Health Stream
INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS
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* Summaries of web bonus articles on these topics are contained in the PDF version of Health Stream on the WQRA website.

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## Hydraulic Fracturing and Water Supplies

The US EPA has delivered the first progress report for a research study on the potential impacts of hydraulic fracturing (commonly known as fracking) on drinking water resources (1). The study was initiated following a request from the US Congress in late 2009, and the final design was developed during an extensive consultation process with stakeholders and a series of technical workshops. The final report from the study is scheduled for delivery in 2014, but delays in establishing some components suggest that not all aspects will be completed by the due date.

Hydraulic fracturing is a process by which fractures are deliberately induced in underground oil or gas-bearing strata through a process involving pumping water-based fluids at high pressure into drilled wells. Sand is added to the fluid as a "proppant" to keep the fractures open when the pressure is relaxed. The network of fine fractures provides increased connection to the surrounding strata and enables recovery of a larger amount of oil or gas from the well. The process was developed in the US in the late 1940s and has been used worldwide to enhance production from "conventional" oil and gas wells since that time. Conventional oil and gas deposits are located in relatively permeable strata and most of the available fuel resource is accessible through the natural porosity of the geological formation. In this context fracking is generally used to enhance recovery as the yield begins to decline and the well approaches the end of its productive lifetime. Fracking may also be used in construction of drinking water wells under some circumstances.

Over the last two decades, advances in technology have permitted a much broader application of fracking to exploit "unconventional" oil and gas deposits. These deposits are located in relatively impermeable formations of shale, coalbeds or tight sands of variable depth and thickness. Many cannot be effectively exploited using traditional vertical wells as the low permeability means that only a small fraction of the resource is accessible from a single well. The ability to identify and accurately characterise such deposits has been increased by the development of modelling techniques using magnetic and seismic data which allow 3-dimensional mapping to depths of several thousand metres below ground level. In addition, technical advances in drilling methods have made it possible for wells to be drilled horizontally (after drilling an initial vertical shaft) or in an S-shape to increase access oil or gas resources in low permeability strata. The horizontal leg of a well can be extended up to 3,000 metres from the wellhead, and multiple horizontal wells can be drilled outwards from a single drilling stage.

After drilling and casing the well, fracking is performed by detonating small explosive charges at intervals along the horizontal section to create breaks in the casing. Fracking fluid containing proppant and other additives is then pumped down the well at high pressures, creating fractures in the surrounding strata around each break in the casing. About 15 to 30% of the fracking fluid returns to the surface (termed flowback water) and requires storage and disposal. Water from the underground deposits is also extracted from the well during gas production (termed produced water). The produced water commonly has high salinity and may also contain a range of contaminants released from the underground strata, potentially including arsenic, barium, hydrocarbons and naturally occurring radioactive elements. Fracking can be repeated several times during the lifetime of a well, with new fractures being created at different locations each time to provide access to more of the oil or gas deposit.

High oil prices in the 1990s provided a driver to exploit the large "unconventional" oil and gas deposits which exist in many countries. In the US, expanded use of these resources was also spurred by concerns about energy security and heavy dependence on supplies from politically turbulent areas of the world. As a result, production of natural gas from unconventional sources rose from 28% to 50% of total US natural gas production between 1998 and 2008. This increase was initially based on gradual development of coalbed and tight sand gas resources, but since 2005 there has been a very rapid increase in production of natural gas from shale deposits. While the basic principles of the fracking process have remained the same since the 1940s, modern fracking practices involve use of a larger range of chemical additives in fracking fluid, much higher pressures and often greater drilling depths than used in the past. Shale beds are generally located at greater depths than coalbeds, and thus require more extensive drilling, use of higher pressures to create fractures and larger volumes of fracking fluid. For shale gas drilling, each drill head and pad typically requires 2-4 hectares (5-10 acres) of land and 19 ML (5 million gallons) of water for each round of fracking. Delivery of construction materials and sufficient proppant, water and chemicals for one round of fracking has been estimated to require over 1600 truckloads per well, with a further 750 truckloads needed to remove the liquefied natural gas and fracking wastewater.

The rapid expansion of the shale gas industry in the US and the use of fracking technology have raised many public concerns, including disquiet over impacts on the quality and quantity of water supplies and potential environmental or human health impacts of exposure to chemicals used in the fracking process or released from underground strata. A number of rural communities have experienced adverse effects on infrastructure and local amenity values from intensive drilling developments in previously quiet farmland and low density residential areas. On the other hand, some individuals, communities and state governments have welcomed the financial benefits of the shale gas boom at a time of high unemployment and decreased activity in the US economy. The issue has also divided the environmental movement, with some groups supporting shale gas development because the resultant natural gas (predominantly methane) produces less greenhouse gases than coal or oil when burned to generate electricity, while others

oppose substitution of one type of fossil fuel for another, arguing it will further delay the eventual changeover to cleaner alternatives.

Public concerns have been exacerbated by the provisions in the US federal Energy Policy Act of 2005 which exempted chemicals used in oil, gas or geothermal energy production activities from requirements in the underground injection control program of the Safe Drinking Water Act. Exemptions are also present in six other federal regulations relating to environmental pollution, remediation and disclosure requirements. Although some information is available on the content of fracking fluids, it is common for companies to withhold information relating to proprietary additives. Among the chemicals which have been identified, a number have toxic properties and could potentially be harmful to human or environmental health, depending on exposure levels. There have been a number of reports of drinking water contamination in areas where fracking is occurring, but the industry has consistently denied any links to fracking activities, saying the separation of the deep shale layer from shallow groundwater aquifers makes it impossible for fractures to penetrate to the aquifer. To date there has been little peer reviewed research on water quality and quantity impacts, or on human or environmental health effects related to fracking (2).

The five questions to be addressed by the EPA research study and potential drinking water issues related to each aspect are as follows:

Water Acquisition: What are the potential impacts of large volume water withdrawals from ground and surface waters on drinking water resources?

- water availability
- impact of large volume withdrawals on water quality

Chemical Mixing: What are the possible impacts of surface spills on or near well pads of hydraulic fracturing fluids on drinking water resources?

- release to surface and ground water (*e.g.* on-site spills and/or leaks, chemical transportation accidents

Well Injection: What are the possible impacts of the injection and fracturing process on drinking water resources?

- accidental release to ground or surface water (*e.g.* well malfunction)
- fracturing fluid migration into drinking water aquifers
- formation fluid migration into drinking water aquifers, mobilisation of subsurface formation materials into aquifers)

Flowback and Produced Water: What are the possible impacts of surface spills on or near well pads of flowback and produced water on drinking water resources?

- release to surface and ground water
- leakage from onsite storage into drinking water resources
- improper pit construction, maintenance and/or closure

Wastewater Treatment and Waste Disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?

- surface and/or subsurface discharge into surface and groundwater
- incomplete treatment of wastewater and solid residuals
- waste water transportation accidents

The EPA research study has been broken down into several separate components:

Analysis of existing data – this part of the study involves collection of data on use of fracking chemicals, well construction and operating practices. The information is being drawn from a recently established voluntary national disclosure database, and more detailed data on 333 wells has been provided by nine hydraulic fracturing companies. These companies include large, medium and small operators, and the wells have been selected to provide a geographically diverse but representative sample of US wells which were hydraulically fractured between September 2009 and October 2010. Information on spills of fracking fluid and wastewater is also being extracted from state and national databases, and an evaluation of peer-reviewed publications and data is being undertaken.

Scenario evaluations – potential impacts on water resources are being evaluated by computer modelling of a range of realistic scenarios relevant to each stage of the hydraulic fracturing water lifecycle. Two climatic scenarios are being examined to estimate impacts of large volume water use on drinking water resources in semi-arid and humid river basins. The potential for migration of gas and fluid from deep shale deposits to overlying aquifers is also being assessed by modelling of six different scenarios. The factors being considered include poor well construction, and the potential for hydraulic communication via natural and induced fractures and existing unplugged wells in proximity to the fractured well. Surface water transport models are also being used to estimate the impact of specific contaminants (bromide and radium) in treated fracking wastewater discharges on downstream drinking water supplies.

Laboratory studies – these studies will be used to examine the effectiveness of wastewater treatment processes for removal of selected contaminants in fracking wastewater, and whether the presence of this type of wastewater in drinking water sources influences the formation of disinfection byproducts (particularly brominated species) during subsequent drinking water treatment. Sampling at multiple sites in two river systems in Pennsylvania is also being carried out to determine the extent to which discharge of treated fracking wastewater is currently contributing to chloride and bromide levels in downstream drinking water supplies. This area of the research study also incorporates the testing, modification and verification of analytical methods for several classes of target analytes.

Toxicity assessments – the EPA has identified more than 1000 chemicals reportedly used in fracking fluids and/or present in flowback or produced water. Information about the chemical, physical and toxicological properties of these chemicals is being compiled from various databases and other information sources. For chemicals which have not been previously characterised, toxicity will be estimated by quantitative structure-toxicity modelling. To date, chemical structures have been assigned to 751 chemicals and Chemical Abstracts Service Registry Numbers to 746 of these.

Case studies – five study sites where fracking operations are already occurring have been selected for water quality testing of domestic water wells, monitoring wells and surface water supplies. One site (in Colorado) has been subjected to fracking for coalbed gas, and three for shale gas (two in Pennsylvania and one in Texas). The fifth site (in North Dakota) experienced a well blowout during the fracking process for shale oil. Two rounds of water sampling have been completed at these sites, with at least one more round of sampling still to be performed. Samples are being analysed for a range of parameters including standard physico-chemical properties, major anions, components from fracking fluids, volatile organic compounds, substances potentially mobilised from natural sources including metals, and radioactivity. Stable isotope analysis is also being used to determine the probable origin of some contaminants.

In addition, it is planned to conduct a prospective assessment of two sites where fracking will soon be commenced. This will allow the collection of baseline data on water quality before any fracking operations occur and thus will enable discrimination between any contamination due to existing conditions (for example, abandoned unsealed well or natural geological conditions) and new contamination from fracking activity. Monitoring will be continued for 12 months after fracking commences. Seven possible sites for the prospective study were nominated during stakeholder consultations, but the two sites for this study have not yet been selected. The delay in commencing this important component of the project means that the planned one year water quality monitoring program is unlikely to be completed by the scheduled finish date for the entire study.

The current US EPA study will not specifically address human health impacts, but it is expected that some of the information collected for the study will facilitate future toxicological exposure modelling and risk assessment. The EPA has also acknowledged the need for further research on a number of issues raised during the stakeholder consultation process but

deemed outside the scope of the current study. These include the effects on air quality from off-gassing of methane and diesel exhaust emissions from trucks and mining machinery, the impacts of solid or liquid waste disposal from fracking processes, impacts on terrestrial or aquatic ecosystems, seismic risks, occupational health risks to workers, public safety risks from well blowouts or major transport spillages, increased sand mining to supply proppant, and the economic impacts on local communities.

In a separate initiative, several US universities have organised a working group to develop joint project proposals examining health issues relating to fracking. The initiative is led by the Center of Excellence in Environmental Toxicology at the University of Pennsylvania. Ten of the seventeen centers affiliated with the US National Institute of Environmental Health Sciences have so far agreed to collaborate in the research program, although funding has yet to be secured for individual projects. The research is likely to include a range of studies including analysis of records from health registries and data from medical insurance companies, as well as surveys of self-reported health status of residents in affected areas.

In Australia, fracking has been used for natural gas production for about 40 years, but it is only relatively recently that rapid expansion of coalbed gas mining in Queensland and New South Wales has drawn public attention and protests from landholders and others. The coalbed reserves in eastern states of Australia are relatively shallow and permeable, and it is estimated that about 50% of wells can be harvested without the need for fracking during their lifetime. Individual well heads are smaller than for shale gas harvesting, and the fracking water needed per well is less because of the shallower depth. However, wellheads are typically located less than 1 kilometre apart with a connecting network of access roads and pipes carrying harvested gas and wastewater to processing facilities. This type of development effectively prevents agricultural use of a significant area of land. In addition, large quantities of the groundwater within coal beds are removed as the gas is harvested, and disposal of this saline and contaminated wastewater presents similar problems to shale gas mining. Most of the current and planned development of coalseam gas is located in productive agricultural land overlying the Great Artesian Basin, and alarm has been raised about the long term consequences for one of Australia's most important water resources. As in the US, many Australian commentators are urging a more cautious approach to further development to ensure that adverse environmental impacts and potential human health impacts are better understood and managed (3).

(1) Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. http://www2.epa.gov/hydraulicfracturing

(2) Rigorous evidence slim for determining health risks from natural gas fracking. Mitka M. JAMA, (2012) 307(**20**) p2135-2136.

(3) Coal seam gas – Toward a risk management framework for a novel intervention. Randall A. Environmental and Planning Law Journal (2012) **29**(2) p152-162.

