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In this Issue:

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UK Revises Water Regulations

The UK Department for Environment, Food and Rural Affairs (DEFRA) has begun to implement a number of significant amendments to the 2000/1 Water Supply (Water Quality) Regulations which govern the supply of drinking water in England and Wales. The amendments were developed following a review of the existing regulations, the requirements of relevant European Directives, and recent changes in the regulatory approach taken by the World Health Organisation. An additional stated aim of the review process was "to consider the possibility of reducing the regulatory administrative burden on the water industry whilst maintaining a tough but fair regulatory regime".

A public consultation process involving major stakeholders including water suppliers, local government authorities, the Drinking Water Inspectorate (DWI) and a range of industries and professional bodies whose members may be affected by the regulations then took place to obtain feedback on the draft amendments. The consultation period was completed at the end of March this year, and the first regulatory changes from the revisions have now been announced.

The proposed amendments included the following changes and new provisions:

- extension of monitoring requirements to include water supplied in bottles and containers during periods of interruption to normal piped water supplies. The current regulations cover water supplied by tankers but not to packaged water.
- a three month delay period after submission of monitoring results and a risk assessment before a new water source can be brought into use. This is

intended to allow the Drinking Water Inspectorate to determine whether the risk assessment and proposed treatment to be applied to the water are satisfactory.

- establishment of a formal requirement for monitoring of raw water quality at the point of abstraction. Separate lists of microbial and chemical monitoring parameters for surface waters and groundwaters were proposed, based on Priority Substances listed in the European Union Water Framework Directive.
- changes to requirements for disinfection to include a definition for "preliminary treatment" of surface water and groundwater under the influence of surface water prior to disinfection to mean reduction of turbidity below 1NTU. Removal of any specific substance, property or element which would interfere with disinfection will also be explicitly required. These provisions will replace current disinfection requirements based on source water quality and treatment.
- introduction of a requirement to carry out a broad-ranging risk assessment for each water treatment works to cover all dangers to human health, rather than current risk assessment provisions which relate specifically to risks from *Cryptosporidium*.
- provision of powers for the DWI to serve enforcement notices for treatment works which are identified to be at significant risk. Such notices may require water suppliers to maintain, review, audit or revise risk mitigation measures. DWI would also have the power to prohibit supply of water from a specified treatment works completely or unless certain conditions are met. Failure to comply with such a notice would be a criminal offence.
- revocation of current regulations which specifically nominate membrane filtration for physical removal of *Cryptosporidium*, and which require daily continuous monitoring for this pathogen at treatment works assessed as being at significant risk. Risks from *Cryptosporidium* will still be covered by the broad risk assessment process applied to each treatment works, and the new regulations will permit use of disinfection technologies such as UV and ozone treatment as an alternative to membrane filtration, provided these are adequately validated and monitored.
- replacement of current offences relating to the supply of water that fails to comply with *Cryptosporidium* regulations with a more general offence relating to public health protection requirements of adequately treating and disinfecting water before it is supplied.
- changes to requirements for water suppliers to provide information to the public and produce reports for local authorities in order to reduce administrative costs and eliminate duplication.

Overall the proposed changes reflect a significant shift towards the preventive risk management approach adopted by the World Health Organisation in the 2004 edition of its Guidelines for Drinking-water Quality. This approach emphasises the identification and management of risks throughout the water supply system, whereas existing UK regulations have tended to promote a focus on water treatment and treated water monitoring. Since the publication of the WHO Guidelines many UK water companies have begun voluntarily to adopt the catchment to tap risk management approach and develop Water Safety Plans consistent with the WHO Guidelines for their water supply systems.

A report on the feedback received through the consultation process has not yet been published by DEFRA, however according to an Information Letter released by DWI on 5 September, a number of water industry respondents expressed concern about the regulations relating to raw water monitoring. The lists of parameters specified for monitoring in surface and groundwaters were derived from the EU Water Framework Directive, a regulation which relates primarily to the protection of environmental and ecological health rather than protection of human health. Many in the water industry felt that this would transfer responsibility and costs for monitoring environmental standards from the Environment Agency to the water industry.

