Health Stream

INFORMATION AND ANALYSIS FOR WATER AND HEALTH PROFESSIONALS

Issue 44 *Public Health Newsletter of the CRC for Water Quality and Treatment* December 2006

In this Issue:

Editor Martha Sinclair
Assistant Editor Pam Lightbody

CRCWQT Internet Address:
www.waterquality.crc.org.au

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Australian Guidelines for Water Recycling (Phase 1) Released

The Australian Guidelines for Water Recycling (Phase 1) were released on 24 November following final approval by the Ministers of the Environment Protection and Heritage Council. The guidelines have been developed over the last three years in collaboration with the Natural Resource Management Ministerial Council and the Australian Health Ministers Conference. The development process included a public comment phase on a draft version of the document in late 2005/early 2006 and an international peer review. The Phase 1 Guidelines (subtitled Managing Health and Environmental Risks) focus on:

- large-scale treated sewage and grey-water to be used for:
  - residential garden watering, car washing, toilet flushing and clothes washing;
  - irrigation for urban recreational and open space, and agriculture and horticulture;
  - fire protection and fire fighting systems;
  - industrial uses, including cooling water; and
- grey-water treated on-site (including in high rise apartments and office blocks) for use for garden watering, car washing, toilet flushing and clothes washing.

The document presents a risk management approach for the use of recycled water modelled on the Framework developed for the Australian Drinking Water Guidelines (2004 Edition). The same 12 element structure has been adapted to deal with the management of risks to human health and risks to the environment through the use of recycled water. The Framework addresses not only the technical issues of recycled water supply but also aspects such as corporate commitment, communication, training and relationships with other stakeholders and with consumers. The preventive management approach puts emphasis on comprehensive risk analysis, planning and implementation of risk management measures (eg water treatment and end use restrictions), setting of critical and operational limits, and appropriate monitoring to ensure that management measures are functioning effectively. In addition to detailed guidance on each of the 12 elements, the Guidelines also contain several appendices with case studies on recycled water schemes, information on specific aspects of the methodology used to develop the Guidelines, and reference tables to assist environmental risk assessment. Also included are case studies on communication about recycled water schemes (both successful and otherwise) and a glossary of terms.

Human health risks from recycled water arise mainly from the presence of microbial pathogens in sewage or greywater. Both of these water types contain a broad range of pathogenic microorganisms, and the levels of these must be reduced by treatment so that exposure to recycled water does not pose an unacceptable health risk. A diverse range of chemicals may also be present in sewage and greywater, but human health risks from recycled water produced from these sources and intended for non-potable end-uses are low, provided that contaminant management processes (eg restrictions on industrial waste discharge) are effective.

The Guidelines have used quantitative microbial risk assessment (QMRA) to set health-based targets for recycled water treatment. The QMRA process involves four steps:

Hazard identification - this involves consideration of the range of pathogens which may be present in sewage or greywater, their likely concentrations and the variability in concentrations over time. For each class of pathogens a reference pathogen was chosen to represent the properties of the group. For bacteria the selected reference organism is *Campylobacter*, for protozoa it is *Cryptosporidium parvum*. For viruses there is no single satisfactory reference organism so a hypothetical virus with the dose-response characteristics of rotavirus and the occurrence characteristics of adenovirus was considered.

Dose-response - information on the relationship between the ingested dose of pathogens and the probability of developing infection and illness has been derived from human feeding studies and expressed mathematically. Appropriate dose-response models were available for the reference pathogens.

Exposure assessment - estimates of the volume of water incidentally ingested during use of recycled water for various non-drinking purposes (eg toilet flushing, garden watering) were made. In addition the possibility that some people would ingest larger volumes of recycled water due to accidental cross-connections with drinking water supplies was factored into the calculations. Deliberate misuse of recycled water (eg use to fill swimming pools) was not considered.

Risk Characterisation - the final step in the process is to integrate the information on hazard identification, dose-response and exposure assessment to produce an estimate of the magnitude of risk for each reference pathogen. From this information it is then possible to calculate the degree of pathogen reduction that is required to produce recycled water that meets specific health-based target values.

Two approaches can be used for setting target values with QMRA. Such values can be based on estimations of the annual infection rates for pathogens regardless of their health impact. In other words the same infection target is set for a pathogen which causes mainly short-term gastroenteritis as for a pathogen which tends to cause more serious illness. For the new Guidelines, a different approach has been adopted where health impacts are measured in terms of Disability Adjusted Life Years (DALYs). This approach is also used by the World Health Organisation. It has the advantages of taking into account the consequences of infection (mild, moderate or severe illness, duration of illness, risk of death, and likelihood of long lasting health effects) as well as the probability of infection. The average

DALY value for each reference pathogen is averaged over the population taking into account the frequency of each health outcome. These calculations include consideration of all age groups in the general population but exclude groups with medical conditions which make them highly vulnerable to infection, such as those with severe immunodeficiency. For such groups, additional measures to reduce exposure to infectious agents from recycled water and other everyday exposure sources may be required.

The level of tolerable risk adopted in the Australian Guidelines is 10^{-6} DALYs per person per year. This is consistent with health target values in the current WHO Guidelines for Drinking-water Quality. The level of risk is approximately equivalent to an annual risk of 1 case of diarrhoeal illness among 1,000 users of recycled water, compared to a background risk of about 800-900 cases of diarrhoeal illness per year from all sources. Using this target together with data on the occurrence of pathogens in raw sewage and information on human exposures it is then possible to calculate the degree of pathogen removal necessary to produce recycled water suitable for a given purpose. These calculations show that viruses require a larger degree of reduction than other classes of pathogens due to their high infectivity and higher disease burden.

The highest exposure category considered in the Guidelines (fire fighting, estimated to result in ingestion of 1 litre of water per year) requires a reduction of 6.5 logs for viruses, 5.3 logs for *Campylobacter* and 5.1 logs for *Cryptosporidium*. Domestic use for non-potable purposes (toilet flushing, laundry, garden watering, plus allowance for cross-connection in 1 household in 1000) involves a slightly lower level of exposure (0.67 litres per year) and thus slightly less stringent requirements for pathogen reduction. Health risks from use of recycled water in non-domestic situations can also be managed by implementation of preventive measures at the point of use; for example using subsurface or drip irrigation rather than spray irrigation of crops, or controlling public access during irrigation of public recreational areas.

Public perception is that greywater has a low level of risk but the available information shows that the microbiological quality of greywater is highly variable. There are little or no published data on levels of pathogens in greywater but levels of faecal indicator organisms sometimes approach those found in sewage. Given that greywater recycling schemes are likely to be fairly small in scale, pathogen testing is not considered practicable, so it is suggested that testing for *E. coli* should be used to assess the amount of faecal contamination. The log reduction values used for sewage can then be applied with appropriate adjustment for the level of faecal contamination in the untreated greywater. Concentrations of microbial and chemical contaminants in grey water depend on individual behaviours and the choice of household products, therefore ongoing education of residents is needed to minimise contamination levels. For on-site greywater systems serving single domestic dwellings, less stringent management processes are appropriate, however care is needed to avoid cross-connections to public drinking water supplies.

Key environmental hazards potentially associated with the use of recycled water for agricultural, municipal, residential and fire control purposes include boron, cadmium, chlorine disinfection residuals, hydraulic loading, nitrogen, phosphorus, salinity, chloride and sodium. These may impact on soil, plants, other aquatic or terrestrial biota, surface waters, groundwaters or infrastructure.

Development of Phase 2 of the Guidelines for Water Recycling has commenced. This phase will address:

- use of recycled water for direct or indirect augmentation of drinking water supplies;
- managed aquifer recharge for end uses including drinking water supply, non-drinking purposes and ecosystem protection; and
- urban stormwater reuse.

The draft version of the Phase 2 Guidelines are expected to be released for public consultation by mid-2007.

The Australian Guidelines for Water Recycling (Phase 1) can be downloaded from: http://www.ephc.gov.au/ephc/water_recycling.html

WHO Fluoride Monograph

The World Health Organisation (WHO) has released a monograph on *Fluoride in Drinking-water* to provide member countries with detailed information and guidance on prevention of adverse health effects from excessive levels of fluoride in water. The publication incudes chapters on the occurrence and geochemistry of fluoride in the environment, the sources of human exposure, the evidence for adverse health effects, and application of the current WHO guideline value to local conditions. There is an extensive section on methods used to remove excess fluoride from drinking water, and a description of five commonly used analytical methods for fluoride determination. The final chapter summarises the available data from 28 countries on dental and skeletal fluorisis associated with exposure to fluoride through drinking water. Indices for scoring dental fluorisis are described in an Appendix.