## Extreme Weather and Waterborne Outbreaks

A systematic review of waterborne outbreaks linked with extreme weather events has identified 87 reports from the conventional scientific literature and 235 reports from the archives of ProMED-Mail (1, 2). The review included reports of human disease (excluding displaced populations) related to extreme weather events where the outbreak was described as waterborne by the author or attributed to a pathogen transmitted solely through water. It was conducted by UK researchers who used detailed keyword terms to search four major medical and meteorological databases and ProMED. In addition, a search was made using a popular internet search engine, reference lists of identified reports were examined and hand-searches of several relevant water journals were conducted. Identified reports for events occurring between 1910 and 2010 were screened against pre-defined inclusion/ exclusion criteria, and key information was extracted in a structured format.

Both scientific articles and official publications (e.g. investigative reports) were eligible, but news articles were excluded. For each article, the quality of evidence linking the waterborne outbreak to an extreme weather event was classified as direct (strong evidence of causality), moderate (strong

circumstantial evidence but careful interpretation required) or indirect (not sufficient evidence for causal inference).

The scientific literature search yielded 79 English language papers and four papers in other languages. These included reports of individual outbreaks, as well as review and analytical papers examining the causes of outbreaks and linkages to extreme weather events or climate change. Overall, 87 different waterborne outbreaks in 29 countries fitting the inclusion criteria were identified in these publications. The 235 identified reports from the ProMED archive covered 304 events in 66 different countries. The majority of extreme weather-related outbreaks reported in the scientific literature occurred in North America, followed by Asia and Europe. In contrast, over 40% of the outbreaks identified from ProMed reports related to Africa.

Causative pathogens were identified in a high proportion of reports from both sources (85.1% of conventional literature reports and 89.8% of ProMED reports). *Vibrio cholerae* was the most frequently identified pathogen, accounting for 27.0% of outbreaks with identified pathogen reported in the scientific literature and 64.9% of outbreaks with identified pathogen reported in ProMED. The second most frequently reported pathogen was *Leptospira* spp., which occurred in 17.6% of outbreaks reported in the scientific literature and 17.1% of outbreaks identified through ProMED reports.

For both sets of data (scientific literature and ProMED reports), flooding and heavy rainfall were the most commonly reported events associated with waterborne outbreaks. Flooding was reported in over 50% of events in both data sets, and heavy rainfall in over 50% of literature outbreaks and nearly 40% of ProMED outbreaks. Not surprisingly, flooding and heavy rainfall frequently occurred together. Among those literature reports from developed countries which provided information on routes of exposure (27 outbreaks), the majority of outbreaks were attributed to contamination of drinking water supplies, with 22.2% attributed to environmental exposures (e.g. contact with flood waters). Among 98 outbreaks identified from ProMED reports with information on causes of disease, contamination of drinking water supplies was most common (32.9%), followed by a shortage of clean drinking water (18.9%), and poor sanitation and hygiene after the extreme weather event (14.7%). Different methods of estimating outbreak case numbers were used in different publications, including laboratory confirmed cases, self-reported diagnosis, clinical diagnosis or estimates made by unspecified means. As would be expected, laboratory diagnosis produced much lower estimates of outbreak size (less than 200 cases) than other methods (estimates as high as 400,000 cases per outbreak).

The authors note that this review has a number of limitations relating to the ability to identify relevant publications for inclusion and the information content of the publications. Although the keyword lists and search combinations were extensive, over 20% of the included papers were not found by the initial searches, but rather by examining the reference lists of publications that were identified by the searches. Initial evaluation of publications for inclusion was limited to the title, keywords and abstract (if available), so those which mentioned an extreme water-related weather event only in the main text may have been missed. Many of the identified papers and reports lacked detail, and classification of the strength of evidence linking a given waterborne outbreak to an extreme weather event was difficult. As result only 8 of the 83 scientific publications were judged as providing “direct” evidence, while 48 were rated as “moderate” and 27 were rated as “indirect”. Few reports provided information on water quality parameters or amounts of precipitation linked to outbreaks, and details of the affected population and routes of disease transmission were often scant or missing. The authors comment that building a better understanding of how extreme weather events impact on waterborne outbreak risks will require more comprehensive reporting of these events.

Comparison of the two data sources (scientific literature and ProMED archive) showed clear differences not only in the geographic distribution of reported events, but also in the types of associated weather events. For example, waterborne disease outbreaks linked to drought or ENSO (El Nino

Southern Oscillation) events were commonly reported in ProMED and these weather events are also more common in developing countries. On the other hand, hurricane-related outbreaks were more commonly reported in the conventional scientific literature with over 40% of these reports originating from the USA. In developed countries the greater availability of resources for disaster response reduces the risk of extreme event-related waterborne outbreaks, but these countries also have more resources for surveillance and academic analysis, leading to a higher probability of scientific publications when outbreaks occur.

The authors conclude that despite the limitations of this review and the underlying literature on which it is based, it is evident that waterborne outbreaks related to extreme weather events are occurring in both developed and developing nations. As climate change models predict an increasing frequency and intensity of such events, better reporting and analysis is important to improve understanding and facilitate future efforts to mitigate these risks.

(1) Extreme water-related weather events and waterborne disease. K. Cann, D RH Thomas, RL Salmon, AP Wyn-Jones and D Kay. Epidemiology and Infection (2013), **141**, 671–686. doi:10.1017/S0950268812001653

(2) Program for Monitoring Emerging Diseases. ProMED-Mail is a moderated email list and archive operated by the International Society for Infectious Diseases. It provides rapid worldwide dissemination of information and expert comment on outbreaks of infectious diseases and acute exposures to toxins that affect human health. http://www.promedmail.org/

## Animal Waste, Water Quality and Human Health

A new publication by the World Health Organisation has drawn together current knowledge on the impacts of pathogens in animal faecal wastes on health risks from drinking water and recreational water. Both mammals and birds can carry a range of pathogens which are potentially infectious to humans, and it has been estimated that domesticated animals contributes about six times more by weight to total annual faecal pollution than human waste. In addition animal waste is seldom subject treatment or disinfection before entering receiving waters.

A ranking system was used to assess the importance of zoonotic pathogens in relation to waterborne disease. In this context "zoonotic" is used to describe the situation where the same or closely related pathogen genotypes are found in animal and human infections. Four priority groups were defined on the basis of several criteria. Pathogens ranking in the first group were defined as those where water had been demonstrated as a significant route of exposure, disease outbreaks affect healthy individuals and infection may result in serious illness or death, the pathogen is global or nearly global in distribution or there is evidence of increasing geographic spread, and the pathogen is resistant to water treatment processes (including disinfection) or other remediation efforts. Second ranking pathogens fulfil all these criteria except they are susceptible to water treatment, while third ranking pathogens are more geographically restricted or exposure is limited to specific occupational groups. Fourth ranking pathogens are those where waterborne transmission appears to be rare or not adequately documented.

Based on current evidence, *Cryptosporidium*, *Giardia*, *Campylobacter*, *Salmonella* and *E. coli* O157 appear to the most significant zoonotic pathogens worldwide. It is believed that efforts to control these organisms will probably reduce the risks from less well characterised or as yet unrecognised zoonotic pathogens. Options for managing zoonotic disease risks are discussed, including reducing carriage rates in animals, control of direct livestock access to water bodies, better on farm management of animal waste, controlling environmental transport of pathogens into waterways, and reducing human exposure through management of recreational water access. These efforts need to be supported by research to improve understanding of the significance of zoonotic pathogens, such as source identification methods. It is feasible that some control measures may improve animal health and productivity. Better modelling and economic analysis is also needed to determine the costs and benefits of interventions, as well as their effectiveness in improving water quality and reducing health risks.

Animal Waste, Water Quality and Human Health (2012) www.who.int/water_sanitation_health/publications/2012/animal_waste/en/

# News Items

### Food Processing During a Crypto Outbreak

Researchers have published the results of food safety assessments on cured meat products (ham) that were processed in the Swedish town of Östersund during a major waterborne *Cryptosporidium* outbreak. Eleven surface samples from two meat products exposed to contaminated tap water during the outbreak were tested, and one putative oocyst was detected in one sample by the immunofluorescent antibody test. However, the putative oocyst was deformed and no visible internal structures were detected by DAPI staining or Nomarksi microscopy, suggesting it was unlikely to be infective. Based on this information and calculations on the theoretical probability of ingesting an oocyst assuming a concentration of 50 oocysts per 1,000 litres in tap water used for food processing, it was concluded that the products were safe to release to market.

Analysis of Cured Meat Products for Cryptosporidium Oocysts following Possible Contamination during an Extensive Waterborne Outbreak of Cryptosporidiosis. Robertson LJ and Huang Q. (2012) Journal of Food Protection **75**(5): 982–988.

### 2013 Water and Health Conference: Where Science Meets Policy

The themes for the 2013 Water and Health Conference, hosted by the Water Institute at the University of North Carolina, are:

· Hygiene and behavioural change
· M&E: local, global and human right perspectives
· Institutions, finance and sustainability
· Sanitation and health
· Water supply and quality: from catchment to consumer and back

The conference will be held from October 14 -18 in Chapel Hill, North Carolina, USA. Abstracts for poster and verbal presentations may be submitted via the conference website until April 30. Proposals for side events, such as meetings, workshops, networking sessions, training courses or open forums, are also open until 30 April.

http://whconference.unc.edu/

### Global WASH Goals, Targets and Indicators

The World Health Organisation and the United Nations Children's Fund recently held a second stakeholder consultation meeting development of water, sanitation and hygiene goals and targets for the post-2015 period, along with indicators by which progress can be measured.

While substantial advances in access to safe water, improved sanitation and hygiene have been made under the current Millenium Development Goals, it is acknowledged that discrimination and inequities in access exist in most countries. While some information is available on income levels, this is not a sufficient measure to describe disadvantaged groups who may be most impacted by lack of access to WASH improvements. For this reason, the post-2015 WHO assessment framework will incorporate new measures of equity and non-discrimination. This will require modifications to data collection mechanisms, use of more data sources and analysis of vulnerable subgroups within populations rather than simple assessment of "average" progress towards national goals. It is hoped that this will influence political policies and help to improve the situation of the most disadvantaged groups within communities. The new framework will also be expanded to include consideration of water, sanitation and hygiene at "extra-household" locations, particularly schools and health facilities.

http://www.wssinfo.org/post-2015-monitoring/overview/

### Urban Water Security Research Alliance Ends

The Queensland-based Urban Water Security Research Alliance came to an end on 28 February this year at the conclusion of its 5 year funding term. The Alliance included three research organisations (CSIRO, the University of Queensland and Griffith University) and was funded by the Queensland state government to address urban water issues in south east Queensland. During its lifespan, the Alliance undertook 23 projects spanning a range of topics including source control, pathogens in reservoirs, stormwater harvesting, rainwater tank management, advanced water treatment, total water cycle management, the water-energy nexus, and climate variability and future water security. The Alliance website will be maintained until 2017, with final project reports being added to the publication archive over the next few months.

http://www.urbanwateralliance.org.au/index.html

# From the Literature

### *Web-bonus articles*

Summaries of these additional articles are available in the PDF version of Health Stream on the WQRA web page:

**www.wqra.com.au**

**Silicon-rich mineral water as a non-invasive test of the 'aluminum hypothesis' in Alzheimer's disease.**
Davenward S, Bentham P, Wright J, Crome P, Job D, Polwart A and Exley C. (2013) Journal of Alzheimer's Disease, **33**(2); 423-430.

**Amoeba-related health risk in drinking water systems: Could monitoring of amoebae be a complementary approach to current quality control strategies?**
Codony F, Pérez L M, Adrados B, Agust G, Fittipaldi M and Morat J. (2012) Future Microbiology, **7**(1); 25-31.

**Arsenic levels in drinking water and mortality of liver cancer in Taiwan.**
Lin HJ, Sung TI, Chen CY and Guo HR. (2013) Journal of Hazardous Materials, http://dx.doi.org/10.1016 /j.jhazmat.2012.12.049

**Pentachlorophenol contamination of private drinking water from treated utility poles.**
Karlsson L, Cragin L, Center G, Giguere C, Comstock J, Boccuzzo L and Sumner A. (2013) American Journal of Public Health, **103**(2); 276-277.

**Detection of Vibrio cholerae in environmental waters including drinking water reservoirs of Azerbaijan.**
Rashid A, Haley B J, Rajabov M, Ahmadova S, Gurbanov S, Colwell RR and Huq A. (2013) Environmental Microbiology Reports, **5**(1); 30-38.

**Risk of congenital anomalies in relation to the uptake of trihalomethane from drinking water during pregnancy.**
Grazuleviciene R, Kapustinskiene V, Vencloviene J, Buinauskiene J and Nieuwenhuijsen MJ. (2013) Occupational and Environmental Medicine, doi:10.1136/ oemed-2012-101093

**A time series study of gastroenteritis and tap water quality in the Nantes area, France, 2002-2007.**
Beaudeau P, Zeghnoun A, Corso M, Lefranc A and Rambaud L (2013) Journal of Exposure Science and Environmental Epidemiology, doi:10.1038/jes.2013.5

**High resolution mapping of reticulated water fluoride in Western Australia: Opportunities to improve oral health.**
Al-Bloushi NS, Trolio R, Kruger E and Tennant M. (2012) Australian Dental Journal, **57**(4); 504-510.