In response to these concerns, this component of the draft regulations has been revised so that there is no longer a requirement to monitor a prescriptive list of parameters. Instead, water companies will be required to develop tailored monitoring programs based on risk assessment of individual catchments, rather than being compelled to monitor for a uniform set of parameters in all catchments. The DWI has emphasised that the changes are aimed at supporting human health risk assessment and water treatment requirements, and that where additional or more sensitive monitoring is needed to support environmental standards, this will not be the responsibility of water companies.

The minimum range of parameters to be considered in designing monitoring programs will be determined by the EU Water Framework Directive and the UK Drinking Water Directive. The monitoring program for each site will be expected to include contaminants that that may be present at levels that may pose a risk to human health or which may have an impact on water treatment processes. The regulations also provide the Secretary of State with powers to direct companies to monitor for specific parameters, although it is envisaged this power would only be used in cases where a company's monitoring program is considered to be inadequate. Monitoring frequencies will be based on those required under the EU Water Framework Directive, which specifies monitoring frequencies for surface water bodies on the size of the population supplied.

The new monitoring requirements will apply from 22 December 2007, although some flexibility will be permitted during the first year to allow water companies time to review their existing raw water monitoring program and amend them as needed. The DWI has stated that it believes many water companies will have already carried out adequate risk assessments on their water sources, and that only minor changes to existing programs may be needed.

The consultation responses from stakeholders, DEFRA's consultation response document and the revised version of the amendments are expected to be published shortly.

Department for Environment, Food and Rural Affairs
http://www.defra.gov.uk/

Drinking Water Inspectorate
http://www.dwi.gov.uk/

US Recreational Water Workshop

In March this year the US Environmental Protection Agency (US EPA) convened an expert workshop to discuss current scientific knowledge on recreational water research and implementation, and provide advice on near-term research needs for the development of new or revised recreational water quality criteria for the US. Forty-three US and international experts participated in the four-day event, including representatives from academia, state and federal agencies, public interest groups and US EPA. A detailed report produced from the workshop has now been published (1).

Recreational water quality criteria in the US are currently governed at the national level by the Clean Water Act (1986) which regulates the protection of surface water for drinking water, recreational, and aquatic food source uses. The Act set out recommended ambient water quality criteria for the faecal indicator bacteria enterococci and *E. coli* for recreational waters. These microbial criteria were considered protective for primary contact recreation such as swimming, surfing or water skiing where ingestion of, or immersion in, water is likely to occur.

The criteria were based on the findings of a series of epidemiological studies carried out in the US in the 1970s and early 1980s which examined the relationship between recreational water quality and reported rates of illness (particularly gastroenteritis) among swimmers. These studies showed that levels of both enterococci and *E. coli* correlated with illness risks in freshwaters, while levels of enterococci showed the best correlation with illness risks for marine waters. Recommended water quality criteria were based on the geometric mean density of these indicator bacteria, together with a range of values for single sample maximum allowable density, depending on the frequency of full body contact recreational use for a given water body. The current criteria permit a higher level of estimated health risk in marine waters (19 cases of gastroenteritis per 1000 swimmers) than in freshwaters (8 cases of gastroenteritis per 1000 swimmers).

Since the setting of the ambient water quality criteria in 1986 there have been major advances in both microbial and chemical analytical methods applicable to recreational waters. A number of additional epidemiological studies of health risks from recreational water have been carried out in the US and other countries, and the discipline of quantitative microbial risk assessment (QMRA) has been increasingly used to assess human health risks from water exposures. In addition, the World Health Organisation and the European Union have adopted some significant changes in their regulatory approach for recreational water quality. This workshop was part of a process to review current scientific and technical information, and identify short-term research needs to enable the development of scientifically defensible new or revised ambient water quality criteria for inclusion in the Clean Water Act in the near future (approximately 2012).

After an initial plenary session to provide information on the context of relevant regulations, and the nature of the desired outcomes from the workshop, the participants were assigned into seven groups, with each group addressing a different topic. The workshop program consisted of a mixture of separate workgroup meeting and joint reporting sessions to assist networking and discussion of common and overlapping issues. Each workgroup began with a list of questions to stimulate and guide a robust discussion of their topic. The seven workgroup topics were:

1. **Approaches to Criteria Development** – focus on a toolbox approach as well suggest other potential approaches for new or revised criteria development.
2. **Pathogens, Pathogen Indicators, and Indicators of Fecal Contamination** – discuss the strengths and limitations of indicators of fecal contamination, pathogen index microorganisms, and specific pathogens for development of new or revised recreational ambient water quality criteria.
3. **Methods Development** – discuss methods for quantifying indicators and pathogens, such as culture-based methods, molecular-based methods (e.g., quantitative polymerase chain reaction), and faster culture-based methods and their applicability for ambient water quality criteria.
4. **Comparing Risks to Humans from Different Sources** – discuss the relative risks of illness to humans in waters contaminated with human fecal material versus animal fecal material.
5. **Acceptable Risk** – discuss the level of risk to various populations that would be associated with numeric ambient water quality criteria. EPA was interested in the science necessary to inform the policy decision regarding the target risk range and the process through which the policy decision could be reached.
6. **Modeling Applications to Criteria Development and Implementation** – discuss predictive modeling approaches and their potential applications in implementation of ambient water quality criteria.
7. **Implementation Realities** – identify and consider factors that influence implementation of criteria for each of the CWA uses (beach monitoring and notification, development of National Pollutant Discharge Elimination System [NPDES] permits, assessments to determine use attainment, and development of total maximum daily loads [TMDLs].

Each working group produced a report detailing the state of the science for each topic and a discussion of critical technical issues and uncertainties that could be addressed by research over the next 2 to 3 years. These reports then became chapters in the final overall report. The workshop participants identified four high priority areas for research:

- Human health impacts from different sources of faecal contamination - recreational waters may be subject to contamination from human or animal faeces, arising from point or non-point sources. Most current knowledge on health risks relates to waters contaminated by point sources of human waste. While it is generally accepted that human faeces pose the greatest risk due to the larger range of human-infectious pathogens present, better information is needed on the difference in risks between human and animal contamination, and point and non-point sources. This might be obtained through epidemiological studies, QMRA, development of methods for quantitative sanitary investigations and models to help characterise site-specific risks. Both cohort and randomised controlled trial designs are useful for epidemiological studies, and consideration should be given to using both designs simultaneously to enable comparison of results. QMRA can be used to compare and rank risks from different exposure scenarios, and to supplement epidemiological information. Quantitative sanitary investigations have the potential to provide information on relative risk, although the design and implementation aspects of this methodology are likely to be complex and lengthy.

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- Measurement issues: climatic, geographic, and temporal variability - it is probable that current indicator organisms (enterococci, *E. coli*) are not suitable for tropical and sub-tropical waters due to their replication in these environments, and new indicators for such waters are needed. More epidemiological studies are needed to characterise health risks in diverse climatic regions and geographic areas, and in flowing (inland) waters. There is also a need for better understanding of spatial and temporal variations in water quality at individual sites, and development of predictive models to assist rapid public health decision-making. QMRA models need to take account of differences in ambient conditions between temperate, tropical and sub-tropical regions. Participants agreed that there was no scientific basis to apply different health targets to different water types (fresh versus marine) or different climatic zones.

- Determining risk level and subpopulations of concern - new or revised criteria should take into account health risks to children as well as adults, and there is also a need for timely risk communication and education of the public for future acceptance of water quality criteria. Planned epidemiological studies should include assessment of risks to children, and components dealing with acceptability of risk to the public. It was felt that risk levels for immunocompromised people should not be used as a basis for establishing water quality criteria, and risks to this group would be better managed by targeted health advice on the risks associated with swimming. Clear and transparent communication with all stakeholders will be important during the development and implementation of new water quality criteria.

- Indicators and methods for measuring fecal contamination - in the short term new or revised ambient water quality criteria should be based on faecal indicators, rather than individual pathogens or suites of pathogens. Potential new or supplementary indicators that should be investigated include *Clostridium perfringens*, adenoviruses, coliphage and *Bacteroides*. Robust and well validated methods are needed for the selected indicators. Investigations are needed into species and subspecies genetic diversity to determine whether human-specific strains or variants can be identified and used to characterise faecal pollution sources, and on the fate and transport of pathogens and indicators in treated effluents and recreational waters.

There was general agreement that a flexible approach was needed to cater for the diverse nature of watersheds across the US, and that implementation guidance should be developed and released simultaneously with the new ambient water quality criteria in order to facilitate adoption by States, Tribes and Territories. EPA is already undertaking a substantial research program into health risks from recreational waters, including support of epidemiological studies, development of rapid risk assessment and monitoring systems and improving public risk communication efforts. Workshop participants urged better communication between EPA and other researchers in this field to identify opportunities for collaboration and sharing of research methodologies and tools. The report from the workshop will be used by EPA as it develops a critical path science plan to guide research activities on recreational waters over the next 2 to 3 years.