The element fluorine is highly electronegative and exists in nature predominantly as the negatively charged fluoride ion (F^-) which forms complexes with a number of cations. Fluorides are a component of many low solubility minerals including fluorspar, rock phosphate, cryolite, apatite, mica, and hornblende. Fluoride is also associated with volcanic activity and geothermal waters. The concentration of fluoride in seawater is about 1 mg/L while surface waters generally have levels below 0.5 mg/L. The concentration of fluoride in groundwater supplies varies enormously depending on the geological characteristics of the aquifer and the presence of other minerals such as calcium which may limit fluoride solubility. The highest levels reported in groundwaters serving as drinking water sources are around 50mg/L.

Other sources of human exposure to fluoride include air, dental products, and foods and beverages. In non-industrial areas, concentrations in air are generally low. However, industrial production of phospate fertilisers, dust from high fluoride minerals, volcanic activity and burning of high fluoride coal in both industrial and domestic settings make air a significant exposure route in some regions of the world. Dental products such as fluoridated toothpaste, topical treatments and tablets contribute to total exposure where these products are used. Fruit and vegetables generally contain low levels of fluoride (less than 0.4 mg/Kg), although somewhat higher levels have been reported in barley, rice, taro, yams and cassava. Fish (2-4 mg/Kg) contains more fluoride than meat (up to 1 mg/Kg). Both human milk (0.02 mg/L) and cow's milk (0.02-0.05 mg/L) have very low fluoride levels. Western-style diets appear to be relatively low in fluoride but significant exposures from dietary sources may occur in some regions due to local dietary customs or airborne exposures that contaminate crops. The overall composition of the diet may affect fluoride excretion, with a high protein diet reported to result in greater retention of fluoride in the body. There is also some evidence that a nutrient deficient diet is associated with higher levels of both dental and skeletal fluorosis. In most circumstances drinking water is the largest single contributor to total fluoride intake. WHO has previously produced a rough estimate that total daily exposure for adults in a temperate climate without fluoridated water is about 0.6 mg/day, while with fluoridated water the daily intake would be about 2 mg/day.

Ingested fluoride is absorbed from both the stomach and the gut, with the amount available for absorption being affected by cations such as aluminium, calcium and magnesium which form insoluble complexes with fluoride. Fluoride is retained primarily in the bone tissue and the teeth. Fluoride is not considered to be carcinogenic, and early reports of adverse developmental or reproductive effects in animals have not been confirmed by recent studies. Acute poisoning episodes have been associated with overdosing of fluoride in water supplies at levels of 30 mg/L or higher. Adverse effects on teeth and bone are considered to be the most significant effect of chronic exposure to excessive levels of fluoride. Dental fluorosis occurs when children are exposed to excessive levels of fluoride at the time when teeth are forming. The effects can range from mild forms which are not cosmetically significant to severe pitting and discolouration of the teeth. Skeletal fluorosis also ranges from a mild form which is detectable only on X-ray to severe cases where the effects on bone structure are crippling.

The WHO Guideline Value of 1.5 mg/L for fluoride was set in 1984 and confirmed by subsequent reviews of the scientific evidence in 1996 and 2004. This level was set to confer a protective effect against dental decay but avoid significant amounts of dental fluorosis. Clinically significant skeletal fluorosis is believed to occur only with chronic ingestion of water with fluoride levels of 10 mg/L or higher. The guideline is not intended as a universally applicable value; rather it should be modified in the light of local knowledge about water consumption, exposure to other significant sources of fluoride, and other factors such as altitude that are known to affect fluoride retention in the body.

Fluoride can be removed from water by some filtration media and other water treatment methods, however successful application of these interventions requires technical skills that may be difficult to provide and maintain in rural and remote locations. Therefore as a first option for reducing fluoride exposure the possibility of using alternative drinking water sources or blending with low fluoride supplies should be explored. The monograph describes five water treatment methods that are considered to be potentially suitable for developing countries. These methods are based on three basic treatment processes:

- sorption media such as bone charcoal, activated alumina and clay are generally used in the form of packed columns through which water is passed. The media eventually become saturated with fluoride and need to be replaced or regenerated.
- co-precipitation uses chemicals such as aluminium sulphate and lime, or polyaluminium chloride and lime to remove fluoride in a daily batch treatment process. These methods generate sludge which must be disposed of.
- contact precipitation chemicals such as calcium or phophate compounds are added to the water prior to passing through a catalytic filter bed causing the precipitation of calcium fluoride or fluorapatite.

Advanced methods such as reverse osmosis, electrodialysis and distillation, and use of patented media are not considered in the monograph due to their high cost and technical demands.

While there are a number of documented case studies where the relatively low-tech treatments described in the monograph have been successfully applied, there are also many instances where such schemes have failed due to lack of social acceptability, high cost, and inability or failure of users to maintain equipment. Careful consideration is needed to address specific circumstances at the local level including water quality factors, social acceptability, proper system design and knowledge of responsible officials, ensuring availability and affordability of media and spare parts, and provision of continuing efforts to motivate and train users of the system.

High fluoride concentrations occur in groundwaters in three geological settings; in the presence of sediments of marine origin in mountainous areas, in strata of volcanic origin, and in granite and gneissic rocks. Elevated fluoride levels in groundwater occur in areas of Africa, China, the eastern Mediterranean, southern Asia, the Americas and Japan.

In China it has been estimated that over 26 million people have dental fluorosis as a result of excess fluoride in drinking water while a further 16.5 million people have developed dental fluorosis as a result of pollution from burning high-fluoride coal. About two million people in China are believed to be suffering from skeletal fluorosis with about half of the cases attributable to drinking water and half to coal. Fluoride of volcanic origin affects large areas of several African countries lying in the East African Rift system, and endemic fluorosis occurs in more than half of India's 32 states. In the developed world, excessive fluoride levels in groundwater have been most extensively documented in the United States where significant dental fluorosis was once widespread in many states. Indeed it was during investigations of dental fluorosis that the link between low levels of fluoride in drinking water and protection from dental caries was first recognised. In the developing world, skeletal fluorosis remains a significant cause of illness, and further efforts are required to reduce population exposures.

Fluoride in Drinking-water (2006) Fawell J et al. ISBN 92 4 156319 2 WHO Press and ISBN 1900222965 (IWA Publishing). Available from the WHO website:
www.who.int/water_sanitation_health/publications/

Canadian First Nations Water Report

The Expert Panel established in June this year by the Canadian Government to investigate safe drinking water supplies for First Nations* communities has delivered its report. Water safety issues have had a high profile in Canada since the Walkerton outbreak, and a number of recent incidents and reports have highlighted high risk situations existing in many First Nations communities. Most of these communities are small and many are extremely remote. In 2000 it was estimated that approximately 368,000 people were living on First Nations reserves.

The Panel was asked to consider the options for a regulatory framework for First Nations communities located on reserves. This included:

- reviewing examples of regulatory frameworks and regimes from other jurisdictions and countries;
- collecting suggestions from stakeholders, through public hearings and written submissions; and
- drafting a paper for the Minister of Indian and Northern Affairs that would examine options for a regulatory framework; analyze the benefits and drawbacks of each option; indicate issues outside the mandate of the expert panel that would need to be addressed to implement the option; and provide a comparative analysis of all options.

The Panel held discussions with stakeholders at nine public hearings and received written submissions. The first volume of the Panel's report discusses the definition of safe drinking water and the required operational, management and regulatory elements needed to achieve and ensure ongoing safety. The difficulties of supplying safe water to First Nations communities are described, and the main themes raised in the consultation process are outlined. The elements required for a regulatory regime are discussed with reference to the special circumstances relevant to First Nations water supplies, and five possible options to develop a suitable regulatory regime are outlined. The second volume of the report details the current regulatory situation and discusses legal aspects of possible future regulatory systems.

The Panel found that First Nations settlements face many water supply problems that are common to all small communities including high capital and operating costs per connection, difficulty in attracting and retaining skilled personnel, limited capacity to manage and govern systems, delays and high costs in obtaining help and supplies in a crisis, and resistance of some community members to chlorination due to taste concerns. In addition many small communities have source water that is scarce and/or difficult to treat. Additional difficulties specific to First Nations communities included the need to deal with four federal government departments and several different bodies within communities, plus a variable degree of interaction with provincial governments.

In 1977 the Canadian Federal government announced a policy "*to provide Indian homes and communities with the physical infrastructure that meets commonly accepted health and safety standards, is similar to that available in neighbouring, non-Indian communities or comparable locations, and is operated and maintained according to sound management practices*", however funding levels have not been sufficient to accomplish these goals in the area of water and wastewater management. Responsibilities formerly carried by government have been increasingly devolved to the First Nations, but this has not been accompanied by provision of adequate resources to fulfill these responsibilities. The historical and legal background in relation to rights, responsibilities, self government and jurisdiction in Canada is complex and currently there is no regulatory framework for drinking water or wastewater on reserves.