**Promoting Household Water Treatment through Women's Self Help Groups in Rural India: Assessing Impact on Drinking Water Quality and Equity.**
Freeman MC, Trinies V, Boisson S, Mak G and Clasen T. (2012) PloS one, **7**(9); e44068.

**Studies on water purification using clay and organic waste products.**
Sharma P and Godbole S. (2012) Journal of Pure and Applied Microbiology, **6**(1); 297-302.

Amoebae

**Polymerase chain reaction detection of potentially pathogenic free-living amoebae in dental units.**
Leduc A, Gravel S, *et al.* (2012) Canadian Journal of Microbiology, **58**(7); 884-886.

This study investigated the presence of potentially pathogenic free living amoebae (FLA) in dental unit water lines (DUWL) using molecular biology techniques. There were 28 randomly selected dental units at the dentistry clinic of Université de Montreal sampled from 21-31 March, 2011. Water samples (10 mL) were collected from DUWLs. The 10 proximal centimetres of the suction lines were swabbed and vortexed in Page's saline. The disposable suction filters were hydrated in Page's saline, vortexed and centrifuged. Five cold water taps in the dental clinic and one water fountain were also sampled (10 mL) as controls. The samples were centrifuged for 15 min and the pellets stored at -80 ºC until used for DNA extractions. Polymerase chain reaction (PCR) was performed on DNA extracts to detect FLA.

Of the 66 samples, 17 (25.8%) were positive for FLA, the majority (15/17) were suction filter samples. *Acanthamoeba* spp. were detected in 16 samples, 9 were from the suction filters, while *Naegleria* spp. were detected only in suction filter samples. Suction filters were much more likely to be positive for FLA (75%), *Acanthamoeba* spp. (45%) and *Naegleria* spp. (10%) than water samples. None of the water samples from the taps and fountains adjacent to the dental units tested positive.

Amoebae from the tap water supplying dental units may grow to high densities in biofilms within DUWLs. Dental treatment of patients may present a risk of infection from opportunistic pathogens as high-speed drills, air and (or) water syringes and ultrasonic scalers all create aerosols, and water is sometimes used to rinse open wounds. Preventive actions to reduce infection risks are needed, including flushing the water lines for 2 minutes every morning and encouraging patients to wear protective goggles during procedures. Suction lines and filters should be rinsed with water between patients and should be disinfected daily.

Arsenic

**Arsenic reduction in drinking water and improvement in skin lesions: A follow-up study in Bangladesh.**
Seow WJ, Pan W-C, *et al.* (2012) Environmental Health Perspectives, **120**(12); 1733-1738.

Skin lesions are associated with chronic arsenic exposure and are usually the first evident sign of arsenic toxicity. The incidence of such lesions is correlated with levels of arsenic exposure, but few studies have examined whether skin lesions improve if arsenic exposure is reduced. This follow-up study was conducted in Bangladesh among participants who had skin lesions at baseline to determine whether change in arsenic exposure was associated with the prevalence and severity of skin lesions.

In 2001-2003 (baseline), there were 900 individuals enrolled in a case-control study who were diagnosed with arsenic-related skin lesions and 900 age- and sex-matched controls in Pabna, Bangladesh. This follow-up study of 550 cases from the original study was conducted during 2009-2011. At follow-up, all participants underwent a physical examination, and assessment of skin lesion status. Interviewers administered questionnaires to collect socio-demographic information, drinking water history, medical history, lifestyle factors, dietary information, water consumption and residential history including identification of the primary water source (tube well), years of use, and use of previous tube wells. Water samples were collected from each participant's primary drinking source and arsenic concentration was analysed. Nail clippings were collected from each participant and total arsenic was measured. Logistic regression and generalised estimating equation (GEE) models were used to evaluate the association between $\log_{10}$ transformed arsenic exposure and skin lesion persistence and severity.

At follow-up, 65 participants had no skin lesions identified (recovered cases), whereas 485 participants still had skin lesions (persistent cases). Overall, drinking water arsenic concentrations declined significantly in the follow-up study population (125 ± 227 µg/L compared with 213 ± 302 µg/L at baseline; $p < 0.001$). Among the recovered cases, drinking water arsenic concentrations declined on average by 70.5%, from a mean of 105.4 µg/L in 2001 to 31.1 µg/L in 2009; in persistent cases however there was a mean reduction of only 43.4% from 221.6 µg/L in 2001 to 125.4 µg/L in 2009. A significantly lower proportion of recovered cases were exposed to ≥ 50 µg/L water arsenic at follow-up compared with persistent cases (13.8% vs 32.8%). Toenail arsenic levels were significantly reduced in recovered cases but not in persistent cases.

Using logistic regression, for every $\log_{10}$ unit decrease in water arsenic, there was a 1.22 times increase in odds of skin lesion recovery [odds ratio (OR) = 1.22; 95% CI: 0.85, 1.78], and for every $\log_{10}$ unit decrease in toenail arsenic, there was a significant 4.49 times increase in odds of skin lesion recovery (OR = 4.49; 95% CI: 1.94, 11.1), after adjusting for age, sex, education, smoking status, betel nut chewing, BMI and baseline arsenic. Analysis with GEE models showed similar results. A reduction in arsenic exposure was found to be associated with increasing odds of recovery from skin lesion and with reduced severity of persistent lesions at follow-up. Longer follow-up is required to assess whether the risks of cancers and other arsenic-related diseases that have longer latency periods have also been reduced.

Chemical Contamination

**Reducing Drinking Water Supply Chemical Contamination: Risks from Underground Storage Tanks.**
Enander RT, Hanumara RC*, et al*. (2012) Risk Analysis, **32**(12); 2182-2197.

Drinking water supplies are at risk from contamination from a variety of sources including release of hazardous materials from leaking or improperly managed underground storage tanks (UST) located at municipal, commercial and industrial facilities. To reduce the risk to human health and the risks to the environment associated with the subsurface storage of hazardous materials, US government agencies have undertaken a variety of legislative and regulatory actions over the past 25

years. These include the establishment of rigorous equipment/technology/operational requirements and facility-by-facility inspection and enforcement programs. A number of states, however, either do not have sufficient in-house inspection resources to meet this requirement or are meeting the mandate at significant cost. In 2006, the State of Rhode Island Department of Environmental Management (DEM) received a State Innovation Grant from the U.S. Environmental Protection Agency's (EPA) National Center for Environmental Innovation to help address this issue. The objective of this three-year study was to evaluate an alternative UST inspection model and determine if it might be a cost-effective alternative to traditional facility-by-facility inspection and enforcement programs.

The study utilised a four-component model which consisted of regulatory assistance, compliance certification using standardised checklists, independent agency inspections and statistically-based performance measurement. Randomised field inspections of a representative sample of facilities were conducted by the agency staff to establish baseline compliance rates before any state-led intervention was launched. A detailed plain-English regulatory guidebook and self-audit checklist package were then mailed to each facility owner/operator in the regulated universe. Facilities were provided a defined time interval to conduct comprehensive self-evaluations, complete audit checklist s and return all certified results to the state – while agency technical expertise and training were provided. At the end of the self-audit period, an additional set of comprehensive, randomised agency field inspections were conducted to assess whether compliance performance improvements occurred. Criteria established by regulation and beyond compliance measures were then quantitatively assessed using objective onsite field inspection data and accepted statistical techniques.

There were 96 randomised baseline facility inspections in 2004 and 93 post-intervention facility inspections undertaken in 2007/08. By applying the ERP methodology, 2004 baseline levels of compliance performance for the 41 measurable indicators were found to range from 0% to 95%, with a median of 76%. The change or observed improvement in compliance among the post-intervention facilities for the 41 measureable indicators was found to range from 22% to 100%, with a median of 85%. The improvements in compliance performance post-EPR intervention were statistically significant. Improvements over time were observed in both categorical (for tank corrosion protection, piping leak detection, spill prevention and overfill protection and groundwater monitoring wells and tank pad observation wells) and individual compliance inspection checklist indicator performance. Modelling of costs under different scenarios indicated that the ERP approach was less costly than the more labour-intensive facility-by-facility inspection and enforcement approach. It also had the potential to allow regulatory agencies to decrease their frequency of inspections among low risk facilities without sacrificing compliance performance or increasing the risk to public health.

Disinfection Byproducts

**Bioanalytical assessment of the formation of disinfection byproducts in a drinking water treatment plant.**
Neale PA, Antony A, *et al*. (2012) Environmental Science and Technology, **46**(18); 10317-10325.

The aim of this study was to assess the formation of disinfection byproducts (DBPs) and associated mixture effects at each step of the water treatment train of a full-scale drinking water treatment plant (WTP) using four *in vitro* bioassays for general cytotoxicity and three bioassays for reactive toxicity. In addition, chemical analyses were carried out for halogen-specific absorbable organic halogen (AOX), organic matter characterisation, and measurement of selected DBPs.

Samples were collected on 3 occasions over a 6 month period from a full-scale WTP in South East Queensland. The plant had two parallel treatment trains, the first consisted of coagulation, sand filtration, chlorination and chloramination (East Bank) and the second train consisted of coagulation, dissolved air flotation, sand filtration, chlorination and chloramination (West Bank). There were several

disinfection points along the treatment train. Dissolved organic carbon (DOC) and concentrations of halogen-specific AOXs ($Cl^-$, $Br^-$ and $I^-$) were measured in the water samples. A range of DBPs, including trihalomethanes (THMs), haloketones (HKs), halonitromethanes (HNMs), haloacetonitriles (HANs) and chloral hydrate (CH) were measured in the samples collected in May 2011.

The quality of the water feeding the WTP was relatively high, and negligible effects were observed in the bioassays, even though organic matter content was elevated. Both nonspecific and reactive toxicity increased with the addition of chlorine before the sand filtration step, suggesting that the observed toxicity was due to the formation of DBPs from the reaction of chlorine with organic and inorganic materials. Halogen-specific AOXs and analysis of individual DBPs confirmed the formation of potentially toxic DBPs. The concentrations of halogen-specific AOXs and DBPs continued to increase throughout the treatment train and the highest concentrations were found in the outlet after chloramination. However, nonspecific and reactive toxicity decreased slightly after storage, possibly suggesting loss of volatile DBPs or further reaction of DBPs to less toxic derivatives over time.

While, overall the general AOX formation and toxicity patterns were similar for all sampling campaigns, the total AOX concentration, absorbable organic bromide (AOBr) to absorbable organic chloride (AOCI) ratio (AOBr/AOCI) and toxic effect varied between the different sampling events. The variations seen in DBP formation were probably related to the source water characteristics as all water treatment processes were consistent for all three sampling campaigns. Maximum levels of nonspecific toxicity, genotoxicity and induction of oxidation stress responses were seen in the middle of the water treatment train.

The effects measured by bioassays in this study cannot be directly translated to adverse health outcomes, however bioanalytical tools can provide information on the mixture effects of all DBPs in a water samples and can be used as an effect-based first tier screening approach by the water industry.

Household Water Treatment

**The joint effects of efficacy and compliance: A study of household water treatment effectiveness against childhood diarrhea.**

Enger KS, Nelson KL, Rose JB and Eisenberg JNS. (2013) Water Research, http://dx.doi.org/10.1016/j.watres.2012.11.034

When assessing the ability of an intervention to reduce illness, both efficacy and compliance must be evaluated, however these are dynamic factors that can vary over time. The effectiveness of household water treatment (HWT) interventions at reducing diarrhoeal disease is related to the efficacy of the HWT method at removing pathogens, how well people comply with HWT, and the relative contribution of other pathogen exposure routes. In this study, the joint effects of 1) pathogen removal by a HWT device, and 2) the degree to which communities use the device are examined. This study focuses on the protective effects of HWT against childhood diarrhoea in developing countries, which is a leading cause of morbidity and mortality. This study uses a quantitative microbial risk assessment (QRMA) model to examine the predicted joint effect between device efficacy (measured by $\log_{10}$ reduction values – LRVs) and compliance (measured by how often the device is used).

The QRMA model, simulated waterborne transmission of diarrhoeal infection (bacteria, viruses, and protozoa, represented by diarrheagenic *E. coli*, rotavirus and *Giardia*, respectively) in children aged < 5 years. Various scenarios were used in the model including: compliance, baseline incidence, etiologic fractions and short-term contamination spikes. Compliance with HWT within a community was modelled taking into account three groups of children: 1) children who exclusively consume treated water (perfect compliance); 2) children who never consume treated water (no compliance); and 3) children who consume fixed proportions of treated and untreated drinking water (partial compliance). Three types of compliance at the community level were defined: α, in which 80% of the children consume treated water 100% of the time, and 20% of the children consume only

untreated water; β, in which 40% of children consume treated water 100% of the time, 50% of children consume treated water 80% of the time and 10% of children consume only untreated water and γ in which every child constantly consumes some untreated water. Modelling also considered differences in the baseline incidence of diarrhoea and the relative contributions of viruses, bacteria and protozoa to diarrhoeal incidence (etiologic fractions), and occurrence of occasional spikes of pathogens.