(1) Report of the Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria. June 2007. EPA 823-R-07-006.
http://www.epa.gov/waterscience/criteria/recreation/

AwwaRF EDC Research

The American Water Works Research Foundation (AwwaRF) has released two reports on the occurrence of endocrine disrupting compounds (EDCs) in US drinking water systems, their removal by drinking and reuse treatment processes (1), and the effects of advanced oxidation processes on their biological activity (2). The first report also examined the occurrence and removal of pharmaceuticals and personal care products (PPCPs). Both reports are currently available only to AwwaRF subscribers, but will be publicly released later this year.

Three criteria were used to choose a suite of EDCs and PCPPs for testing in the first project. First, that the compound had already been reported in natural waters or was considered likely to occur there. Second, that the selected compounds represented a range of product types (eg antibiotics, fragrances, steroid hormones) and a diversity of chemical structures and properties. Third, that compounds present at the low nanograms per litre level could be concentrated and analysed using relatively rapid and simple methodologies and commercially available reference standards. It was also necessary that the selected compounds were available in sufficient and affordable quantities to carry out spiking studies at the bench and pilot scale.

A review of published methods and a series of preliminary experiments resulted in development of a method using concentration by a single solid phase extraction, and analysis by tandem mass spectroscopy (GC-MS/MS and LC-MS/MS). Sample preservation, handling and processing protocols were also investigated and refined in this stage of the project. Biological assay methods (eg for EDCs) were not used in this study.

The final list of 36 substances selected for testing comprised 7 steroid hormones, 4 antibiotics, 5 analgesics, 6 psychoactive compounds, 5 pesticides, 2 fragrances, 2 poly-aromatic hydrocarbons, 2 heart medications, 1 flame retardant, 1 sunscreen and 1 X-ray contrast medium. Occurrence of these compounds was tested in raw and finished waters at 20 full-scale drinking water plants. Water treatment plants drawing water from sewage-impacted sources (thus expected to contain EDCs and PCPPs) were deliberately chosen for the project. Removal of the selected compounds by various physico-chemical, oxidation and biological treatment processes at the bench and pilot scale was assessed using four natural waters and one model water.

The study concluded that the selected analytical methods could provide accurate measurement of a wide range of EDCs and PCPPs, but care was needed with sample preservation and oxidant quenching to avoid errors. It was also found that removals observed in full-scale plants could be accurately predicted by bench and pilot scale testing. Conventional coagulation, flocculation and sedimentation were not effective for removal of most tested compounds. Disinfection with free chlorine was effective for removal of some compounds but not others, while chloramination was less effective. UV irradiation at doses typically used for disinfection was not effective against most tested compounds but high energy UV (oxidative doses) was generally effective. Ozone was also generally effective, and advanced oxidation processes (ozone/peroxide or UV/peroxide combinations) were highly effective at removing most tested compounds.

For filtration technologies, activated carbon was found to be effective for removal of most compounds but only if the carbon was not exhausted. Ultrafiltration, microfiltration and magnetic ion exchange resin were ineffective, while reverse osmosis and nanofiltration were highly effective. Biological and sorption processes such as riverbank filtration, biological filtration and soil aquifer treatment produced 10 to 100-fold reductions for many tested compounds.

Twenty-five of the 36 tested compounds were detected in at least one of the twenty source waters, and twenty compounds were detected in at least one of the twenty treated drinking waters. Among the most commonly detected compounds were the pesticides DEET (found in 100% of source waters and 90% of treated waters) and atrazine (85% and 75%), and the pharmaceuticals carbamazepine (90% and 55%) and dilantin (90% and 70%). Steroid hormones were less frequently detected in source water (20%) or treated water (20%), despite the deliberate selection of sewage-impacted water sources for this project. The detected levels of the hormones were close to the method reporting limit of 1 nanogram per litre. The researchers note that the high sensitivity of current detection methods permits detection of many contaminants at trace levels. They urge that monitoring and regulation of such contaminants should be based on human health considerations, not merely their occurrence in water.