The Expert Panel concluded that although an effective regulatory system is necessary to ensure the supply of safe drinking water, the most critical need is for adequate human and economic resources. Federal government financial support is needed by most First Nations communities as they currently lack the economic capacity to provide the required resources themselves. The Panel advocates significant capital investment to improve water and wastewater systems on First Nation reserves, in addition to development of a new regulatory system.

The Report of the Expert Panel can be downloaded from: http://www.eps-sdw.gc.ca/index_e.asp

* The First Nations are the indigenous peoples of Canada.

Recycled Water Cleared In Outbreak

Investigations into the source of the *E. coli* O157 strain involved in a multi-state outbreak in the US have shown that the contamination originated from animals on one of the farms used to grow the spinach. Some early news reports quoted a local politician who had attempted to draw a link with recycled water and called for a ban on its use for crop irrigation. *E. coli* O157 subtype EXHX01.0124 was identified in clinical specimens from patients and in 11 bags of spinach recovered from nine homes. Packaging codes showed the bags originated from a batch of baby spinach leaves processed at one plant on a single work shift. Produce from four farms had been processed during the shift. An intensive sampling program subsequently identified the outbreak strain at a single farm, where it was detected in a number of domesticated cattle and calves, in one wild pig and in water from a stream. The most likely routes of contamination appear to be direct faecal contamination of the spinach field by wild pigs which broke through a fence, or flooding with contaminated surface water following heavy rain in the area.

Over 200 cases occurred in 26 states and about half of the victims required hospitalisation. Two deaths have been confirmed due to the outbreak, with a suspected third fatality not able to be definitely attributed due to lack of subtyping information. The rates of haemolytic uremic syndrome among both children (39% developing HUS) and adults (10%) has been higher than usual, suggesting this strain is particularly virulent. Only 109 cases of the EXHX01. 0124 subtype have been recorded through the Pulsenet surveillance program from late 1998 when the strain was first identified until the end of 2005, out of about 73,000 *E. coli* O157 infections reported each year in the US. While this infection is predominantly associated with undercooked ground meat products, US health authorities are concerned about a growing number of outbreaks from salad vegetables. Indeed, as the spinach outbreak subsided a new multi-state outbreak of E. coli O157 affecting at least 169 people has been traced to cut green onions (also known as scallions) grown in California, processed in New Jersey and distributed to a fast food chain in several northeastern states.

News Items

Swimmer's Itch Hits Runners

About 320 college students have been affected by an apparent outbreak of "swimmer's itch" following a cross-country running event in the US state of Connecticut. Swimmer's itch (also known as cercial dermatitis) is caused by penetration of the skin by the larval stage of certain schistosome parasites which occur in water. The eggs of these parasites are excreted into fresh water in the faeces of their normal bird or non-human mammalian hosts, where they release miracidia which then infect a water-dwelling snail host. After two generations of growth within the snail, cercariae larvae are released into the water where they may infect a suitable bird or animal to continue the life cycle. The larvae are not able to successfully infect humans and die shortly after entering the skin, but they cause an intense itching within a few hours followed by development of inflammatory papules. Scratching by the victim may lead to subsequent skin infections.

It is believed the runners came into contact with the parasites when they had to wade through 1 metre-deep water following flooding of one section of the course by heavy rain. Over 60% of the competitiors were affected by swimmer's itch, with the severity of symptoms probably exacerbated by the fact that they remained wet due to the rain and many did not have an opportunity to shower and dry off until some hours after exposure. Organisers say the race has previously been run on the same course but no incidents of this nature have occurred before.

NZ Water Filter Test Backfires

The demonstration of a water filtration system by New Zealand inventors backfired badly when four reporters who drank the water produced by filtering a mixture of sewage and polluted river water became ill with gastroenteritis a few days later. The husband and wife inventor team had developed a three-stage filtration system using ceramic and carbon-iodine filters followed by an iodine-removing resin filter for use in developing countries. Several models including a gravity-fed bag that produces 12 litres of water per hour, and a bicycle driven model producing up to 8 litres per minute were developed. Although the units have performed well under laboratory conditions, the demonstration to a group of journalists went wrong when all four who drank the water became ill, with two reportedly needing emergency medical treatment. When asked for comment on the incident, one of the inventor team reportedly said she noticed her husband had not sanitised his hands when assembling the filter after making up the sewage-water mixture, and this may have led to contamination of the filter system.

Refilling The Glass

The Water Services Association of Australia has issued a Position Paper entitled *Refilling the Glass* which explores the issues surrounding water recycling in Australia. The paper is designed to provide Australian communities with information on the issues associated with recycled water use, and to assist informed discussion and debate on the topic. The 40-page document includes:

- an explanation of terminology and a glossary
- an outline of existing water and sewerage systems
- a description of the issues associated with use of recycled water in agriculture
- an explanation of the limitations on non-drinking uses of recycled water in cities
- a discussion of recycling to supplement drinking water supplies
- an explanation of differences between Australian and northern hemisphere population distribution and river systems and how these affect water recycling options
- information on recycling of stormwater and greywater
- appendices on recycled water projects in Australia and overseas, and an advice checklist for water utilities considering supplementation of drinking water supplies with recycled water.

The Position Paper emphasises the need for community acceptance of water recycling schemes and advocates a systematic and transparent process to evaluate water resource options and ensure community confidence in the decision-making process.

The Position Paper can be downloaded from the WSAA website: http://www.wsaa.asn.au/

From the Literature

Web-bonus articles

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

www.waterquality.crc.org.au/pubs

Blood arsenic as a biomarker of arsenic exposure: results from a prospective study. Hall, M., Chen, Y., Ahsan, H.,et al. (2006) Toxicology, **225**(2-3); 225-33.

Endocrine-disrupting compounds: a review of their challenge to sustainable and safe water supply and water reuse. Falconer, I.R., Chapman, H.F., Moore, M.R. and Ranmuthugala, G. (2006) Environmental Toxicology, **21**(2); 181-91.

Evaluating Cryptosporidium and Giardia concentrations in combined sewer overflow. Arnone, R.D. and Walling, J.P. (2006) Journal of Water & Health, **4**(2); 157-65.

Occurrence of Toxoplasma gondii in water from wells located on farms Sroka, J., Wojcik-Fatla, A. and Dutkiewicz, J. (2006) Annals of Agricultural & Environmental Medicine, **13**(1); 169-75.

Validation of a water consumption questionnaire for a study of the adverse health outcomes associated with disinfection by-products. Maskiell, K.E., Heyworth, J.S. and McCaul, K.A. (2006) International Journal of Environmental Health Research, **16**(2); 145-53.

Evaluation of measured and predicted environmental concentrations of selected human pharmaceuticals and personal care products. Liebig, M., Moltmann, J.F. and Knacker, T. (2006) Environmental Science & Pollution Research, **13**(2); 110-9.

Concentrations of inorganic elements in 20 municipal waters in Sweden before and after treatment--links to human health. Rosborg, I., Nihlgard, B., Gerhardsson, L. and Sverdrup, H. (2006) Environmental Geochemistry & Health, **28**(3); 215-29.

The use and performance of BioSand filters in the Artibonite Valley of Haiti: a field study of 107 households. Duke, W.F., Nordin, R.N., Baker, D. and Mazumder, A. (2006) Rural & Remote Health, **6**(3); 570.

Microbiological performance of a water treatment unit designed for household use in developing countries. Clasen, T., Nadakatti, S. and Menon, S. (2006) Tropical Medicine & International Health, **11**(9); 1399-405.

Sustained high levels of stored drinking water treatment and retention of hand-washing knowledge in rural Kenyan households following a clinic-based intervention. Parker, A.A., Stephenson, R., Riley, P.L., et al. (2006) Epidemiology & Infection, **134**(5); 1029-36.

Aluminium

Analysis of the effect of aluminum in drinking water and transferrin C2 allele on Alzheimer's disease.
Rondeau, V., Iron, A., Letenneur, L., et al. (2006) European Journal of Neurology, **13**(9); 1022-5.

Both genetic and environmental factors are known to influence the risk of developing Alzheimer's Disease (AD), and it has been suggested that aluminium (Al) may play a role although this theory remains controversial. Some epidemiological studies have suggested that aluminium in drinking water may be associated with AD risk. Transferrin (Tf) is a major transport protein for both iron and Al. The main variants of the Tf protein are the C1 and C2 alleles. Some previous studies have suggested that individuals carrying the C2 allele may be at greater risk of developing AD, but others have not. This study investigated whether the common C1 and C2 alleles of the Tf gene and exposure to Al in tap water could predispose an individual to developing AD. The combined genetic effects of Tf and the ε4 allele of apolipoprotein E gene (APOE), a major susceptibility factor for AD, was also studied.