The simulation was implemented in two steps: calibration and estimation. The calibration step simulated transmission of diarrhoeal infection by drinking water in the absence of HWT. It estimated concentrations of bacteria, viruses and protozoa that are consistent with: 1) assumptions of low, medium, or high incidence of diarrhoea and 2) assumptions about the relative importance of these pathogen type to diarrhoea etiology. The estimation step used these pathogen concentrations to estimate the risk of diarrhoea under various HWT scenarios, defined by different LRVs and different levels of compliance. As a comparison, the QRMA model that was used to develop the WHO HWT recommendations was replicated with some modifications.

Under perfect compliance conditions, the model used here and the WHO model produced consistent estimates of diarrhoea risk reduction with diarrhoeal incidence decreasing as LRVs increase. If compliance slightly decreases to 99% and there are no pathogen spikes, this model predicts little or no additional benefit from LRVs above 3 in many scenarios. If compliance is 80%, there is little benefit from increasing LRVs beyond 2. If pathogen spikes are included and some of the population complied perfectly (compliance types α or β), LRVs above 3 sometimes prevented additional diarrhoea episodes. In contrast using compliance type γ in which every child constantly consumes some untreated water had the least benefit. The benefit from higher LRVs was more pronounced under conditions of high incidence, large spikes, compliance type α and high compliance.

The results of the simulations indicate that the health benefits of HWT devices are limited by compliance. Therefore the classification system used in the WHO guidelines incompletely informs HWT users and promoters regarding effectiveness of these devices. Compliance should be carefully measured during HWT field studies and HWT dissemination programs and incorporated in to the development of policy. Studies are also needed of pathogen concentrations in a variety of developing-country source water. Guidelines are required for measuring and promoting compliance when using HWT.

Indicator Organisms

**Presence of Torque Teno Virus (TTV) in Tap Water in Public Schools from Southern Brazil.**
Vecchia AD, Kluge M, *et al*. (2012) Food and Environmental Virology, DOI 10.1007/s12560-012-9096-7.

Torque teno virus (TTV) is a member of the *Anelloviridae* family, is highly stable in the environment and has been proposed as a potential viral marker of water contamination. It is believed that transmission of TTV occurs through the faecal-oral route as well as via blood transfusion, organ transplants, sexual intercourse and mother to child transmission. This virus seems to be ubiquitous in the population and more than 90% of healthy people have been found to be infected in one study in Russia. In Brazil, infection by TTV has been described in transfusion donors and the virus has also been found in 92.3% of water samples collected from streams in Manaus, in the north of the country. As TTV may suggest the presence of other viruses related to children's diarrhoea, it is of interest to assess whether this virus is present in drinking water. In this study, the occurrence of TTV genomes was surveyed in tap water samples from schools located in three municipalities in Rio Grande do Sul, the southernmost state of Brazil.

Tap water samples (500 mL) were collected in sterile plastic bottles between July and September 2009 from faucets that had been sterilised with ethanol before collecting the samples. Collection was undertaken once per school, with 34 tap water samples taken: 19 from taps in the kitchens of schools in the city of Caxias do Sul, 8 in Pelotas, and another 7 in the municipality of Santa Cruz do Sul.

All schools received water treated at conventional water treatment plants and monitored according to the Brazilian guidelines for the quality of drinking water. The detection of TTV was compared to the percentage of sewage treatment in each municipality and to the counting of thermotolerant coliforms for each sample. Putative viral particles that were present in the samples were concentrated using an adsorption-elution method with negatively charged membranes. Viral nucleic acids were extracted and a conventional polymerase chain reaction (TTV-PCR) was applied for the detection of TTV DNA.

Overall, TTV genomes were found in 11.7% (4/34) of the samples. TTV DNA was detected in 10.5% (2/19) of the samples from the city of Caxias do Sul and 25% (2/8) of the samples from Pelotas. All Santa Cruz do Sul samples were negative. The detection rate of TTV was compared to the detection rates of *Escherichia coli* and a strong correlation was found ($r$ = 0.97). The detection rate of TTV compared to the level of sewage treated in each municipality revealed a mild negative correlation ($r$ = -0.76).

The strong correlation found between the detection rate of TTV and *E. coli* indicates that TTV may be a suitable marker of faecal contamination. There needs to be priority given to initiatives to improve sewage treatment and minimise the discharge of wastewater in many Brazilian cities in order avoid the burden of gastroenteritis in Brazil.

Comment *TTV is a small non-enveloped virus with a single-stranded DNA genome. It was discovered in 1997, and to date has not been definitely linked to disease in humans. Virus detection by PCR does not permit conclusions to be drawn about infectivity, however detection of E. coli in some samples indicates water treatment is suboptimal or recontamination is occurring.*

Mycobacteria

**Nontuberculous mycobacteria in household plumbing as possible cause of chronic rhinosinusitis.**

Tichenor WS, Thurlow J, *et al*. (2012) Emerging Infectious Diseases, **18**(10); 1612-1617.

There are a subset of patients with chronic rhinosinusitis (CRS) who experience persistent symptoms despite undergoing many medical and surgical treatments. Current theories as to the cause of CRS include immunologic reactions to microorganisms. One of the possible reasons for the persistence of symptoms is the presence of microorganisms that are resistant to typically prescribed antimicrobial drugs, such as nontuberculous mycobacteria (NTM). NTM are environmental opportunistic pathogens found in natural and human-engineered waters, including drinking water distribution systems and household plumbing. This study reports the isolation, identification and fingerprinting of NTM isolates from patients with CRS and from their household plumbing.

The medical records of adult outpatients in whom CRS was diagnosed in a medical practice in New York were reviewed, and 33 patients with NTM found in endoscopically directed sinus cultures were identified. A total of 39 NTM isolates belonging to 10 *Mycobacterium* species were recovered from samples from the ostiomeatal unit or paranasal sinuses of these patients. Most of the patients (31/34, 94%) had reported using some form of nasal irrigation at the time of endoscopy, and 26 were known to have used tap water. The patients or family members were contacted and asked to provide hot and cold water samples (500 mL) and biofilms/sediment from water taps and showerheads in their home. Biofilm samples were collected by swabbing the inside of taps and showerheads. Swabs of in-line or point-of-use water filters were also submitted by some patients. Samples were provided from 8 of the 33 homes.

Patient NTM isolates (apparently stored since the initial isolation) were identified by various methods including: DNA probe, high-performance liquid chromatography, gas-liquid chromatography, internal transcribed spacer region or 16S rDNA sequencing. NTM in water and swab (taps and filters) samples were enumerated and isolated. Household NTM isolates and those from patients were identified by nested PCR of 16S rRNA gene and PCR amplification and analysis of restriction endonuclease

digestion fragments of the *hsp 65* gene. When the *Mycobacterium* species of the patient and household water system isolates were identical, isolates were fingerprinted by *rep*-PCR and pulsed-filed gel electrophoresis (PFGE).

There were a total of 80 samples (i.e., 43 water, 31 biofilm and 6 from filters) received from 8 collaborating CRS patients. NTM were isolated from 35 of the 80 samples, and at least one positive sample was obtained from 5 of the 8 households sampled. In 4 households at least 1 of the samples yielded an NTM isolate that was the same species and had the same *rep*-PCR fingerprint as that of the patient. To confirm relatedness between isolates from patient and household plumbing, PFGE was performed for the same isolates. It was found that for 3 of the 8 CRS patients, the patient and household plumbing isolates were clonally related with *M. avium* identified sharing *rep*-PCR and PFGE fingerprints.

This study confirms the possibility that a proportion of patients with CRS could be infected with NTM. Therefore sinus samples should be cultured for NTM so appropriate therapy can be undertaken. In addition, CRS patients need to avoid sinus irrigation with tap water as tap water may contain NTM and it may not be possible to remove it. Sterile saline should be used instead of tap water.

Comment *This paper states that the 33 patients with NTM-positive sinus cultures represent 1% of patient samples collected over a 10-year period. It is said that NTM detection from the sinus cavity is rare in healthy people, but it would appear to be rare in CRS patients also. It is not clear how much time elapsed between the initial isolation of NTM from the sinuses of the 8 patients who provided water samples and collection of the samples from their homes.*

Outbreaks

**Outbreak of cryptosporidiosis associated with a man-made chlorinated lake--Tarrant County, Texas, 2008.**

Cantey PT, Kurian AK *et al*. (2012) Journal of Environmental Health, **75**(4); 14-19.

On July 8, 2008, Tarrant County Public Health (TCPH) in Texas, USA was notified of an outbreak of gastrointestinal illness among people who had participated in a picnic at a chlorinated man-made lake. Further reports were received over the next few days, with five separate groups reporting development of gastrointestinal symptoms within several days of visiting the lake. Laboratory-confirmed cases of cryptosporidiosis were notified for 5 people on 11 July and an investigation was launched on 14 July. TCPH collaborated with the Texas Department of State Health Services (DSHS) and CDC to confirm the lake as the outbreak source, determine the magnitude of the outbreak, identify risk factors associated with infection, identify the source of contamination of the lake and develop and implement control measures.

Investigators identified 112 confirmed cases that had a stool specimen testing positive for *Cryptosporidium* and who developed at least one gastrointestinal symptom after June 20, following a visit to the lake. There were 142 probable case patients with diarrhoea characterised by ≥ 3 watery stools per day lasting ≥ 3 days, 2-10 days after June 20, 2008. A matched case-control study was undertaken with fifty-six matched pairs enrolled among households that visited the lake. Controls were defined as a household contact of a confirmed or probable case that went to the lake on the same day as the case patient but did not develop gastrointestinal illness. The case-control study used a standardised questionnaire including questions about specific water and food exposures at the lake, visits to other recreational water venues (RWV's) and other potential exposures such as exposure to animals, restaurants and grocery stores. Matched univariable and multivariable analyses of data on risk factors for infection were undertaken. In additional to *Cryptosporidium* testing, the first 22 people with diarrhoeal illness at the time of interview were asked to submit stools for testing for *Salmonella*, *Shigella*, *E. coli*, *Campylobacter*, *Yersinia enterocolitica* and norovirus. Genotyping and subtyping of *Cryptosporidium* isolates were also performed.

The environmental health investigation involved testing water from the wells supplying the lake and the concession stand for faecal coliforms.

*Cryptosporidium* testing of additional samples from the wells, the lake itself and the backwash of the two sand filters used to filter recirculated late water was also undertaken. Drinking water sources were inspected. The property was inspected for potential sources of lake contamination, including the septic system, the restroom facilities and the stream that runs along the border of the lake. Multiple lake samples from numerous locations were tested for free chlorine concentration, pH and temperature to identify areas of poor circulation.

There were three peaks to the outbreak all of which occurred on weekends. The onset of symptoms then peaked 5-10 days after each of the exposure peaks. The univariable analysis found significant risk factors to be swallowing lake water (OR = 39.9), putting one's head under water (OR = 21.1), entering the lake (OR = 8.2), male sex (OR = 2.7) and younger age (OR = 0.95 for each year increasing age). Multivariable analysis showed one significant risk factor: swallowing lake water (OR = 16.3, 95% confidence interval 2.5 – infinity). *Salmonella*, *Shigella*, *E. coli*, *Campylobacter*, *Y, enterocolitica* and norovirus were not detected in any of the 22 stool specimens tested for these pathogens. *Cryptosporidium hominis* was detected in 12 specimens. Ten of the isolates were of the IaA28R4 subtype and two (both cases from one family) were of IaA15R3 subtype. *Cryptosporidium* species were detected in the 120-L composite lake sample by microscopy and real-time PCR. *Cryptosporidium* was not detected in the composite well water sample. The parasite was also detected in one filter backwash sample. The free chlorine level range was 0.0-0.6 ppm, pH range was 7.0-8.0 and water temperature range was 29.4 – 31.1 ºC in the multiple lake water samples.

Hyperchlorination of the lake to more than 20 ppm free chlorine for 13 hours was undertaken on the 24th of July to inactivate *Cryptosporidium*. By the 27th of July the lake was reopened when chlorine levels had dropped to 8 ppm. Together the epidemiological, laboratory and environmental health investigations suggested that the lake was most likely contaminated by one or more human diarrhoeal faecal incident(s). The chlorine levels in the lake were too low to inactivate pathogens, particularly *Cryptosporidium.* This investigation highlights the importance of close cooperation among epidemiology, laboratory and environmental health professionals in response to recreational water illness outbreaks.