The second project describes a laboratory study on degradation of the known EDCs bisphenol-A, ethinyl estradiol, estradiol and nonylphenol by UV and UV/peroxide oxidation treatments. The study also assessed whether the byproducts formed by oxidation were also estrogenic, and characterised the treatment conditions required for optimum removal of estrogenic activity. Chemical assay methods and *in vivo* and *in vitro* bioassays were compared.

It was found that polychromatic medium pressure UV lamps were more effective for direct photolysis degradation of EDCs than monochromatic low pressure UV lamps. However combined UV/peroxide oxidation was clearly more effective than either type of UV treatment, and this should be the preferred approach for water treatment. For bisphenol-A degradation by UV/peroxide, the rate of removal of estrogenic activity was faster when measured by the *in vitro* assay compared to the *in vivo* assay. The researchers comment that such differences illustrate the need to use more than one bioassay method when assessing EDC activity. Spiking experiments in laboratory or natural waters showed that rates of reduction of estrogenic activity were slower in natural waters, and that degradation of EDC mixtures was slower than predicted by the degradation rates of individual substances. Removal kinetics were affected by the characteristics of the water matrix including pH, alkalinity and TOC content.

(1) Removal of EDCs and Pharmaceuticals in Drinking and Reuse Treatment Processes (AwwRF Project #2758, Order #91188).
(2) Impact of UV and UV/(H_2O_2) AOP on EDC Activity in Water (AwwRF Project #2897, Order #91175).

News Items

Galway Boil Water Notice Lifted

The boil water notice imposed on the Irish city of Galway and surrounding areas was lifted on 20 September after installation of UV disinfection at the main water treatment plant. The boil water notice for about 90,000 households had been in effect for over five months after a waterborne *Cryptosporidium* outbreak was recognised. A total of 242 laboratory confirmed cases of cryptosporidiosis have been recorded in County Galway since January 2007, with the majority believed due to the outbreak. Water problems for Galway have not ended however, with another boil water notice issued on 13 September due *E.coli* contamination of one section of the distribution system. The contamination was attributed to infrastructure works in the area, and about 15,000 households are affected by the notice. Flushing and chlorination are being carried out, and it is expected the boil water notice will be lifted within a few days.

(See Health Stream Issue 46 (p3) for a report on the Galway *Cryptosporidium* outbreak).

Polonium Found In Fallon Wells

Elevated levels of polonium-210 have been found in groundwater supplies near the town of Fallon, Nevada, the site of a childhood leukemia cluster. The finding was made by the US Geological Survey (USGS) during a survey of radioactivity in groundwater that was conducted as a follow up to the CDC investigation of the cancer cluster. The isotope occurs naturally in at low levels in uranium ore, and can also be manufactured using nuclear technology. Polonium-210 came to public notoriety in 2006 when it was used to poison a retired KGB agent living in the UK. The polonium in groundwater in Nevada is derived from naturally occurring uranium deposits in geological strata.

The recent USGS survey was carried out to investigate the cause of unexpectedly high levels of alpha-particle radiation found in water samples from some private wells during the initial cancer cluster investigation. The radiation could not be accounted for by measured concentrations of uranium, and the repeat survey confirmed polonium-210 as the source. Thirteen of 25 wells rested had alpha-particle levels above the US EPA maximum contaminant level

(MCL) of 15 picocuries/L, with the maximum level being 67.7 picocuries/L. The MCL represents a concentration which is considered safe to consume every day over a lifetime. The public water supplies in the area originate from a deeper aquifer and contain only 0.2 picocuries/L of alpha-particle radiation. Home owners with high levels of alpha-particles in their well water have been advised to use reverse osmosis filtration to treat the water before consumption by people or animals. At present it is not known whether the leukemia cluster may be linked to exposure to polonium-210 in water, but investigations are continuing.

(See Health Stream Issues 29 (p1) and 33 (p4) for reports on the Nevada leukemia cluster).

Recycled Water Cross Connection In California

A cross-connection between recycled water and potable water supplies at a business park in San Diego County, California had existed for two years before it was discovered recently. The plumbing error resulted in 17 businesses receiving recycled water through their drinking water taps, and was detected when the property manager at the park had water samples analysed due to concerns over the colour, taste and odour of the water. Investigations revealed that recycled water had been mistakenly connected when the business park was built, but remained undetected because a mixture of 80% potable water and 20% recycled water was being supplied through the recycled water system. When the local water utility expanded its recycled water program recently, the supply was switched to 100% recycled water, leading to detection of the cross-connection. Two food businesses at the park were forced to close for a week while the problem was corrected and water pipes decontaminated. Staff at the business park are said to be concerned about possible health effects from exposure to chemicals or microorganisms in the water over the last two years.