Data for this investigation came from the Paquid cohort, complemented by the ALMA+ cohort (*for aluminium-maladie d'Alzheimer*). The baseline Paquid cohort included 3,777 people aged 65 years or older in 1988-1989, living at home in one of the 75 randomised parishes of the administrative areas of Gironde or Dordogne in south-western France. Subjects were randomly selected from electoral rolls and followed up for 10 years. At the same time as the 10-year follow-up of the Paquid cohort, another cohort of 400 subjects was randomly selected (ALMA+). These subjects were aged 75 years or more and lived at home in one of the 14 parishes of the administrative area of Dordogne with mean levels of Al in tap water greater than 50 microg/L, five parishes with levels of 50-100 microg/L and nine parishes with levels of higher than 100 microg/L.

This study included a sub-sample of 292 subjects from the Paquid cohort (seen at the 10-year follow-up) or from the new cohort who volunteered to give a blood sample for ApoE and Tf genotyping and for whom data on Al in tap water was available. The sample included 181 subjects who were exposed to high levels of Al (above 100 microg/L) and 111 subjects exposed to low levels of Al (below 100 microg/L). For each parish a weighted mean of all measurements of Al was calculated by using results of chemical analyses of drinking water carried out by the sanitary administration between 1991 and 1994 for the Paquid cohort and between 1991 and 1997 for the new cohort. Venous blood samples were collected and genotyping of ApoE and Tf was carried out.

The 292 subjects included 55 cases of AD. The frequency of Tf C2 polymorphism was not significantly different between AD and control patients (25.9% vs 20.0%, P=0.68). There was no difference between the control group and the AD population in the frequencies of the different Tf genotypes. The logistic regression analysis with adjustment for potential confounders did not show an increased risk of AD for Tf C2 carriers (OR =0.95, P=0.88). The presence of ApoE ε4 posed a significantly higher risk of AD (OR =3.97, 95% CI = 1.94-8.12, P less than 0.001). The interaction between ApoE ε4 and Al exposure was not significant, nor was the interaction between ApoE ε4 and Tf C2.

The findings of this study showed that neither the TF C2 allele nor the combination Tf C2/Al contributed to the development of AD, however the statistical power was limited because of the small sample size. More studies are needed to clarify the exact effect of Tf and whether exposure to Al affects AD risk.

Comment *Aluminium in drinking water forms only a small percentage of daily aluminium intake, and human volunteer studies have shown the bioavailability of aluminium from food and water is similar. The brain tissue of people with Alzheimer's Disease show disturbed metabolism and distribution patterns for several metals but it is not known whether this is a cause of the disease or an effect.*

Arsenic

Association between arsenic exposure from drinking water and anemia during pregnancy.
Hopenhayn, C., Bush, H.M., Bingcang, A. and Hertz-Picciotto, I. (2006) Journal of Occupational & Environmental Medicine, **48**(6); 635-43.

Several studies have reported anaemia in people highly exposed to arsenic, however there are few reports examining more moderate arsenic levels and no published studies of arsenic exposure and anaemia during pregnancy. Anaemia during pregnancy has been associated with several adverse outcomes including low birth weight, preterm delivery, low Apgar score and perinatal death. This study examined the rates of anaemia in a cohort of pregnant women over time from two cities in Chile with different arsenic exposures from drinking water.

The cohort consisted of about 900 women from two Chilean cities: Antofagasta, with water arsenic levels averaging around 40 microg/L and Valparaiso with low exposure to arsenic in water (less than 1 microg/L). Eligible women were 18 years or older, between their 16th and 35th week of pregnancy at the time of enrolment and used tap water for drinking and cooking. A detailed interview was conducted of all subjects regarding their sociodemographic characteristics, dietary and other lifestyle habits, fluid consumption, exercise, medical history and other factors. The medical records were reviewed and information on haemoglobin (Hgb) and hematocrit (Hct) measurements was obtained as well as other relevant pregnancy and birth information. A subgroup of women provided blood samples which were analysed for various biomarkers including folate and transferrin receptor (TfR) concentrations. Folate and TfR measurements were used as indicators of folate-deficiency anaemia and iron-deficiency anaemia, respectively to differentiate from a potential arsenic-related anaemia.

This study assessed 810 women whose pregnancy resulted in birth of a singleton, live-born infant with information on gestation age and Hgb measurements recorded in their medical records. Hgb and Hct concentrations were found to be very closely and significantly correlated so Hgb concentration was used as the outcome measure for anaemia. Exposure to arsenic was estimated by city on the basis of measurements on water samples taken before and during the study as well as individually for each participant. Individual exposure levels were based on the self-reported consumption of water and water-based drinks and the mean arsenic drinking water concentration in each city. Study participants were classified as anaemic if the Hgb concentration was below 11 g/dL. For the dichotomous analysis folate deficiency was set at 3 ng/mL or less and iron deficiency as TfR above 8.5 microg/mL. Potential confounders examined included maternal age, marital status and smoking during pregnancy, education and income. Maternal body mass index (BMI) was calculated. The adequacy of prenatal care (PNC) was also assessed.

First trimester anaemia was associated with intake of iron supplements (probably because those with low HgB were more likely prescribed iron), low BMI and single marital status, second trimester anaemia was associated with residence in Antofagasta, lower education and lower BMI, and third-trimester anemia was associated with city of residence (Antofagasta), increasing parity, higher PNC scores, and intake of iron supplements. In multivariable analysis an upward trend in the percent of anaemia was found with the progression of pregnancy in both cities. The rate of increase in Antofagasta was significantly higher than in Valparaiso, increasing the gap between the cities. By the third trimester the percent of anaemia in Antofagasta (49%) was nearly three times that of Valparaiso (17%). The measurements of TfR and folate on the subsample of subjects allowed for assessment of the potential difference across the two exposure groups. The results showed essentially no differences in the mean levels of serum folate by city ($P = 0.76$ and $P = 0.91$, respectively).

This study found that pregnant women who consume moderate levels of arsenic in drinking water (40 microg/L) are more likely to develop anaemia. The prevalence of anaemia rose more sharply as the pregnancy progressed among women consuming water with moderate arsenic levels compared with those with negligible drinking water arsenic exposure. The differences in anaemia rates between the two cities were unlikely to be the result of differences in iron or folate deficiency. Further studies are required to differentiate the specific type of anaemia involved, the mechanism by which it is associated with arsenic exposure and the potential detrimental effects to the mother and/or the foetus.

Copper

Evaluation of copper speciation and water quality factors that affect aqueous copper tasting response.

Cuppett, J.D., Duncan, S.E. and Dietrich, A.M. (2006) Chemical Senses, **31**(7); 689-97.

The World Health Organization (WHO, 1998) recommends a limit of 2 mg/L Cu to prevent adverse health effects from copper exposure. The US

Environmental Protection Agency (USEPA) has developed a health-based action level of 1.3 mg/L Cu in drinking water and an aesthetic-based standard of 1 mg/L Cu. The aim of this study was to evaluate the role of free, soluble and particulate copper in taste and do so at concentrations below and near health-based standards. Copper speciation was controlled by the pH and presence of anions.

Four studies were conducted using 36 healthy adults (15 male and 21 female) ranging from 22 to 54 years of age with no previous copper taste threshold experience. Panel members underwent initial training to familiarise themselves with the taste of copper and the sensory test methods. Only one tasting session was administered per day and only one copper concentration was tasted per session. Fourteen Cu concentrations were used for testing.

The first experiment evaluated which copper concentrations consumers could taste in water. The test waters were distilled-deionised water compared to mineralised water at pH 7.4 designed to simulate a typical drinking water from the eastern United States. Copper was added to produce concentrations of 0-8 mg/L Cu in each water type. Under these conditions the mineralised water could contain a maximum of 1.3 mg/L soluble copper with the remainder in particulate form. To decrease the possibility of guessing correctly the one-of-five method was used (four controls and one copper sample). Panelists were asked to taste each sample only once and to choose the "odd" sample. Panelists were exposed to increasing concentration steps within the testing range on subsequent days. Taste thresholds were found to range from 0.4 to 0.8 mg/l Cu and similar values were found for both distilled and mineralised water. The results showed that soluble copper can be readily tasted whether it is free or complexed with anions. Therefore waters containing 1 mg/L free copper or 1 mg/L soluble complexed copper would product the same copper taste intensity.