Comment *This recreational water venue was of an unusual type – an artificially created lake of 2 million gallons capacity that was filtered and disinfected, but was not covered by state swimming pool regulations. The authors note that this outbreak took place at a time when a large community outbreak of cryptosporidiosis was already occurring in this region of Texas.*

Protozoa

**Prevalence and distribution of *Cryptosporidium* and *Giardia* in wastewater and the surface, drinking and ground waters in the Lower Rhine, Germany.**
Gallas-Lindemann C, Sotiriadou I, Plutzer J and Karanis P (2013) Epidemiology and Infection, **141**(1); 9-21.

This study was undertaken in North Rhine-Westphalia on the Lower Rhine in Germany. Water samples were collected and investigated for the presence of *Cryptosporidium* oocysts and *Giardia* cysts from 2009 to 2011. Samples included pooled 24 hour influent and effluent samples from eight wastewater treatment plants over a period of 15 months. Samples were also collected from the recreational swimming area during the 2009 and 2010 bathing seasons. Samples were also collected from the drinking water supply [tap water, raw water (drinking water before disinfection); ground water; and drinking water produced from the River Rhine].

Of the 206 WWTP samples, 134 (65%) were found to be positive for *Giardia* cysts and 64 (31.1%) for *Cryptosporidium* oocysts. The WWTP influent numbers ranged from 0 to 1745 *Cryptosporidium* oocysts/l and from 0 to 2436 *Giardia* cysts/l. Effluent numbers ranged from 0 to 36 *Cryptosporidium* oocysts/l and from 0 to 56 *Giardia* cysts/l. The average rates of reduction by wastewater treatment ranged from 73.3% to 100% for *Cryptosporidium*

oocysts and from 75.3 to 100% for *Giardia* cysts. The average removal efficiency of all the WWTPs was 0.7 $\log_{10}$ for *Cryptosporidium* oocysts and 1.3 $\log_{10}$ for *Giardia* cysts. *Cryptosporidium* and *Giardia* were more prevalent from late summer throughout winter, depending on rainfall. There were 77 samples from surface water (recreational sites = 54, River Rhine = 23), and *Cryptosporidium* oocysts were detected in nine of these (11.7%). The numbers of oocysts ranged from 20 to 2000 oocysts/100 l. *Giardia* cysts were detected in eight samples (10.4%), and the numbers of cysts ranged from 6.7 to 4000 cysts/l. Of the 113 samples in the catchment area of the drinking water supply, 14 (12.4%) were contaminated with *Cryptosporidium* and two (1.8%) were contaminated with *Giardia*. *Cryptosporidium* was detected in 3 of 24 drinking water samples, and *Giardia* was not detected in 24 samples. The mean level of *Cryptosporidium* was 1.3 oocysts /100l and the maximum was 1.6/100l.

*Cryptosporidium* oocysts were present in all water sources, with the highest levels in running surface waters from the River Rhine. The oocysts were found to be able to infiltrate into the aquifer and pass through the sediments, thereby reaching consumers. From surface water via groundwater to the final drinking water, a reduction of 1-2 orders of magnitude was found. Even though there was a reduction in *Cryptosporidium* oocysts, drinking water still poses an infection risk to the population, particularly to immunocompromised patients. *G. lamblia* cysts were detected in a few samples of surface water and groundwater. The small number in groundwater and negative results in the raw and treated drinking water may be because the larger *Giardia* cysts are removed by filtration through sand and gravel more effectively than *Cryptosporidium* oocysts.

Comment *The authors note that the drinking water treatment plants in this area use UV disinfection for inactivation of Cryptosporidium in addition to riverbank filtration. Therefore the low numbers of oocysts detected in final drinking water are not likely to be infective and should not pose a health risk even to immunocompromised people.*

Rainwater

**Risk of gastrointestinal illness associated with the consumption of rainwater: A systematic review.**
Dean J and Hunter P R (2012) Environmental Science and Technology, **46**(5); 2501-2507.

The collection of rainwater for domestic use is practiced globally however there is ongoing debate regarding its quality and associated health risks. There is growing interest in rainwater harvesting (RWH) as a means of providing potable water with the ever increasing demands placed on limited water resources throughout the world. The health risks from rainwater harvesting are at present unclear and it would appear from previous studies that quantitative microbial risk assessment (QRMA) overestimates the risk. The aim of this review was to try and improve estimates of the health risk associated with consumption of harvested rainwater through a systematic review and meta-analysis. This review focused on gastroenteritis and microbial risks.

Systematic searching of online bibliographic databases was conducted up to January 2011 for epidemiological studies that attempted to quantify the risk of gastrointestinal disease associated with rainwater consumption. Both observational and experimental studies were included. Also reference sections of key articles were searched and authors of previous studies were contacted if appropriate. Studies were included if gastroenteritis, or diarrhoeal illness was recorded as a health outcome; where pathogens known to cause gastroenteritis diseases were isolated from specimens of symptomatic patients; or where diagnoses were presented based on predictable patterns of gastrointestinal illness, i.e.., cholera. Studies were assessed for relevance and for methodological quality. Studies relevant to the review were further subdivided into research that compared the health risk from rainwater with that of "improved" water sources and those that compared the health risk from rainwater with that of "unimproved" water sources. Heterogeneity, or between-study variation that was not due to chance, was explored using meta-analysis. Where heterogeneity was thought to be limited, pooled relative risk values were calculated.

The systematic searching of the databases returned 758 articles. A further 16 articles were found from searching reference sections, conference reports and publication citations. There were 13 studies that met the selection criteria and included: 5 outbreak reports, 2 case-control studies, 1 cohort study, 2 randomised controlled trials and 3 others. The chosen studies were mostly undertaken in Australasia and publication dates ranged from 1978 to 2007. There were 8 studies that investigated health risks associated with rainwater consumption although one was not included in the meta-analysis due to a lack of an alternative water source control group. Three cross-sectional studies compared risk associated with rainwater with that of unimproved sources. The pooled subgroup analysis suggested that rainwater poses no additional risk compared with unimproved sources and was associated with a lower risk of diarrheal disease (relative risk 0.57 95% CI 0.42, 0.77). There were four studies that compared risk from rainwater consumption with that of improved sources. The pooled subgroup analysis suggested that there is no additional health risk or benefit from the consumption of rainwater compared with improved water sources (0.82 95% CI 0.38, 1.73). There were 5 outbreak reports included and theses were classified according to the strength of association between water exposure and illness. It was determined that 4 out of the 5 outbreaks were "strongly associated with rainwater use" and 1 outbreak was 'probably associated with rainwater".

This review found evidence that when compared with unimproved sources, rainwater consumption is associated with fewer episodes of diarrheal diseases. Although no excess risk was found in people consuming rainwater compared to improved water sources, there was evidence of heterogeneity. One study in particular found an excess risk of campylobacteriosis. It is important to consider that these results are based on a small number of studies of variable quality and design and therefore further research is required in order to draw conclusions with greater certainty. Where possible, rainwater harvesting should be encouraged as a step towards achieving the millennium development targets on access to improved water supplies.

Water Intake

**A randomized trial on the effects of regular water intake in patients with recurrent headaches.**
Spigt M, Weerkamp N, *et al*. (2012) Family Practice, **29**(4); 370-375.

This paper describes a randomised controlled trial conducted to test the hypothesis that recommending increased water intake reduces the frequency and severity of headaches. Participants were recruited via 16 health care centres in The Netherlands between June 2005 and June 2006. Patients between 18 and 65 years of age were eligible if they had been diagnosed with 'headache', 'tension headache' and/or 'migraine'. A screening questionnaire was used to exclude patients who suffered from headache less than 1 year, those with secondary headaches (trauma or known cause) and patients who had developed headache after 50 years of age. The remaining 333 patients were invited for baseline measurement. Patients were required to have at least two episodes of moderately intense headache or at least five mildly intense episodes per month, and have a fluid intake of less than 2.5 l/day.

A total of 102 eligible and willing patients were randomly allocated into two groups. Both groups received information about stress reduction and sleep improvement strategies. The intervention group was also advised to drink 1.5 l of water per day, additional to their normally consumed beverages, for a period of 3 months. All patients were blind to the hypothesis of the study. Baseline assessment of headache severity included a 24-hour drink diary to assess total fluid intake and the Migraine-Specific Quality of Life (MSQOL) questionnaire. Patients also reported self-perceived effect by indicating how much effect the advice had on their headache on a scale from 0 = no improvement to 10 = much improvement. A 4-week headache diary was used to record symptoms and medication use. All measurements were repeated at the end of the intervention period. Participants were contacted one week after randomisation and asked how much effect they expected from the lifestyle advice they had received.

There were 50 patients randomised to the control group and 33 (66%) completed the study. In the intervention group 52 patients were randomised and 41 (79%) completed the study. Participants in the intervention group had a significantly more positive expectations of the effect of their advice than the control group. The advice to increase daily water intake by 1.5 l resulted in a mean difference in total 24 hour fluid intake of 842 ml. Drinking more water resulted in a significant improvement of 4.5 points on MSQOL. Also, 47% of the water group reported much improvement against 25% in the control group. However, the water intervention group did not show significant changes in objective effect parameters including days with at least moderate headache or days with medication use. There was no significant effect modification seen for headache intensity at baseline, age, gender, migraine, migraine with aura and tension type headache. To assess the effect of actual fluid consumption, a per-protocol analysis was carried out excluding intervention patient cases who had not increased their fluid intake by > 1000 ml and cases from the control group who had increased their fluid intake by > 1000 ml. This left only18 patients in the water group and 3 patients in the control group for comparison. The effects were slightly more positive in this analysis, but the effects on headache frequency and duration remained non-significant.

This study found that patients who regularly suffer from headaches reported better quality of life after 3 months of increased water intake, despite no significant change in monthly headache frequency and duration. Given the observed positive subjective effects found here, and taking into consideration the previously documented effects of drinking more water, it is possible that some headache patients do benefit from drinking more water. It therefore seems reasonable to recommend headache patients to try this non-invasive intervention for a short period of time to see whether they have improvement.

Water Quality

**Relative benefits of on-plot water supply over other 'improved' sources in rural Vietnam.**
Brown J, Hien V T, *et al*. (2013) Tropical Medicine and International Health, **18**(1); 65-74.

A post-implementation assessment was conducted to evaluate a large-scale implementation of community piped water systems in rural central Vietnam. The objectives of this study were to determine: (i) whether water systems consistently delivered safe drinking water to users and (ii) whether on-plot access to piped water systems provided health and other advantages over access to other available water sources, including 'improved' water sources.

This observational study in Da Nang province included two phases: (i) an initial cross-sectional sampling and recruitment phase (1 month) and (ii) a longitudinal data collection phase (3 months). The 300 households in the study were spread across seven community project areas served by nine water supply projects. Systems were constructed between 2002 and 2008 and were managed either by a cooperative (private) or a people's committee (public) and used similar conventional water treatment methods. There were 224 households connected to a piped water supply system and 76 unconnected households from the same areas relying mainly on 'improved' water sources outside the home, all selected randomly. Each household was visited once for recruitment and then three more times over three months. Data collected for each household included water use and handling practices; sanitation access and behaviour; other water, sanitation and hygiene practices; and other covariates. Each household respondent was asked to provide a 1-week recall of diarrhoeal illness for herself and all members of the household. Drinking water samples were collected from all households at each visit. The types of water sampled were: stored household water from control households or water as delivered via the household/yard tap for other households and stored, treated drinking water (usually, boiled water) if available. If household used another source or treatment step for drinking water at the time of the visit, a sample of that water was also collected. Samples were analysed for total coliforms and *Escherichia coli*.

The geometric mean piped water *E. coli* counts (not including those samples that were treated by boiling) were 16 (95% CI 13-18) bacteria/100 ml compared with 63 (95% CI 47-84) bacteria/100 ml among

control households and 36 (95% CI 31-42) bacteria/100 ml among those from 'improved" sources. The geometric mean piped water total coliform counts were 310 (95% CI 260-370) bacteria/100 ml compared to 1600 (95% CI 1200-2100) bacteria/100 ml among unconnected households and 1200 bacteria/100 ml (95% CI 1100-1400) in the subset of households using 'improved' sources. For both measures of water quality, the piped water supply systems delivered statistically meaningful improvements in water quality over alternative sources serving the area. No disinfectant (free chlorine) residual was detected at the household level in any samples. All connected households reported occasional to frequent intermittent service, a mean of 1.8 times per month. Among households with a piped water supply, 68% stated the quantity of water available supplied all daily needs, while only 1.3% of control households did so. The adjusted longitudinal prevalence ratio for diarrhoeal disease in the previous 7 days was 0.57 (95% CI 0.39-0.86, P = 0.006) when households with piped water were compared to all other sources and 0.59 (95% CI 0.39-0.91, P = 0.018) if only households with access to an 'improved' source were used as a comparison.

The results of this study suggest that on-plot piped water access results in benefits to connected households over other available sources, even those that meet the definition for 'improved' sources. Those households connected to piped water supply systems had better water quality and greater water quantity. Connected households were also at lower risk of diarrhoeal disease compared with unconnected households and households with access to 'improved' sources and sources very near to the household (within a self-reported 20-min total collection time). Although the systems in this study did provide improved water quality over other available sources, microbial counts in water samples were still elevated beyond what would be considered safe according to historical water quality standards from wealthier countries. A water safety plan (WSP) approach is recommended to identify and control the risks for such systems.