Water Intake Protective Against Bladder Cancer

Analysis of data from a large case-control study of bladder cancer conducted in Spain has shown that increasing water intake was associated with a decrease in cancer risk. Researchers on the study have previously reported that exposure to higher levels of trihalomethanes (THMs) in tap water supplies was associated with increased bladder cancer risk in men but not in women. Using the same data set they then examined the relationship between fluid intake (broken down into coffee, beer, wine, liquor, champagne, soda, juices, tea, milk and water) and bladder cancer risk. Water made up the largest component of fluid intake, accounting for 42% of total fluid consumption in men and 50% in women.

Total fluid intake and total water intake showed an inverse relationship with bladder cancer risk in both men and women. In men there was a statistically significant difference in risk between the highest and lowest water (OR=0.47) and fluid (OR=0.61) intake categories, while for women the differences were similar in magnitude but not statistically significant. The same relationship was seen when cases were stratified by THM concentration in tap water, with decreasing risks being seen as water intake increased within each THM exposure category. There was no interaction between THM exposure and water intake. Increasing consumption of individual non-water beverages, or total non-water fluid intake was not significantly associated with changes in bladder cancer risk.

Total fluid and water consumption and the joint effect of exposure to disinfection by-products on risk of bladder cancer. Michaud DS, Kogevinas M, Cantor KP et al. (2007) Environmental Health Perspectives doi:10.1289/ehp.10281 (available at http://dx.doi.org/)

(See Health Stream Issue 46 (p4) for a report on the analysis of DBP exposure and bladder cancer risk).

New Water Safety Website

The U.S. National Academy of Sciences and the Global Health and Education Foundation have launched a new website to provide peer-reviewed scientific and technical information about drinking water safety. The website *Safe Drinking Water Is Essential* provides detailed information on water sources and options for distribution and treatment, plus case studies on specific regional issues. The site is particularly aimed at supporting decision makers in developing countries, and provides information in English, Arabic, Chinese, French, and Spanish. It also includes a useful Glossary and an Atlas of geographic data on safe water and sanitation access, populations and water use, and specific problems such as arsenic and fluoride in groundwater.

http://www.drinking-water.org

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

Arsenic exposure from drinking water, dietary intakes of B vitamins and folate, and risk of high blood pressure in Bangladesh: a population-based, cross-sectional study.
Chen, Y., Factor-Litvak, P., Howe, G.R., et al. (2007) American Journal of Epidemiology, **165**(5); 541-52.

Microbial content of drinking water in Finnish and Russian Karelia - implications for atopy prevalence.
von Hertzen, L., Laatikainen, T., Pitkanen, T., et al. (2007) Allergy, **62**(3); 288-92.

Lead in bottled waters: contamination from glass and comparison with pristine groundwater.
Shotyk, W. and Krachler, M. (2007) Environmental Science & Technology, **41**(10); 3508-13.

Cryptosporidiosis outbreaks associated with recreational water use - Five states, 2006.
Centers for Disease Control and Prevention (2007) Morbidity & Mortality Weekly Report, **56**(29); 729-32.

Association between trihalomethane concentrations in drinking water and adverse pregnancy outcome in Taiwan.
Yang, C.Y., Xiao, Z.P., Ho, S.C., Wu, T.N. and Tsai, S.S. (2007) Environmental Research, **104**(3); 390-5.

Dracunculiasis eradication.
Karam, M. and Tayeh, A. (2006) Bulletin de la Societe de Pathologie Exotique, **99**(5); 377-85.

Monitoring progress of the role of integration of environmental health education with water and sanitation services in changing community behaviours.
Metwally, A.M., Saad, A., Ibrahim, N.A., et al. (2007) International Journal of Environmental Health Research, **17**(1); 61-74.

Brass corrosion as a source of lead and copper in traditional and all-plastic distribution systems.
Kimbrough, D.E. (2007) J AWWA, **99**(8); 70-6.