The second experiment was designed to assess the role of particulate copper in affecting taste. This study used pH 6.5 mineralised water to increase the amount of soluble copper to a maximum of 4 mg/L Cu. The panellists in this experiment were chosen from those who showed particularly high or low taste thresholds in the first experiment. There were 7 panelists who had individual thresholds greater than 8 mg/L Cu in pH 7.4 water. This "insensitive" group was compared to a group of 11 "sensitive" panellists who all had individual thresholds below the level where particulate copper began to form (at about 1 mg/l Cu). The 11 sensitive panelists would detect the taste of copper in a soluble form at pH 5.5, 6.5 or 7.4 and therefore act as the control group. Five of the 7 insensitive panellists were able to taste copper in the pH 6.5 mineralised water that provided them with 2.7 mg/l more soluble copper than was available in the pH 7.4 water. Therefore soluble copper seems to play an important role in the taste sensation and particulate copper is poorly tasted if at all.

The third experiment was conducted to determine if panellists would perceive the sample with more soluble copper as having more copper taste. Twenty-one panellists took part in this experiment. The reference sample consisted of pH 9 mineralised water containing 1 mg/l total copper of which 0.25 mg/l was soluble and 0.75 mg/l was particulate. The comparative sample was either the same as the reference sample and used to measure the placebo effect or consisted of pH 7 mineralised water containing 1 mg/l total copper that was all in soluble form with no particulate copper present. The comparative sample with more soluble copper was found to have a more intense copper taste than the reference sample. Therefore when the soluble copper concentration was increased but the total copper kept the same, the sample with more soluble copper was perceived as having a more intense copper taste while the particulate copper was poorly tasted.

The forth experiment investigated the role of particulate copper in affecting taste perception using pH 8.5 mineralised water with 4.7 mg/l particulate copper and 0.3 mg/l soluble copper. All 36 panellists were included and samples were presented in semitransparent blue cups of shallow depth to prevent visual detection of copper precipitate. Detection of a copper taste in the pH 7.4 control sample was significantly different ($P = 0.023$) from the pH 8.5 mineralised water. Seven of the panellists who did not taste copper in the control tasted it in the pH 8.5 water. Five of these seven panellists had copper thresholds relatively close to the soluble limit of the pH 8.5 water (0.3 mg/l Cu). Particulate copper may therefore have some role in taste perception but not to a great degree. It is also possible that particulate copper may become soluble due to dilution and pH changes in the mouth in the presence of human saliva.

It was found that 70% of the panellists could taste copper at or below a concentration of 1 mg/l, while

75% of the panellists could taste copper at or below the health-based standards of USEPA or WHO. Therefore only a minority of the population could potentially ingest higher levels of copper without having an adverse effect on taste.

Comment *Taste thresholds for copper may be higher in beverages (coffee, tea, cold drinks made with tap water) than in plain water, however solubility and bioavailability may also be affected. The most common adverse effects of excess copper exposure in the short-term are gastrointestinal (nausea, vomiting, diarrhoea). Prolonged high level exposure may lead to liver damage, although this effect also appears to be associated with genetic susceptibility.*

Cyanobacteria

Cyanobacterial lipopolysaccharides and human health - a review.

Stewart, I., Schluter, P.J. and Shaw, G.R. (2006) Environmental Health: A Global Access Science Source, **5**(7).

Cyanobacterial lipopolysaccharides (LPS) are frequently quoted as being responsible for a variety of health effects in humans including gastrointestinal illness, cutaneous signs and symptoms, allergy, respiratory disease, headache and fever. This paper presents a review of the literature on cyanobacterial LPS to assess the strength of evidence on adverse health effects. Information on Gram-negative bacterial LPS is also presented including mechanisms of toxicity, the history of its discovery and the present perception of its pathogenicity.

The review demonstrated that references in the literature to the association between cyanobacterial LPS and the rather diverse range of symptoms were not based on any research evidence specific to cyanobacterial LPS. The symptoms attributed to contact with cyanobacterial LPS seem to be a default diagnosis for illnesses that can not otherwise be explained by the current knowledge of specific cyanobacterial exotoxins. There is also confusion in terminology even in the recent literature where specific toxins such as hepatotoxins are sometimes incorrectly referred to as endotoxins.

Toxic properties were attributed to cyanobacterial LPS dating from the 1970s when it was thought that lipid A, the toxic part of LPS, was structurally and functionally conserved across all Gram-negative bacteria. More recent research has shown however that the endotoxic potential varies enormously across Gram-negative bacteria. In addition cyanobacteria have an unusual cell wall architecture which has sometimes been described as having features of both Gram-negative and Gram-positive organisms. Aquatic cyanobacteria will have experienced very different selective pressures to gut-dwelling Gram-negative bacteria which may be reflected in different lipid A structures (cyanobacterial lipid A structures have not yet been characterised). The small number of formal research reports which are available describe cyanobacterial LPS as weakly toxic compared to LPS from the *Enterobacteriaceae*.

Cyanobacteria-related illnesses are viewed as intoxication rather than infection mostly on the basis of sudden onset of symptoms occurring soon after exposure and the lack of secondary cases. Two research groups have claimed that cyanobacteria may be capable of establishing infections if ingested, but this view is not widely accepted and is not supported by clinical evidence. Observations on the behaviour of Gram-negative bacterial LPS in the gut cast doubt on the idea that cyanobacterial LPS alone could be responsible for initiating acute gastro-intestinal illness in human by the oral route. The normal bacterial flora of the human gut contains large numbers of Gram-negative bacteria, and it is evident that the presence of endotoxin derived from these organisms does not usually cause adverse effects.

The authors also note that there does not appear to be adequate evidence to suggest that cyanobacterial LPS is likely to initiate cutaneous reactions in healthy people exposed in recreational or occupational settings, but do not discuss this aspect in detail as it has been reviewed it in other publications. The most plausible exposure route by which cyanobacterial LPS may cause illness appears to be inhalational exposure during recreational water activities. There is ample evidence that Gram-negative LPS can produce measurable airway function changes in animal models and in some healthy individuals. Adverse health effects have been well documented in occupational settings involving inhalation of organic dusts containing Gram-negative LPS, and there are a small number of reports of similar effects from inhalation of water aerosols containing high numbers of Gram-negative bacteria. However to date there is no convincing experimental evidence supporting similar effects for cyanobacterial LPS. The authors consider that cyanobacterial exotoxins may be more likely to produce respiratory illness in non-atopic individuals, with endotoxins from cyanobacteria or commensal bacteria possibly augmenting the symptoms. The question remains on the potential for cyanobacterial and/or contaminant endotoxin alone to produce symptoms by inhalation exposure.

Overall, there was not sufficient evidence in the literature to suggest that cyanobacterial LPS, in the absence of other virulence factors, is responsible for acute gastrointestinal, dermatological or allergic reactions from natural routes of exposure in humans. The authors recommend that the practice of attributing a diverse range of clinical symptoms to cyanobacterial LPS should cease until appropriate and specific research is undertaken to support or refute this hypothesis.

Household Interventions

Preventing diarrhoea with household ceramic water filters: assessment of a pilot project in Bolivia.
Clasen, T.F., Brown, J. and Collin, S.M. (2006) International Journal of Environmental Health Research, **16**(3); 231-9.

Diarrhoeal diseases in Bolivia are the main cause of morbidity among children under 5 years of age with an estimated 500,000 cases and 7,900 deaths annually. Systematic reviews of water quality interventions have shown that treatment of water at the household level is more effective in preventing diarrhoea than improvements of water quality at the source. A pilot project to introduce ceramic water filters to a remote village in central Bolivia was implemented by the Food for the Hungry International (FHI). This project was assessed by conducting a five-month randomised controlled trial of all the households in the pilot community.

The study site was located in a rural community (Chiniri) along the Arque River. Household water is mainly piped from the river or from irrigation canals fed by the river, via cisterns to private or shared taps. Some households take their water directly from the canals. Both the surface water and the piped water were shown to be faecally contaminated. The intervention consisted of a gravity-fed filtration system assembled on-site using two stacked 15 l transparent plastic buckets. Two ceramic filters (commonly referred to as candles) were threaded through rubber washers and a hole manually drilled into the bottom of the top bucket and a tight-fitting lid on the bottom bucket. Raw water is pored into the top bucket and it passes through the ceramic candles into the bottom bucket where it is accessed by a tap.

All 60 households in the community agreed to participate. A baseline survey was conducted in June 2003 where the head of each household provided information on family members, household water supply and handling, sanitation facilities, hygiene instruction and practices and other variables that could be associated with differences in household drinking water quality and diarrhoea. Households were randomly allocated into the intervention group (n=40) or the control group (n=20). Half of the households in the intervention group received a filter fitted with Katadyn candles (nominal pore size 0.2 microns, silver impregnated, 2-3 years useful life) and the other half had a filter fitted with Stefani candles (nominal pore size 1.0 microns, silver coated, 8-12 months useful life). The intervention group was instructed to use filtered water for drinking, cooking and washing fruits, vegetables, plates and cooking utensils. The households in the control group were asked to continue using their usual practices for water handling. An investigator made follow-up visits over 5 months to collect data on water quality (2 visits) and diarrhoea (5 visits).