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# Web Bonus Articles

Alzheimer's Disease

**Silicon-rich mineral water as a non-invasive test of the 'aluminum hypothesis' in Alzheimer's disease.**
Davenward S, Bentham P, Wright J, Crome P, Job D, Polwart A and Exley C. (2013) Journal of Alzheimer's Disease, **33**(2); 423-430.

While it is known that aluminium is present in the human brain and that it has neurotoxic properties, there has never been a direct experimental test of its contribution to the etiology of AD. The contention of this article is that the only direct and ethically acceptable experimental test of the 'aluminium hypothesis' is to provide data specific to the link by testing the null hypothesis that a reduction in the body burden of aluminium to its lowest practical limit would have no influence on the onset, incidence, progression or severity of Alzheimer's disease. Silicic acid is a natural antagonist to the toxicity of aluminium in biota and in humans, and it has been shown to reduce aluminium uptake across the gut and facilitate the excretion of systemic aluminium via the kidney. This study tests the null hypothesis that regular drinking of a silicon-rich mineral water over a period of 12 weeks has no influence on the urinary excretion of aluminium in individuals with AD and their spouse or carer (controls).

Participants comprised 16 individuals with a diagnosis of AD and 16 spouses or carers that were recruited through memory clinics in Stoke-on-Trent and Birmingham, United Kingdom. In the first week (Wk 0), both patient and control collected their first urine sample of the day for 7 consecutive days. In the second week (Wk 1), patient and control collected urine samples in the same way as in Wk 0 and during these 7 days they each drank up to 1L of a silicon-rich mineral water (35 mg/L total silicon) each day. For the following 10 weeks (Wk 2-Wk 11), both patient and control continued to drink up to 1L of the mineral water, but collected a first morning urine sample only on Wednesday of each week. In the final week (Wk 12), patient and carer continued to drink the mineral water and they collected daily urine samples in the same way as to Wk 0 and Wk 1. The Alzheimer's disease assessment scale-cognitive (ADAS-Cog) was used to measure cognitive performance of both patients and controls at the beginning (Wk 0) and the end (Wk 12) of the study. ADAS-Cog comprises 11 different components which have been designed to test broad areas of cognition, memory, language, orientation and praxis. The test is scored out of 70 with a lower score indicating better performance. Urine samples were measured for creatinine (CRt), total silicon, aluminium, iron and copper. Urinary excretion of metals was standardised against creatinine excretion.

The study was completed by 29 individuals, 15 diagnosed as AD and 14 non-AD. There were no statistically significant differences between the non-AD control group and the AD patient group in the urinary excretion of each of Si, Al, Fe and Cu during Wk 0. However when the genders were considered separately there were significant gender-related effects for Al excretion. Non-AD females excreted significantly more Al than females with AD, but the opposite was true for males as AD males excreted significantly more Al than non-AD males. The two female groups (with and without AD) had similar demographic characteristics but male AD patients were older than non-AD male controls. Overall, females, in which there is a known higher incidence of AD, excreted more Al than males. In Wk 1, all groups showed an approximate doubling in the urinary excretion of Si, and there were no statistically significant differences between non-AD and AD groups. During Wk1 all groups also showed statistically significant increases in the urinary excretion of Al, with the non-AD group excreting significantly more Al than individuals with AD. Again there were gender-related effects with females in the non-AD group excreting more Al than females with AD and also more than males with or without AD. There were no differences between Wk 0 and Wk 1 in terms of excretion of Fe and Cu in those with or without AD diagnosis. Throughout Wks 2-12, urinary Si excretion remained high for both non-AD and AD groups. The non-AD group was found to excrete significantly more Al during week 12 than the AD group and this difference was due to a

statistically significant fall in urinary Al excretion between Wk 12 and Wk 1 for the AD group. There were no statistically significant differences in the urinary excretion of either Fe or Cu between the two groups in Wk 12 or between Wk 12 and Wk 1.

The ADAS-Cog tests were conducted without knowledge of the subjects' urinary excretion results. None of the individuals within the non-AD group presented with an ADAS-Cog score ≥ 10. It has been suggested than a minimal clinically-relevant change (MCRC) is ≥ 3 units on the scale. Using this MCRC criterion 14 control subjects showed a deterioration in cognitive function, 2 subjects improved and 9 subjects showed no change over the 12 weeks of mineral water therapy. Among the 15 participants diagnosed with AD, cognitive function deteriorated in 7 subjects, improved in 3 subjects and was unchanged in 5 subjects.

It was shown in this study that silicon-rich mineral water increased the urinary excretion of Si and Al without affecting Fe and Cu excretion. For the AD group there was evidence that longer term drinking of silicon-rich mineral water statistically reduced the body burden of Al over 12 weeks and that 8 out of 15 individuals had either unchanged cognitive function or improved cognitive function during the same period. Longer term studies are needed that show that any reductions in the body burden of Al can be further improved and sustained and that any cognitive benefits are also long-term.

*Comment The small number of participants in this study precludes meaningful statistical analysis of any changes in cognitive performance among the participants. A considerably larger study comparing AD groups randomly assigned to zero/low silica or high silica water, with participants and researchers blinded to the water type, would be required to provide a definitive test of this hypothesis.*

*Amoebae*

**Amoeba-related health risk in drinking water systems: Could monitoring of amoebae be a complementary approach to current quality control strategies?**

Codony F, Pérez L M, Adrados B, Agust G, Fittipaldi M and Morat J. (2012) Future Microbiology, **7**(1); 25-31.

To assess the potential health risks from drinking water systems, monitoring for faecal indicator microorganisms using culture-based methods is standard protocol. However, it is well known that in some circumstances, the most used microbial indicators such as faecal *Escherichia coli* and enterococci may not be adequate for health risk assessment because many measureable pathogens are more resistant to conventional water treatment and can persist much longer in the environment than these faecal indicators. Amoebae can colonise virtually any kind of water system and survive harsh physical and chemical conditions such as elevated temperatures or the presence of biocides. Some amoebae are pathogenic but many others may play a role in the survival of bacterial pathogens in water supply systems. This paper summarises the published laboratory based evidence that amoebae can act as environmental vectors and/or transport hosts for the seven bacterial pathogens (*Campylobacter jejuni, E. coli* 0157:H7, *Helicobacter pylori*, *Legionella pneumophila*, *Mycobacterium avium*, *Salmonella enterica* and *Shigella sonnei*) on the CCL.3 (US EPA Contaminants Candidate List 3). The CCL.3 is a list of contaminants that are not currently subjected to any proposed or promulgated national primary drinking water regulations that are known or expected to occur in public water systems and may require some kind of regulation.

Current knowledge indicates that amoebae could play a role in the survival and spread of significant bacterial pathogens in drinking water systems. There is also the potential that these faecal-related pathogens may survive within amoebae at low levels that are not detectable by conventional testing for faecal indicators. Most CCL.3 pathogens are currently detected by conventional culture-based methods, which are time consuming and expensive. In contrast, molecular-based methods are available and PCR primers and probes can be designed for most microorganisms. Quantitative PCR (qPCR) however does not generally discriminate between viable and nonviable target microorganisms. To

overcome this limitation a sample pretreatment step with propidium monoazide (PMA) has been used in combination with qPCR in several studies. PMA is a DNA-intercalating dye with the ability to only penetrate membrane-compromised cells, blocking the amplification cycle. Using this approach, cell viability is based on membrane integrity. Recently, the use of qPCR and PMA has been positively evaluated in *A. castellani*. The authors advocate more research on amoebae detection with molecular methods with the aim to use amoebae levels as a complementary health risk indicator, avoiding the need to analyse for the presence of specific microorganisms. The use of amoebae is warranted because of the evidence regarding the role of amoebae in bacterial survival and also because some amoebae are also pathogens such as *N. fowleri* and *Acanthamoeba*.

Arsenic

**Arsenic levels in drinking water and mortality of liver cancer in Taiwan.**

Lin HJ, Sung TI, Chen CY and Guo HR. (2013) Journal of Hazardous Materials, http://dx.doi.org/10.1016/j.jhazmat.2012.12.049

The carcinogenic effects of arsenic have been documented for more than a century and the occurrence of liver cancer in patients with arsenic intoxications has been documented since the 1950s. Epidemiological studies on liver cancer and arsenic intoxication however are quite limited, especially those on the dose-response relationship. This study was undertaken to further evaluate the association between arsenic levels in drinking water and occurrence of liver cancer.

This study included four hyper-endemic townships of the blackfoot disease (BFD) area of Taiwan and six nearby townships. BFD is an obstructive peripheral vascular disease associated with chronic high arsenic exposure which characterised by the black discolouration due to gangrenous changes of the lower extremities. In the BFD endemic area, many artesian wells that were used by residents as a source of drinking water had high levels of arsenic. Original measurement reports were available from a census survey of wells conducted by the Taiwan Provincial Institute of Environmental Sanitation for 138 villages in the study townships. Most of the measurements were made between 1974 and 1976. Arsenic levels were grouped into six categories: below 0.05 mg/L, 0.05-0.08 mg/L. 0.09-0.16 mg/L, 0.17-0.32 mg/L, 0.33-0.64 mg/L and above 0.64 mg/L. Liver cancer cases were identified from death certificates filed to the ten household registry offices in the study townships between January 1, 1971 and December 31, 1990. Data was obtained on residents in each village from the household registry offices and residents were divided into four age groups: 0-29, 30-49, 50-69 and > 70 years old. The study villages had a total population of around 235,000. There were 6,103 wells in the villages with each village having an average of 44.2 wells and an average number of 38.5 people using each well. Using village as the unit, multivariate regression analyses was performed and then post hoc analyses to validate the findings.

Over the 20-year study period, 802 male and 301 female liver cancer deaths were identified in the study villages. After adjusting for age, arsenic levels above 0.64 mg/L in drinking water were associated with a statistically significant increase in liver cancer mortality in both males and females. A 1% increase in the proportion of wells in this category (> 0.64 mg/L) was associated with an increase of 0.21 per 100,000 persons per year in the mortality of liver cancer in men, and 0.09 per 100,000 persons per year in women. There was no significant increase in liver cancer mortality associated with any of the other four exposure categories (below 0.05 mg/L was the reference category). The post hoc stratified analyses were conducted using two models which generated point estimates for the increases in liver cancer mortality associated with arsenic levels above 0.64 mg/L. The results of the stratified analyses confirmed the dose-response relationships projected by the regression analyses.

A review of the literature of epidemiological studies on the associations between arsenic ingestion and liver cancer was also undertaken and the studies examined supported the findings of an increased risk associated with exposures above 0.64 mg/L and no increased risk below 0.64 mg/L. The findings from

this study suggest that both the Joint FAO/WHO Expert Committee on Food Additives guidelines for lung cancer (3.0 µg/kg bw per day: 2-7 µg/kg bw per day) and the new U.S. EPA arsenic standards for drinking water (0.1 mg/L) may provide adequate protection against the carcinogenic effect of arsenic on the liver.

*Comment The authors note that this ecological study could not assess individual water exposures or assess the impact of other known risk factors for liver cancer including chronic hepatitis infections or alcohol consumption.*

Chemical Contamination

**Pentachlorophenol contamination of private drinking water from treated utility poles.**
Karlsson L, Cragin L, Center G, Giguere C, Comstock J, Boccuzzo L and Sumner A. (2013) American Journal of Public Health, **103**(2); 276-277.

Pentachlorophenol (PCP) is an organochlorine wood preservative that is used to treat utility poles in the United States. There are about 36 million PCP-treated poles in use across the United States. The US Environmental Protection Agency (EPA) maximum contaminant level (MCL) for PCP in drinking water is 0.001 milligrams per litre. The odour threshold for PCP in water is 0.857 milligrams per litre at 30ºC. Effects of PCP exposure can range from skin, eye and respiratory irritation to more severe toxic effects at high exposure levels. PCP is classified by the EPA as likely to be carcinogenic to humans.

Two incidents of contamination of private drinking water supplies associated with PCP-treated poles were reported in Vermont in 2009. Both were discovered after householder complaints about chemical-like odours in drinking water. Investigation of the first incident revealed that a new utility pole had been installed upgradient of a shallow dug well used as a domestic water source. It was concluded that the pole was likely to be in contact with the water table. The home owner was advised by the Vermont Department of Health advised the caller not to ingest, have dermal exposure to, or inhale vapours from the water. A similar incident occurred about one month later in a different location. In this case three utility poles had recently been replaced upgradient of a private spring. VDH again advised the resident not to ingest, have dermal exposure to or inhale vapours of the water.