Spatial distribution of orofacial cleft defect births in Harris County, Texas, 1990 to 1994, and historical evidence for the presence of low-level radioactivity in tap water.
Cech, I., Burau, K.D. and Walston, J. (2007) Southern Medical Journal, **100**(6); 560-9.

Issues for microbial regulation: Aeromonas as a model.
Edberg, S.C., Browne, F.A. and Allen, M.J. (2007) Critical Reviews in Microbiology, **33**(1); 89-100.

Bottled, filtered, and tap water use in Latino and non-Latino children.
Hobson, W.L., Knochel, M.L., Byington, C.L., et al. (2007) Archives of Pediatrics & Adolescent Medicine, **161**(5); 457-61.

Arsenic

Fifty-year study of lung and bladder cancer mortality in Chile related to arsenic in drinking water. Marshall, G., Ferreccio, C., Yuan, Y., Bates, M.N., Steinmaus, C., Selvin, S., Liaw, J. and Smith, A.H. (2007) Journal of the National Cancer Institute, **99**(12); 920-8.

In the northern regions of Chile (administrative region II), drinking water is mainly supplied by rivers originating from springs in the Andes mountains. Some of these sources contain high levels of inorganic arsenic. Prior to 1958 the arsenic concentration in the water supply in the city of Antofagasta was 90 microg/L, which is well above the current WHO drinking water guideline of 10 microg/L and the previous guideline of 50 microg/L. In 1958 this source was supplemented with water from the Tococe and Holajar rivers which have very high levels of arsenic. As a result of this during the period 1958-1970 arsenic concentrations in the water supply of Antofagasta and the nearby city of Mejillones averaged 870 microg/L. In 1971 a water treatment plant was installed in Antofagasta which led to a substantial reduction in water arsenic concentrations. Arsenic levels in water supplies of other towns were also reduced from this time onwards. Increased mortality from lung and bladder cancers has been reported in region II of Chile compared with the rest of the country. Arsenic in drinking water has been classified as a cause of lung and bladder cancers as well as skin cancers, however little is known about the latency period. This study investigated lung and bladder cancer mortality in the years 1950-2000 in region II of Chile compared with region V, which is not exposed to arsenic in drinking water but is otherwise similar to region II and has a larger population three times larger.

Mortality data were obtained for the years 1950-2000 for individuals over 30 years. For the years 1950-1970 218,174 death certificates were obtained for regions II and V from the Chilean Civil Registry and Identification Department. For the years 1971-1975 and 1977-1982 computerised mortality data that included cause of death was obtained from the Chile National Institute to Statistics. This included 52,155 deaths for both regions for 1971-1975 and 58,638 deaths for 1977-1982. There was no mortality data available for the country for 1976. From 1983-2000, mortality data was obtained from the ministry of Health for all of Chile and included 196,748 deaths for regions II and V. Census data was obtained for region II and V and the rest of Chile from the National Institute of Statistics to estimate the population counts. Data on water arsenic concentrations for all towns and cities in region II from 1950 to 1994 was obtained from a previous study. Poisson regression models were used to analyse time trends in rate ratios (RR) of mortality from lung and bladder cancer comparing the regions.

The highest population-weighted average arsenic concentration in drinking water for region II was 569 microg/L. Arsenic concentrations were low in the rest of Chile including region V. An example of this is Valparaiso, the largest city of region V, where the tap water arsenic concentration ranged from 0.5-1.1 microg/L when sampled in 1998. Lung cancer mortality rates and mortality RRs were calculated separately for men and women, comparing region II with region V for the 50 year period and comparing region II with the rest of Chile for the years 1971-2000. The peak RR for lung cancer in men was between 1992-1994, with an RR estimate of 3.61 (95% CI = 3.13 to 4.16) and the peak RR for lung cancer among women was between 1989-1991 with an RR of 3.26 (95% CI = 2.50 to 4.23). A similar analysis was conducted for bladder cancer. The peak bladder cancer among men was between 1986-1988 with a RR of 6.10 (95%CI = 3.97 to 9.39) and the peak among women was between 1992-1994 with a RR of 13.8 (95%CI = 7.74 to 24.5). Combined lung and bladder cancer mortality rates in region II were highest in the period 1992-1994, with a mortality rate of 153 per 100,000 persons for men (lung cancer, n=130, bladder cancer, n=23) in region II compared with 54 (lung cancer, n=47, bladder cancer, n=7) in region V. The corresponding rates for women in 1992-1994 were 50 in region II (lung cancer, n=34, bladder cancer, n=16) compared with 19 in region V (lung cancer, n=17, bladder cancer, n=2).