At the first two follow-up visits, water samples were taken from each household. Water from the intervention groups was sampled directly from the filter tap and water from the control group was sampled from the household tap or stored vessel used by the household to fill a drinking cup. At each of the follow-up visits the female head of household was asked to recall episodes of diarrhoea among all household members in the 7 days preceding the visit. In March 2004 a cross-sectional survey was conducted to determine the use and effectiveness of the filters *in situ* after 9 months.

In the water sampled in the two visits following the introduction of the intervention, water samples from the intervention groups were significantly lower in thermotolerant (faecal) coliforms (TTC) and turbidity than samples from the control households. Of the intervention households, 100% and 89% of samples from the filters were free of TTC at the first and second rounds of testing respectively. Water samples from the control households had a mean TTC count of 108 TTC/100 ml compared to 0.13 TTC/100 ml from the intervention households, a difference of 99.9% (*p* less than 0.0001). Water samples from the control group households had a mean turbidity of 24.5 NTU compared to below 5 NTU for the intervention group.

At baseline the prevalence of diarrhoea among the entire study population was 9.9% in the previous 7 days. Over the study period, the all-age prevalence in the intervention group was 2.9% compared to 5.3% in the control group, a reduction of 45.3% (*p*=0.02). After adjustment for household clustering and repeated episodes in individuals and controlling for age and baseline diarrhoea the protective effect of the filter was borderline significant (OR 0.49, 95% CI: 0.24, 1.01, *p*=0.05); the effect was less significant among children under 5 years of age (OR 0.48, 95% CI: 0.22, 1.08, *p*=0.08). At the 9 month visit, 67% of the filters of the 48 households visited were found to be in regular use, 13% were in intermittent or occasional use and 21% were not being used at the time of the visit. Reasons for not using the filter included it being too slow for their needs (31%), the filter was broken (25%), and not knowing how to use it (13%). Clogging of filters with high turbidity water was also a problem. All of the samples of the filtered water from filters in regular use were found to be free of TTC. The main concern expressed by users during the follow-up was that replacement candles were not available locally and as a consequence some users avoided regular cleaning of filters due to fear of breaking the unit.

This study provides additional support for the WHO-backed strategy to promote household water treatment as an alternative means of gaining the health benefits of safe drinking water while the provision of regulated, piped-in water supplies is pending. The authors note that the high compliance with filter use after 9 months is encouraging and there appears to be very little information available on long term compliance with other household interventions. The present study was not of sufficient duration to examine the lifespan of the two different filter brands but additional follow up is planned. There is also a need to address concerns about rates of filtration to improve acceptability of the intervention.

Rainwater

Consumption of untreated tank rainwater and gastroenteritis among young children in South Australia.

Heyworth, J.S., Glonek, G., Maynard, E.J., Baghurst, P.A. and Finlay-Jones, J. (2006) International Journal of Epidemiology, **35**1051-8.

Rainwater is the main source of drinking water for 82% of rural households in South Australia however consumption of rainwater may be associated with health risks from faecal pathogens arising from birds and animals. This study aimed to determine the incidence of gastroenteritis among 4- to 6-year old children in rural South Australia and the Adelaide Hills and to determine whether the risk of gastroenteritis among 4- to 6-year old children who drank tank rainwater differed from that of children who drank treated public mains water.

A total of 1042 children were recuited into the study from among 9543 who had participated in an earlier survey on gastroenteritis and water consumption. Participants completed a baseline questionnaire, a daily diary (covering 6 weeks) and telephone questionnaires at 3 weeks and 6 weeks. The diary collected gastrointestinal and respiratory symptoms, water consumption and risk factors that were likely to vary on a daily basis. Respiratory symptoms were included in order to distinguish between gastrointestinal symptoms occurring due to respiratory illness rather than gastroenteritis. In the 3 and 6 week questionnaires, data was collected on any action taken as a result of the gastroenteritis and the parents' belief of the cause. Gastroenteritis was defined on the basis of a cluster of symptoms (defined as highly credible gastrointestinal illness or HCGI) similar to previously published studies.

There were 982 parents who completed at least one part of the study and 965 who completed all of the study. Over the 6 week diary period there were 524 episodes of HCGI among 965 children, 33% (*n* = 317) had one episode, 9% (*n*=84) had two episodes and 1% (*n*=13) had three episodes. The incidence rate of all HCGI was 5.3 episodes per child-year (95% Confidence Interval: 4.9-5.8 episodes per child-year). Excluding those episodes that had associated respiratory symptoms and those that occurred on the first day, the incidence of non-respiratory HCGI was 3.8 episodes per child-year (95% CI: 3.5-4.3 episodes per child-year). Most of the episodes of HCGI were mild, lasting only one day. In the initial analysis considering only drinking water sources the incidence of HCGI per child-year was significantly greater among children who drank public mains water only compared with those who drank tank rainwater only, 7.3 (95% CI: 6.0-8.9) vs 4.7 (95% CI: 4.1-5.4) episodes per child-year respectively. However in the final multivariable logistic regression analysis (adjusting for other risk factors) the adjusted odds ratio for gastroenteritis associated with rainwater consumption compared with mains water consumption was not statistically significant, 0.84 (95% CI 0.63-1.13). Cleaning of rainwater tanks by householders was rudimentary, although most reported that roof catchments were free of overhanging trees (77%) and gutters had been cleaned in the last year (65%) .

The incidence of gastroenteritis found in this study was high compared with that reported in previous community studies but most episodes of gastroenteritis were mild. Consumption of tank rainwater did not increase the risks of gastroenteritis compared with public mains water for four to six year old children. One possible reason for the lack of an observed increase in odds of gastroenteritis associated with tank rainwater is acquired immunity to a range of potential microbial contaminants. Nearly all the children who drank tank rainwater in this study had drunk this water for more than a year and could have developed immunity to some organisms present in rainwater during this time. Thus these results may not reflect the risk to new users of rainwater tank water supplies and further studies are needed to clarify this.

Norovirus

Short- and long-term variations of norovirus concentrations in the Meuse river during a 2-year study period.

Westrell, T., Teunis, P., van den Berg, H., et al. (2006) Water Research, **40**(14); 2613-20.

Noroviruses (NoV) are highly infectious and are believed to be the most common cause of gastroenteritis in people of all age groups. This pathogen has been reported with increasing frequency as an agent of waterborne gastroenteritis. This study was undertaken to quantitatively describe NoV concentrations in surface water over one year and to perform statistical analysis using adaptive dynamic filtering to study the occurrence of peaks and possibly their shapes and/or magnitude.

Water samples were collected from the river Meuse at the intake to the Biesbosch storage reservoirs that serve as the raw water supply for several waterworks in the southern and western parts of The Netherlands. Large volume water sampling (200-500L) of the river was conducted monthly during 2001. An intensified sampling was subsequently carried out between 9 December 2002 and 10 January 2003 with weekly large volume water samples followed by small volume water samples (10L) from each of the four consecutive days. Turbidity was determined in the water samples. NoV were detected using RT-PCR assay on serially diluted RNA extracts. Concentrations of rotaviruses, enteroviruses and F-specific bacteriophages were also determined. Time series of observations were analysed with an adaptive dynamic filtering method. This procedure consists of two stages applied alternatingly: a prediction and a correction stage. It allows prediction of forthcoming sample concentrations based on previous samples.

During 2001 NoV were found in surface water in high concentrations in the winter months with a maximum concentration of about 240 pdu/L (PCR detectable units) in January. There were no positive samples between the middle of February until the beginning of October apart from one sample in May. No rotaviruses could be detected in any of the samples taken during 2001. Enteroviruses were detected throughout the whole of 2001 ranging in concentration from 0.003 to 0.90 pfu/L, with minor peaks in March-April and October-December. F-specific bacteriophages ranged in concentration from 6 to 7400 pfu/L with the highest concentrations found in February and the end of November. Turbidity levels were higher in March and April as compared to the rest of the year. There was a common trend found for all viruses and turbidity with the occurrence of two coinciding peaks early in 2001 (January-April) and late 2001 (October–December).