Samples of tap water were taken in June 2009 after the first call. The water had a PCP concentration of 2.06 milligrams per litre and a subsequent sample had a concentration of 1.15 milligrams per litre, respectively about 2000 and 1000 times the EPA maximum contaminant level (0.001 mg/L). In July 2009, the utility company replaced the pole with a non-treated cedar pole and paid for a new 705-foot drilled well, which tested negative for PCP. After the second call, a tap water sample was taken and the PCP concentration was 0.007 milligrams per litre, and a subsequent sample had a concentration of 0.002 milligrams per litre, both of which were above the EPA maximum contaminant level (0.001 mg/L). In August, the utility company replaced the poles with non-treated cedar poles and paid for a point-of-entry charcoal filtration system. PCP was not detected in tap water samples taken after filtration. Samples collected directly from the spring had diminishing PCP, with none detected after October 2009.

In January 2012, Vermont introduced legislation that proposed regulation of both the siting of treated utility poles near drinking water sources and the reapplication of pesticide wood treatments. Also recommended was the removal of the exemption for placement of utility poles under the Federal Insecticide, Fungicide and Rodenticide Act. The authors suggest that PCP contamination from utility poles should be considered when owners of private water supplies report chemical or gasoline-like odours in their water.

Cholera

**Detection of Vibrio cholerae in environmental waters including drinking water reservoirs of Azerbaijan.**
Rashid A, Haley B J, Rajabov M, Ahmadova S, Gurbanov S, Colwell RR and Huq A. (2013) Environmental Microbiology Reports, **5**(1); 30-38.

*Vibrio cholera* is the causative agent of cholera and has been isolated from marine, estuarine and fresh surface water throughout the world. The global burden of the illness cause by *V. cholera* is likely to be significantly underestimated as mild cases may go undiagnosed, disease reporting systems are often inadequate and many sick individuals fail to seek medical attention. In Azerbaijan, a former Soviet Union republic in the Caucasus region, cholera has been reported sporadically with large outbreaks occurring at times. Historically, cholera outbreaks in this country have been repeatedly linked to drinking water reservoirs that serve the majority of the urban populations. Water resources in Azerbaijan are poor and information on water quality and quantity in this country are limited. This study presents the first report of the presence of *V. cholera* in surface waters of Azerbaijan and its seasonality using a combination of bacteriological and molecular methods.

For this study, sampling sites were classified as freshwater or saline water. Water and plankton samples were collected from four freshwater sites: Kura River, Lake Karkhana, Jeyranbatan reservoir and Mingachevir reservoir, and five sites along the Caspian Sea. Physical and chemical parameters were measured, including pH, conductivity, salinity and water and air temperature at all sampling sites at the time of sample collection. A series of biochemical tests were undertaken to identify presumptive *V. cholera*. To confirm the presence of *V. cholera*, polymerase chain reaction (PCR) targeting the *V. cholera*-specific 16S-23S rRNA intergenic spacer region was performed on a subset of presumptive *V. cholerae* isolates. Confirmed *V. cholera* isolates were further tested for virulence factors by PCR and for cholera toxins. All isolates were also evaluated for the O1 and O139 serogroup regions by PCR. Statistical models of *V. cholera* detection were used to explain the observed data with binary logistic regressions.

All *V. cholerae* isolates were determine to be *V. cholerae* non-O1/non-O139. *V. cholerae* was confirmed to be most frequently isolated during July 2010, with an occurrence of 80% in plankton and water samples. Detection of *V. cholera* was less frequent after July, but *V. cholerae* could be detected in the cooler winter months also, with an anomalous peak in numbers in the Jayranbatan reservoir in November, 2010. The frequency of *V. cholerae* peaked again during the warmer months of 2011, but not to the same level as seen during the previous year. Water temperatures were found to be significantly higher at times when the organism was detected compared with water temperature when it was not detected at the Caspian Sea sites ($P < 0.05$). The median temperature at times of detection in this environment was 20.9ºC and 14.2ºC when not detected. These temperature relationships were not significantly different for the freshwater sites. There were no significant differences in other environmental parameters when these data were compared for both the Caspian Sea and freshwater sites. For the Caspian Sea models, as water temperature increased, so did detection of *V. cholerae* and when distance from optimal water temperature increased, detection of *V. cholerae* decreased. Applying historical averages of water temperatures recorded in the Caspian Sea to the model showed detection rates highest in August when conditions are favourable to growth of *V. cholerae*. The detection of *V. cholera* in Jeyranbatan reservoir water is important as it is the source of drinking water for Baku and the entire Absheron peninsula. *V. cholera*e was detected at this location during three of 11 sampling rounds. The Mingachevir reservoir was also positive for *V. cholera*e in July 2010. The detection of *V. cholerae* in these reservoirs poses a potential health risk to the population served by them and indicates limited and insufficient treatment of the water.

Water bodies in Azerbaijan used for recreation and as a source of drinking water should be routinely monitored for public health safety. The models constructed in this study suggest that other factors not accounted for also influence the detection of *V. cholerae*. There is evidence that pollution similar to that which occurs in the Caspian region influences aquatic microbial communities and these sources of pollution, such as polyaromatic hydrocarbons (PAHs), can have as significant influence on microbial communities as seasonal shifts in environmental parameters.

Disinfection Byproducts

**Risk of congenital anomalies in relation to the uptake of trihalomethane from drinking water during pregnancy.**

Grazuleviciene R, Kapustinskiene V, Vencloviene J, Buinauskiene J and Nieuwenhuijsen MJ. (2013) Occupational and Environmental Medicine, doi:10.1136/oemed-2012-101093

Some epidemiological studies have suggested that women exposed to water disinfection by-products (DBPs) containing elevated trihalomethanes (THM) concentrations may be at greater risk of adverse pregnancy outcomes, including foetal growth and congenital anomalies, characterised by structural deformities. However the outcomes of previous studies have been inconsistent and most have used aggregate municipal measurement of exposure to THM rather than information on individual water consumption, showering or bathing habits. Studies have also varied in their ability to control for maternal characteristics that could also be associated with adverse pregnancy outcomes. To estimate exposure to THM at an individual level, this study assessed different routes of THM uptake in a cohort of pregnant women in Kaunas, Lithuania.

A prospective cohort study of pregnancy women was conducted between 2007 and 2009 in Kaunas (Kaunas HiWATE cohort study). A questionnaire was designed to collect individual information on the source and amount of drinking water, frequency of showering and bathing, residence duration and health characteristics. This questionnaire was used to interview 3341 women who agreed to participate in the study, 76% were interviewed during the third trimester of their pregnancy and 24% by telephone within the first month after delivery.

Pregnancy outcomes were abstracted from medical records. Congenital anomalies, including both structural defects and functional abnormalities, were detected and diagnosed through routine medical procedures in the delivery unit. Congenital anomalies in live infants were coded using the international Classification of Diseases (ICD) $10^{th}$ revision. Questionnaires were used to gather information on potential risk factors for congenital anomalies, including maternal age, ethnicity, education, parity and smoking, among others. The final analysis included data from 3074 women. There were a total of 85 water samples collected from 12 monitoring sites in four water supply zones in Kaunas for THM analysis. Mean THM constituent concentration for each of the three sampling sites per treatment plant was calculated. Depending on the total THM (TTHM) levels at each plant water supply zones, a value was assigned of 'low level' (mean 1.33 μg/l) and 'high level' zone (mean 21.9 μg/l, 54.9% of subjects). Each woman was assigned a value based on the sampling site closest to her geocoded address at delivery. Total exposure was estimated by using THM concentration combined with water usage. Water usage was defined as ingestion, showering and bathing. Daily internal dose was calculated by using the uptake factors of 0.001536 and 0.001321 of THM in blood per minute per microgram from showering and bathing, respectively. Average daily TTHM uptake (μg/d) was used in the analysis as a continuous and a categorised variable. Tertiles of THM internal dose for the first trimester of pregnancy were calculated to study congenital anomalies. To study heart, musculoskeletal and urogenital anomalies, THM uptake was determined for the first, second and third months of pregnancy. Multiple logistic regression analysis was used to investigate the association of THM exposure with congenital anomalies. Adjustments were made in the analysis for potential confounders and congenital anomalies risk factors.

Mothers who were unmarried, underweight or of normal weight, had one or more previous children or a previous pre-term delivery were significantly more likely to have a child with a congenital anomaly. When analysed as continuous variables, TTHM and CH exposure in the first trimester of pregnancy showed slightly elevated, but statically non-significant, increases in the risk of congenital heart, urogenital and musculoskeletal anomalies. For the two brominated THMs analysed the relationship was stronger. There was a statistically significant relationship for bromodichloromethane (BDCM) (OR = 2.16, 95% CI 1.05 to 4.46, highest vs lowest tertile) during the first month of pregnancy and congenital

heart anomalies. During the first trimester of pregnancy, the probability of developing heart anomalies increased for every 0.1 μg/d increase in BCDM and for every 0.01 μg/d increase in the internal dibromochloromethane (DBCM) dose (OR 1.70, 95% CI 1.09 to 2.66, and OR 1.25, 95% CI 1.01 to 1.54, respectively). There were statistically significant dose-response trends across DBCM exposure categories for musculoskeletal anomalies (p = 0.024); and across the BDCM exposure categories for urogenital anomalies (p = 0.039). When exposures were compared as categories rather than continuous variables, statistically significant associations were less commonly seen.

This study suggests that increased prenatal exposure to brominated THMs may increase the risk of congenital heart and musculoskeletal anomalies. Further larger studies are required that have more variability in THM concentrations and internal THM doses to confirm the results of this study.

Endemic Gastroenteritis

**A time series study of gastroenteritis and tap water quality in the Nantes area, France, 2002-2007.**

Beaudeau P, Zeghnoun A, Corso M, Lefranc A and Rambaud L (2013) Journal of Exposure Science and Environmental Epidemiology, doi:10.1038/jes.2013.5

The residual risk of infection due to faecal pathogens in large drinking water supplies in developed countries is poorly documented and controversial. A time series study (TSS) of gastroenteritis and tap water quality for the period 2002-2007 was conducted in the Nantes area, France. Nantes is a city located in western France, which is supplied by a conventional water system. To indicate the incidence of acute gastroenteritis (AGE) the daily count of AGE-specific medical prescriptions (CSP), estimated from the drug reimbursement database of the French Health Assurance system was used. In France it is estimated that 33 % of people suffering AGE visit a doctor and 96% of these buy subsidised prescribed drugs for their illness. Firstly, the association between CSP in children (CSPch) and finished water turbidity as a proxy for exposure to waterborne faecal pathogens was tested. Then, the available water-processing data and river flow data was used to model the risk. After this, a sensitivity analysis was performed based on variations in data and time lag and adult data was used to validate the exposure covariates demonstrated in children. The plausibility of the model and its public health scope are also considered.

In the Nantes area, 410,000 inhabitants are supplied with water pumped from the Loire River. The water is treated through the following process – $CO_2$ injection and preozonation, coagulation, flocculation, settling and rapid sand filtration, ozone disinfection then activated carbon filtration. Finally pH was adjusted with soda and chlorine was added to provide a residual of 0.4mg/L. Treated water was stored about 30 hours before distribution. In order to maintain a free chlorine residual of at least 0.1 mg/L in distal parts of the system, rechlorination was performed at the outlets of some storage tanks in the distribution system. During the study period (2002-2007) the water treatment plant was monitored continuously by an automated monitoring system based on the measurement of effluent and influent turbidity and free chlorine. In addition to turbidity, the daily finished water flow, the daily number of hydrant flushes and the daily number of service interventions for broken-pipe repair were tested as potential proxies for exposure. River flow data was also provided as well as precipitation and temperature data.

The health outcome of interest was the daily number of AGE-specific prescriptions (CSP) issued by general practitioners to patients who lived in the distribution zone of the water treatment plant. Only patients who both lived and consulted a doctor within the 10 zip codes areas that corresponded to the distribution zone were included. Prescription data were separated by age into child (CSPch, for those aged 15 years and under) and adult categories (CSPad, for those aged 16 years and over). This time-series was modelled using Poisson regression within the framework of a Generalised Additive Model (GAM). The analysis took into account time intervals between turbidity measurement and the time that the water reached homes (1-3 days), variable incubation

times for pathogens (1-10 days), and delays between symptom onset and consulting a doctor. This produced a probable lag time of 3-14 days (median 8 days) between turbidity increases (presumed to coincide with increased pathogen load in finished water) and doctor consultations.

CSPch fluctuated seasonally and also showed a weekly pattern with a peak on Mondays. The pattern was also affected by public holidays and vacation times. Over the year, maximum levels occurred in January (winter) each year and minimum levels in August (summer) (max/min ratio = 5.6). Regular winter peaks reflected patterns of viral outbreaks. A linear decrease of 23% was observed in the background level of CSPch over the 2003-7 period. Similar time patterns were seen for adults (CSPad) although the difference between winter and summer rates was less. Daily river flow and raw water turbidity also showed seasonal variations with peaks in winter. Winter turbidity corresponded with river flows, but secondary peaks in warmer seasons were considered likely to be attributable to algal growth rather than flow changes. Finished water turbidity had a 24-hour mean of 0.050 NTU, 98$^{th}$ percentile of 0.083 NTU and a maximum of 0.345 NTU. Variations in finished water turbidity were weakly correlated to raw water turbidity. The water system in Nantes complied with the then current turbidity and microbiological standards throughout the study period. Broken-pipe repairs mainly occurred in winter when dropping temperature cause pipe breaks and leakages.

