some participants used bottled water as they considered it to be superior in taste and safety compared to regular tap water. Some of the participants were concerned that off-colours and odours of tap water were suggestive of problems with water safety. The use of water treatment devices was common and many participants perceived these devices to be safer than regular tap water. There was much discussion of the perceived benefits of treatment devices however only one participant mentioned the possible problems that can result with

water quality if these devices were not properly maintained. Participants reported that marketing influenced societal perception of tap water and consequently the use of alternative water sources. Negative effects on the perception of tap water by children were considered important. Some participants showed trust and support for water utility employees in the City of Hamilton however many in the wake of the Walkerton *E. coli* outbreak were suspicious and sceptical regarding the abilities and integrity of these employees and the safeguards in the system. Concerns about the municipal water system were wide ranging and included: source water protection, water treatment and testing and the distribution system.

Participants stated they were largely uninformed regarding municipal water testing and treatment and indicated a keen desire for more information regarding all aspects of water testing as well as the treatment process, its efficacy and what health hazards might remain after water treatment. The participants in the study were unaware that much of this information is currently available on the City of Hamilton's website. Participants required information in clear language without scientific jargon. Participants obtained information about drinking water using a variety of media including newspapers, flyers, television, radio and the internet.

This study provided a more in-depth understanding of participants' perceptions of drinking water in the City of Hamilton. There were some positive perceptions however there were wide-ranging concerns about the municipal water system and many reasons for alternative water use. The collection of valid and reliable information regarding the perceptions of drinking water is essential to the development of effective public educations programs, water utility strategic planning and drinking water policy. These focus groups demonstrated that some residents had serious concerns about tap water, and further research is needed to evaluate how representative these views are of the whole community.

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