The intensified sampling program from December 2002 to January 2003 found NoV in all samples, ranging from a mean of 12 to 1700 pdu/L. The peak levels were about ten-fold higher (2000-3000 pdu/L) in 2002/2003 than in 2001. The intensified sampling showed the winter peak consisted of several shorter peaks of varying magnitude and duration. One sample in 2002 was found positive for rotavirus at 32 pdu/L. The concentration of F-specific bacteriophages was fairly constant during the sampling period apart from a peak of 5100 pdu/L in the second half of December. There was a considerable increase in turbidity over the sampling course with two distinct peaks in the beginning of January at 69 and 67 NTU, respectively. Unlike 2002, fluctuations in F-specific bacteriophages and turbidity did not coincide with the peaks found in NoV concentrations.

The peak concentrations of NoV found in 2001 were estimated to occur during 5% of the year. In 2002/2003 peaks were predicted to occur more frequently. The annual median concentration in 2001 based on the probability density function was 0.062 pdu/L compared to a median of 151 pdu/L during the winter peak in 2002/2003.

In summary, NoV were found in the river Meuse mostly during winter, concurrent in time with NoV outbreaks in the Dutch population. The shorter peaks of varying duration found with the intensified sampling could be the result of different types of events in the catchment or they may be due to the presence of different NoV variants. The concentration of NoV could constitute a significant health risk to people using the water (presumably for recreational purposes although this is not stated in the paper), and if treatment is insufficient viruses could be transmitted via drinking water. This methodology could become a useful early warning system in risk management of water sources.

<u>Perchlorate</u>

Thyroid function and perchlorate in drinking water: an evaluation among California newborns, 1998.

Buffler, P.A., Kelsh, M.A., Lau, E.C., Edinboro, C.H., Barnard, J.C., Rutherford, G.W., Daaboul, J.J., Palmer, L. and Lorey, F.W. (2006) Environmental Health Perspectives, **114**(5); 798-804.

It has been estimated that environmental emissions of perchlorate may have resulted in levels of greater than 4 ppb (micrograms per litre) in the drinking water supplies serving around 11 million people in 35 U.S. states. The detection of perchlorate in a number of groundwater sources in the U.S., including the groundwater in many communities in California has raised concern about potential health impacts. Of particular concern is the potential disruption of the thyroid in the newborn and subsequent neurodevelopmental effects. The aim of this study was to assess and compare rates of primary congenital hypothyroidism (PCH) or high thyroid-stimulating hormone (TSH) levels among newborns in California communities with and without detectable perchlorate in their drinking water supplies, and to evaluate the extent to which inconsistent results of previous studies could be the result of methodological differences.

The study population included all California newborns screened by the California Newborn Screening (NBS) Program in 1998 whose mothers resided in communities where groundwater drinking sources were tested for perchlorate by the California Drinking Water Program (DWP). Newborns exposure was based on the average perchlorate concentration calculated from the mother's city of residence. The 1997 and 1998 DWP testing data for approximately 200 California communities was used. There were 342,257 newborns identified with complete data residing in communities where groundwater wells were tested for perchlorate. Of these newborns there were 50,326 newborns from 24 communities residing in areas with average perchlorate concentrations on drinking water sources above 5 microg/L and 291,931 newborns from 287 communities residing in areas with average perchlorate concentrations less than or equal to 5 microg/L. To consider the potential impact of the Colorado River as a source of perchlorate, a subgroup analysis of 102,966 newborns from communities that did not receive Colorado River water and where groundwater was tested for perchlorate and 239,291 newborns who lived in areas that received Colorado River water was undertaken. The Colorado River has various concentrations of perchlorate contamination in different sections of the river.

There were 15 cases of PCH in 1998 in areas of California where perchlorate was detected at average concentrations of above 5 microg/L (20.4 cases were expected) [adjusted prevalence odds ratio (POR) = 0.71; 95% confidence interval, 0.40-1.19) and 126 cases of PCH from communities with average concentrations of perchlorate in drinking water less than or equal to 5 microg/L. For newborns in the normal birth weight category, the POR was slightly lower than for newborns from communities with average perchlorate concentration above 5 microg/L

(POR = 0.64; 95% CI, 0.32-1.15) than the results for all birth weights. When PCH cases were compared in communities with average perchlorate concentrations above 5 µg/L that did not receive Colorado River water, an excess number of cases was not found, nor was an excess number of cases seen among the population receiving Colorado River water as a drinking source.

There were 684 newborns identified as having high TSH levels among the 342,257 newborns screened from communities where drinking water was tested for perchlorate. Of these 537 (78.5%) were from communities with average perchlorate concentrations in drinking water of 5 microg/L or less, and 147 (21.5%) were from areas with average perchlorate concentrations above 5 µg/L. California communities that did not receive Colorado River water but had average perchlorate concentrations above 5 µg/L were compared and there was no excess risk of high TSH levels found. The majority of newborns with high TSH levels (79.7%) were screened within the first day. As TSH concentrations rise rapidly in the first 12 hours of life then decline and stabilised by 24 hours after birth, the results for newborns screened before 24 hours were uninformative for assessing an environmental impact. For newborns screened at 24 hours or later, the adjusted POR for high TSH was 0.73 (95% CI, 0.40-1.23).

This study found that exposure to perchlorate in drinking water supplies in California at the levels reported did not appear to be associated with either PCH or high TSH levels. This is consistent with the findings of a recent review by the National Research Council which concluded that the data across animal, human volunteer and epidemiological studies was not consistent with a causal associations between exposure to perchlorate in drinking water and either congenital hypothyroidism or thyroid function in normal full-term newborns.

Pollution Tracing

Combined sewer overflows to surface waters detected by the anthropogenic marker caffeine.

Buerge, I.J., Poiger, T., Muller, M.D. and Buser, H.-R. (2006) Environmental Science and Technology, **40**(13); 4096-102.

Phosphorus is a key factor in the eutrophication of lakes, and this contaminant may enter water bodies from domestic wastewater, agricultural runoff or geological sources. Characterising the relative importance of these sources is necessary if eutrophication levels are to be managed. In the densely populated catchment area of Greifensee in Switzerland, nearly all the households are connected to wastewater treatment plants (WWTPs). In combined sewer systems however, the capacities of WWTPs and retention basins may be exceeded during or after rain events with untreated wastewater being discharged to the receiving water (combined sewer overflows, CSO). It is difficult to quantify these wastewater discharges as there are usually numerous retention basins with overflows situated in different locations throughout the catchment area. Chemical markers may be helpful for detecting wastewater inputs from combined sewer overflows. This study aimed to assess caffeine as a suitable chemical marker to estimate the fraction of sewer overflows in the catchment area of Lake Greifensee.

More than 99% of caffeine is mostly eliminated in the WWTPs of the Greifensee region with loads of less than 0.15 mg/person/day remaining in treated wastewater. In contrast the load in influent waste water ranges from 10-13 mg/person/day. In the receiving streams of Greifensee, caffeine loads were found to be higher (0.1 -1.6 mg/person/day) than those in WWTP effluents, which indicates additional sources. It was concluded that combined sewer overflows were the most probable source of caffeine as the loads in the streams correlated with precipitation during sampling.

From mass balance calculations for caffeine, it was estimated that the fraction of untreated wastewater discharged to the two major inflows of Lake Greinfensee was up to 10% during the period of observation (9 weeks in Summer 2002). An alternative explanation may be that elevated loads of caffeine in receiving waters during heavy rainfall may be the result of lower elimination efficiencies in WWTPs at higher throughput of (diluted) wastewater and therefore shorter residence time in the plant. However studies have shown that caffeine removal efficiency declines only slightly with increasing throughput of sewage.

Sources of phosphorus inputs to Greifensee were estimated applying the concept of caffeine as a Two marker for combined sewer overflows. It was found that CSOs contributed a similar amount of phosphorus as WWTPs annually, and that the estimates of phosphate input derived from this study closely matched those from other independent assessments.

This study shows caffeine can successfully be used as a marker for combined sewer overflows to surface waters if region-specific conditions are considered. Proportional sampling over 24 hours is important to account for peaks and troughs in the caffeine content of wastewater.

Radium

Radium-contaminated water: a risk factor for cancer of the upper digestive tract.
Hirunwatthanakul, P., Sriplung, H. and Geater, A. (2006) Asian Pacific Journal of Cancer Prevention: Asian Pacific Journal of Cancer Prevention, **7**(2); 295-8.

There is a 3 to 4 times higher incidence of oral cavity, pharynx and oesophagus cancer among males in the Na Mom district in Songkhla Province in Thailand than in other areas in this province. The Na Mom area contains higher concentrations of uranium in granite bed rock than other nearby districts. Faults in the rock allow dissolution of heavy metals, including radium (an important daughter element of uranium) in underground water. Shallow well water in the area has been found to contain radium in concentrations ranging from 3.51-292.1 mBq/litre. The United States Environmental Protection Agency (USEPA) has set a maximum allowed radium concentration in drinking water of 185 mBq/litre. Shallow well water has been the main source of drinking water in the area until recently when piped water has been supplied to some areas. This population-based case-control study investigated whether the contamination of radium in the well water is responsible for the very high incidence of cancer of the upper digestive tract in this area.