Finished water turbidity showed significant correlation ($P<0.05$) to CSPch when used in GAM as the only exposure covariate. There was no clear pattern below 0.045 NTU and a nearly linear relationship above this value. The interquartile excess of relative risk (IQERR) was 4.2% (CI95 = (1.5%; 6.9%)) corresponding to an ERR of 3.0% (CI95 = (1.1%, 4.9%)) for a turbidity increase of 0.01 NTU.
The final GAM model selected for further analysis incorporated four exposure covariates – finished water turbidity, river flow, finished water flow and the number of interventions for broken pipes. Using this model, at high river flows (over 95$^{th}$ percentile), the risk was highly sensitive and linearly related to finished water turbidity. At low flows (under 40$^{th}$ percentile), there was also a relationship to turbidity but it was weaker. No relationship was observed to finished water turbidity at medium river flows. The CSPch response function to finished water flow was fairly linear and highly significant ($P < 0.001$). The excess risk reached ERR = 19.3%, (CI%95 = 12.7 - 26.3) for an increase in finished water flow from the 50$^{th}$ percentile to the 95$^{th}$ percentile. Each intervention for a pipe breakage resulted in a 1.5% ERR (C195 = [-1.4%; 4.4%]).

Application of the same model to the adult data (CSPad) using finished water turbidity as the sole covariate showed a similar but weaker relationship as that seen in children: IQERR = 2.9% (C195 = (0.5%; 5.4%)). Using the more complex model for adults also showed that CSPad was affected by both finished water turbidity and river flow. However the pattern of changes in risk levels were different in adults and children; when river flow was low, a 0.01 NTU rise in finished water turbidity was associated with a larger increased risk in children (4.3%) than adults (2.6%), but when river flow was high an increase in finished water turbidity was associated with a 5.4% increase in children but a much larger 15.6% increase in adults. The response function to finished water flow also differed between adults and children; in children risk increased as finished water flow increased but in adults the relationship was U-shaped although still highly significant ($P<0.001$). The covariate broken pipes was not significant in the adult model.

The authors conclude that there was a clear association in both children and adults between daily number of specific prescriptions issued by general practitioners for AGE and finished water turbidity. The relationship was stronger at both high and low river flows compared to intermediate flows. The risk was also influenced by finished water flow. However modelling the effect of removing turbidity fluctuations above 0.05 NTU indicated that only 1.9% of child prescriptions and 1.4% of adult prescriptions would be avoided. They suggest that increased disinfection levels would be more beneficial in controlling health risks.

*Comment Viral pathogens are considered the most likely cause of endemic waterborne gastroenteritis in treated water supplies although its very existence remains controversial. Water turbidity in this supply is low, but no information is provided on variations in individual filter performance which may strongly influence overall pathogen removal at times of high challenge. It is also not clear whether interactions between weather parameters, water quality /quantity and disease risks are accounted for in the analysis. For example, seasonal high temperatures are known to be associated with increased risks of foodborne bacterial pathogens and would also be associated with low river flow and high finished water production. The differences between AGE risk patterns in children and adults relative to water quality and quantity parameters are also puzzling.*

Fluoride

**High resolution mapping of reticulated water fluoride in Western Australia: Opportunities to improve oral health.**
Al-Bloushi NS, Trolio R, Kruger E and Tennant M. (2012) Australian Dental Journal, **57**(4); 504-510.

This study examined the distribution of fluoridated drinking water in Western Australia (WA) with the aim of enhancing the understanding of population wide fluoride exposure. About 90% of WA's 2.2 million population receive their drinking water from four regulated scheme suppliers. In this study, three main suppliers (Water Corporation, Remote Aboriginal Essential Services Program (RAESP) and AqWest) were contacted and asked for data relevant to the quality of reticulated water, sampling locations and supply areas. For this study, reticulated water with fluoride concentrations above 0.5 ppm were considered as fluoridated and below 0.5 ppm as not.

There were a total of 338 sample points mapped to WA. These were predominately the 247 Water Corporation sample points, with the majority in metropolitan Perth or other high population density regions. Average yearly fluoride concentrations of water were calculated for each region. A total of 188 (56%) tested points were identified with either an average yearly concentration (Water Corporation) or a most recent test (AqWest and RAESP) above 0.5 ppm. There were 149 test points where fluoride concentrations were below the 0.5 ppm cut-off level. A total of 44% of regions had an average annual water fluoride concentration of less than 0.5 ppm and these were mainly in rural and remote areas. Of the 286 identified Indigenous communities in WA, 84 (29.3%) were covered through the water testing schemes of the providers. Among these communities only 36 (12.5%) had a tested water fluoride level of higher than 0.5 ppm. Of all the 338 test points, 34% were recorded with an average fluoride concentration below 0.3 ppm, using the most recent year of data available. Only 18% had fluoride levels in the range of 0.3 to 0.7 ppm, while 48% were found to be above 0.7 ppm.

This study found that although a very significant proportion of the population has access to water with fluoride concentrations that would protect against caries, most of these are large urban centre based. In WA those with high burdens of dental disease mostly reside in rural and remote areas where water is either not fluoridated, nor regulated, or low in fluoride. However it is acknowledged that water fluoridation, for a multitude of reasons is not always feasible in rural and remote communities. Preventive efforts through alternative fluoride source (e.g. toothpaste) need to be considered, even if they are less effective at a community level.

Household Water Treatment

**Promoting Household Water Treatment through Women's Self Help Groups in Rural India: Assessing Impact on Drinking Water Quality and Equity.**
Freeman MC, Trinies V, Boisson S, Mak G and Clasen T. (2012) PloS one, **7**(9); e44068.

India has over 386,000 deaths attributable to diarrheal diseases per year and ranks first among countries contributing to this worldwide disease burden. Whilst considerable progress has been made in recent years in improving water supplies in both rural and urban settings in India, only 12% of the rural population is served by a household connection. Also surveys of microbial water quality throughout

India have shown extensive faecal contamination of drinking water supplies. Household water treatment and safe storage (HWTS) including boiling, chlorination and filtering water at home, has been shown to be effective in improving the quality of drinking water and preventing diarrheal diseases among vulnerable populations. Only about 10% of the Indian population reports boiling their drinking water before use. Chlorinating water with sodium hypochlorite has not been successfully promoted in India. The use of gravity water filters is one of the HWTS options that has achieved scale nationally however the up-front cost of microbiological quality filters had generally made them too expensive for low-income populations who are at greatest risk. Promotion through microfinance institutions (MFIs) may provide a way to overcome the barriers of access and affordability of HWTS. A pilot program was undertaken to explore the potential for using microfinance institutions to improve awareness of and access to a commercial HWTS products among lower-income rural populations in India. Through the program, women's self-help groups (SHG) members were offered the opportunity to purchase Hindustan Unilever Limited's (HUL's) Pureit® filter and micro loans to mitigate the up-front costs. This study was conducted to evaluate the extent to which the pilot program improved drinking water quality among the target population and therefore achieved health gains.

The study was conducted between September and October 2009 in Andhra Pradesh, India. A case-control study was conducted where a case was a female SHG member whose household has acquired a Pureit; a control was a female member of an SHG that offered loans for Pureit but had not purchased the product. Community respondents were also interviewed to provide comparison of several metrics. There were 33 villages surveyed. Purchasers of Pureit were defined as 'adopters' and adopters who met criteria for use (treated current drinking water with Pureit) as 'users'. The female head of the household was asked about water handling and treatment practices, Pureit purchase and use history and demographic information. Household assets and use of water treatment methods was confirmed with observation when possible. Following survey administration, a sample of water was collected directly from the storage vessel the informant identified to be used for drinking. Samples were also collected from community water sources. Water samples were tested for thermotolerant coliforms (TTC).

The study included 281 adopters, 247 non-adopters and 251 other community members. Adopters were more likely than non-adopters to have children under 5 years, they were more educated, more wealthy, more likely to have access to improved water supplies and more likely to have previously used a water filter. Water quality samples included 520 households and 33 source water samples. There were 273 adopters and 247 non-adopters that had complete data for analysis of household and source samples. In general, water quality at the source was of poor microbiological quality with fewer than 10% of source samples meeting the WHO Guideline for safe drinking water by being free of detectible TTC. Household samples overall had lower levels of faecal contamination compared to source, with about one quarter of household samples with no detectible faecal contamination. Among household samples adopters had better water quality than non-adopters. The geometric mean TTC count was 13.7 (95% CI: 9.9-18.8) among adopters and 44.5 (95% CI: 33.7-58.8) among non-adopters ($p < 0.01$). Respondents that treated their current water with Pureit had the highest proportion of their household samples (43.0%) free of faecal contamination compared to respondents who treated with boiling ($p<0.01$), those who used a ceramic filter ($p=0.01$) or those who used unsafe methods or used no method ($p<0.001$). However, about one-third of water samples from adopter households had TTC levels in excess of 100 TTC/100 ml putting them in the high risk category. Only 73% of households observed to have a Pureit were using their unit to store water at the time of the survey, and fewer than 80% of adopter households reported using Pureit to treat the water they were actually drinking. Over two-thirds of Pureit users required a replacement "battery" (prefilter, chlorine cartridge and carbon media) and yet many continued to use the filter. The poorest households had a smaller proportion of samples with no detectable TTC/100 ml as compared to the least poor (18.4% vs 32.4%, $p=0.007$), and a greater proportion of samples

with more than 100 TTC/100 ml in their household water (45.1% vs 36.2%, p =0.14), though the difference was not statistically significant.

Overall this pilot program resulted in increased water quality among households that adopted Pureit water filter use, however the program only had limited success in achieving its aim of providing safe drinking water to a vulnerable population. This in part could be due to the tendency of adopters to come from potentially lower risk strata having better socioeconomic indicators and being more likely to have previously used effective HWTS products, i.e. boiling and ceramic water filters. Also there were sub-optimal improvements in water quality even among adopters and this is likely to be because of a lack of correct and consistent use of the device. The findings of this study show the need for better monitoring approaches to ensure the technology is benefiting those in greatest need. The challenge is to find strategies to improve the correct, consistent and sustained use of these water treatment products.

**Studies on water purification using clay and organic waste products.**
Sharma P and Godbole S. (2012) Journal of Pure and Applied Microbiology, **6**(1); 297-302.

Indian villagers commonly use earthen pots to store drinking water, and the use of porous clay pots and sandstone receptacles for water filtration dates back hundreds of years in Central American and Asia. The aim of this study was to make a suitable water purification system using locally available resources which could be easily used by individual Indian households for their drinking water needs.

It was decided to use organic materials (tea, coffee and saw dust) in different proportions that were abundantly available in rural areas, to prepare clay pots with. The tea leaves and coffee were washed and dried in a hot air oven. After the three organic materials were mixed in the clay in various proportions, the pots were made using the traditional method on a potter's wheel and then dried and fired in a kiln. These pots were used as the filtration system and water was collected in another earthen receiving pot. The different proportions were marked as 30T, 40T and 50T, 30S, 40S, 50S and 30C, 40C, 50C to represent the amount in grams of tea, saw dust and coffee respectively. A control pot was made with only clay without any organic material in it. Well water samples were collected in sterile water bottles from different areas of Napur city, India and used to study the efficiency of the pots in removing coliforms and faecal coliforms. The time required for complete filtration for 250 ml of well water by the different pot filtration systems was measured and compared. Tests for coliforms and faecal coliforms were conducted using Membrane Filter Technique (MFT) and Most Probable Number (MPN), to determine the efficiency of the clay pots to remove the coliforms. Water samples were tested for the presence of total and faecal coliforms before and after filtration through the clay pots.

Out of the filtration systems, 50T had the fastest filtration rate of 13 hours and proved to be the most efficient in reducing coliform count. It was found that 6 out of 10 samples filtered with 50T gave 99.9% reduction of total and faecal coliforms. The first set of experiments water was treated with $CaCo_3$ and bleaching powder and as a result before filtration very little growth was obtained on the plates of agar. Over a two month period the effect of these chemicals had diminished and as a result heavy growth was obtained on the agar plates in samples tested before filtration. The 50T pot still showed the same results with a 99.9% reduction of total and faecal coliforms.

A clay pot with optimum concentration of organic material could be easily be prepared by the villagers, who regularly use clay/earthen pots for storing their drinking water. This type of system would provide villagers with safe and low cost drinking water.

<u>Comment</u> *Successful implementation of any water treatment device in developing countries would be dependent on a number of features including the capacity to supply an adequate volume of water for the daily drinking requirements of a household. The filtration rate of the device described here appears to be too low to be practicable, and further design improvements would be needed.*