Cases or oral cavity, pharynx and oesophagus cancer in residents in Na Mon district were identified from 1999 to 2004. There were 32 cases with a pathological diagnosis. Only two were living and 30 were deceased. Four controls were selected for each case from the general population of Na Mom within the same sex and 5-year birth cohort stratum. All of the cases and controls were permanent residents of the district for more than 10 years. Participants were interviewed (or relatives interviewed for those who were deceased) as to the amount of drinking water consumed per day, tobacco smoking, alcohol drinking, betel chewing and exposure to other potential risk factors in the past. The level of radium contamination in shallow well water was estimated at the subject's house location using a GIS map. Exposure to radium-contaminated water was estimated by multiplying the daily volume of drinking shallow well water (litres/day) by the concentration of radium (mBq/litre) in shallow well water, estimated at the subject's house location.

A strong and dose-dependent association was found between consumption of radium-contaminated shallow well water and cancer of the upper digestive tract. In a multivariate analysis after adjustment for important risk factors, the odds ratios for exposure to oral radium consumption of 50-100 mBq/day and more than 100 mBq/day compared with less than 50 mBq/day were 2.83 (95% CI: 0.50-16.19) and 29.76 (95% CI: 4.39-201.6) respectively. Tobacco smoking and betel quid chewing were identified as significant risk factors but not alcohol consumption. Consumption of freshwater fish was also identified as a risk factor of cancer of the upper digestive tract. Frequent consumption of sea food and vegetables was associated with a decreased risk of cancer.

This study suggests that exposure to radiation-contaminated drinking water is likely to increase the risk of developing cancer of the upper digestive system , especially in the southern region of Thailand where uranium and radium are significant components of the granite rock. The finding of an increased risk from freshwater fish consumption was not expected. It is possible that the freshwater fish in the area might be contaminated with dissolved radium ions in the water. Further investigation is needed to confirm the results found here.

Comment The authors note that no information is available about variation in radium levels in groundwater over time and the exposures relevant to these cancers would have occurred some decades before the water tests were performed. The study is limited by a small sample size and the necessity to conduct proxy interviews for the majority of cases.

Recreational Water

Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness.

Wade, T.J., Calderon, R.L., Sams, E., Beach, M., Brenner, K.P., Williams, A.H. and Dufour, A.P. (2006) Environmental Health Perspectives, **114**(1); 24-8.

About 89 million people in the United States who swim in recreational waters each year. Indicator organisms are used to indicate the presence of sewage and faecal contamination of recreational and drinking waters, however current microbiological methods require at least 24 hours to obtain results, which makes it not feasible to assess the water quality in a day. A modified version of polymerase chain reaction (PCR), quantitative TaqMan PCR (QPCR) has been developed to quantify indicator bacteria in recreation waters in 2 hours or less.

A prospective cohort study of beachgoers at two beaches in the Great Lakes region was undertaken. Beach A was located in the Indiana Dunes National Lakeshore, in Indiana on Lake Michigan and beach B was located near Cleveland, Ohio on Lake Erie. Both beaches were affected by discharges from waste treatment plants. A health survey of beachgoers was administered in three parts: enrolment, beach interview and telephone interview. The beach interview included questions on demographics, swimming and other beach activities, consumption of raw or undercooked meat or runny eggs, chronic illnesses, allergies, acute health symptoms in the past 48 hours, contact with sick persons in the past 49 hr, other swimming in the past 48 hr, and contact with animals in the past 48 hours. The telephone interview was conducted 10-12 days after the beach visit and consisted of question about health symptoms experienced since the beach visit, other swimming or water-related activities, contact with animals and consumption of high-risk foods since the beach visit.

Two water samples were collected three times a day along three transects perpendicular to the shoreline at beach A for each study day including weekends and holidays. Samples were collected three times a day at nine beach B locations for the study period. QPCR was used to detect and quantify *Enterococcus* and *Bacteroides* in water samples based on the collection of these organisms on membrane filters, extraction of their total DNA and PCR amplification of a genus-specific DNA sequence using the TaqMan PCR product detection system.

Data were analysed for 5,667 individuals who reported no GI illness at the baseline interview. The incidence of GI illness among swimmers at beach A was 10% compared to 5% among nonswimmers. The incidence among swimmers at beach B ranged from 12% for those with any contact with water to 14% among those who immersed their head compared to 10% in nonswimmers. At beach A, those with any contact with water were almost twice as likely to have GI illness compared with nonswimmers [adjusted OR (AOR) = 1.96; 95% confidence interval (CI), 1.33-2.90]. Those who immersed their body and head were at slightly higher risk (for body immersion: AOR = 2.26; 95% CI, 1.51-3.39; for head immersion: AOR = 2.14; 95% CI, 1.41-3.27). The risk of GI illness associated with swimming was slightly less at beach B (for head immersion: AOR = 1.50; 95% CI, 1.06-2.13).

At both beaches a trend between increasing mean $\log_{10}$ QPCR cell equivalents (QPCRC) of *Enterococcus* and risk of GI illness was found. Bacteroides QPCRCE was positively associated with illness at beach B, but trends were of borderline statistical significance (p less than 0.1). No association was found between Bacteroides QPCRCE and GI illness at beach A. Trends tended to be stronger when swimming was defined as body or head immersion than when swimming was defined as any contact with water. When the results of both beaches were combined, significant trends with both daily averages and averages of samples collected at 0800 hr only were found. The trend between increasing Enterococcus QPCRCE with illness was stronger among swimmers who spent more time in the water.

This is the first study to show the ability of rapid indicator methods to predict health effects. Using more rapid methods will result in the ability to make decisions about recreational water on the day the samples are collected and this therefore has the potential to significantly reduce GI illnesses in communities and also to reduce errors in beach closing or public notifications.

Uranium

Analysis of uranium in drinking water samples using laser induced fluorimetry.
Rani, A. and Singh, S. (2006) Health Physics, **91**(2); 101-7.

This study was undertaken to estimate naturally occurring uranium concentrations in drinking water collected from some areas of Punjab and Himachal Pradesh using laser induced fluorimetry, and to observe the trend in the variation of uranium content in drinking water sources from Punjab to Himachal Pradesh. A few of the collected water samples were also analysed using the fission track registration technique.

There were 55 drinking water samples from 7 sites analysed for uranium concentration using laser induced fluorimetry (4 to 13 samples per site). The uranium concentration in the Punjab drinking water samples was in the range of 1.39 ± 0.16 to 98.25 ± 2.06 ppb and in Himachal Pradesh 0.16 ± 0.08 to 18.13 ± 0.84 ppb. The uranium concentration in 10 of the 23 samples from Punjab exceeded the safe limit as recommended by WHO (2003). All except one of the water samples from Himachal Pradesh were well within the safe range. Overall about 20% of the samples had uranium concentrations that exceeded the recommended safe limit. The annual effective dose value from drinking water samples due to ingestion of uranium in 2 litres of water for the ages under 17 years was calculated. The cumulative annual dose was found to vary from 80.50-5711.30 microSv in Punjab and 9.10-1054.20 microSv in Himachal Pradesh (compared to the WHO recommended limit of 0.1 mSv/year). The calculated excess cancer risks for lifetime exposure to these levels of uranium in drinking water ranges from 0.01-5.96 x 10^{-6} (ie up to 6 excess cases of cancer per one million exposed population).

Comment *The toxic chemical effects of naturally occurring uranium on the kidney occur at concentrations which are lower than those where radiological effects become an issue, therefore chemical safety is the primary concern for drinking water supplies.*

Health Stream is the quarterly newsletter of the *Health and Aesthetics* Program Group of the CRC for Water Quality and Treatment. Health Stream provides information on topical issues in health research which are of particular relevance to the water industry, news and updates on the recent literature. This newsletter is available free of charge to the water industry, public health professionals and others with an interest in water quality issues. An electronic version of the newsletter and a searchable archive of Health Stream articles are available on the Web page of the CRC. Summaries of Web-bonus articles are available only in the electronic version.

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Pam Lightbody
Epidemiology and Preventive Medicine
Monash University - Central & Eastern Clinical School
Alfred Hospital, Melbourne VIC 3004
AUSTRALIA

Phone +61 (0)3 9903 0571
Fax +61 (0)3 9903 0576
Email pam.lightbody@med.monash.edu.au

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Established and supported under the Australian Government's Cooperative Research Centres Program.