When mortality rates were plotted over time, trends of increasing risk began to be evident between about 1968 (10 years after high exposure started) and 1978 (20 years after high exposure started). By 1968-1970 the rate of lung cancer in men in region II was already about twice that in region V (RR = 1.98, 95% CI = 1.57 to 2.51). Among women the lung cancer RR had reached 2.89 (95% CI = 2.00 to 4.18) by the period 1977-1979. Bladder cancer mortality RRs rose even higher than those for lung cancer. Among men the RR had reached 5.95 (95%CI = 2.22 to 16.0) in the period 1974-1975 and among women the RR had reached 3.45 (95% CI = 1.34 to 8.91) in the period 1971-1973.

Clear latency patterns for lung and bladder cancer mortality for men and women were found in this study that are consistent with the large increase in exposure of these populations to arsenic beginning in 1958. No other environmental or behavioural factor is likely to explain these changes in mortality. Smoking (a known cause of both lung cancer and bladder cancer) occurs at similar rates in regions II and V. Close to 10 years after arsenic exposure increased, increased rate ratios became evident. Rates peaked in the years around 1990 and continued to be noticeably elevated up to the year 2000. Such large increases in total population cancer mortality rates appear not to have been documented for any other environmental exposure.

<u>Comment</u> *The authors note that this was an ecological study which examined population exposures and mortality, not individuals. They were unable to control for migration between regions, however this would tend to lower apparent differences in risk rather than increase them. The arid nature of the northern region of Chile also means that few water sources are available, and therefore there is a high likelihood that most residents did drink from municipal water supplies during the relevant period.*

<u>Cancer</u>

Risk of breast cancer for women living in rural areas from adult exposure to atrazine from well water in Wisconsin.

McElroy, J.A., Gangnon, R.E., Newcomb, P.A., Kanarek, M.S., Anderson, H.A., Brook, J.V., Trentham-Dietz, A. and Remington, P.L. (2007) Journal of Exposure Science & Environmental Epidemiology, **17**(2); 207-14.

This study evaluated the relationship between atrazine exposure from drinking water and breast cancer using exposure data from three sequential agricultural chemical monitoring studies. Previous epidemiological studies have given mixed results, with some suggesting an increased risk of breast cancer is associated with atrazine exposure. Study participants were female Wisconsin residents between ages 20-79 who had a listed telephone number. The Wisconsin mandatory statewide tumour registry from 1988 to 2001 was used to identify incident invasive breast cancer cases. Controls who did not have a previous diagnosis of breast cancer were selected randomly from records held by the Wisconsin Department of Transportation (ages 20-64) and the US Health Care Financing Administration (ages 65-79) to yield an age distribution similar to the cases.

A structured telephone interview was conducted for cases and controls between September 1988 and May 2001 to collect information on known or suspected risk factors for breast cancer including: exogenous hormone use, reproductive history, physical activity, alcohol consumption patterns, medical and family history, and demographics. For cases, information was collected for the period up to one year before diagnosis. For controls a reference year was assigned based on the diagnosis date for controls of similar age. Data collection included cases and controls in all areas of the state, however this paper reports data analysis only for the subgroup of women who lived in rural areas of Wisconsin that did not have a public water system (3,275 cases and 3,669 controls). The larger study had high participation rates (83% for both cases and controls).

The addresses at diagnosis or reference year of study participants were assigned latitude/longitude coordinates (geocodes). The Wisconsin Department of Agriculture, Trade and Consumer Protection conducted studies of atrazine levels in well water in 1994, 1996 and 2001 with 289, 278 and 336 wells sampled respectively. Natural neighbour interpolation was used to estimate atrazine exposure levels across the entire state for each of the three years. An averaged atrazine exposure level – over the time periods (1994, 1996 and 2001) was assigned to each participant based on their geocode.

Women with breast cancer were more likely to have established risk factors for breast cancer than controls including later age of first birth, fewer children, a family history of breast cancer, a higher body mass index during postmenopausal years, a later age of menopause, higher rates of alcohol consumption and more education compared with controls. For the years of 1994, 1996 and 2001, 20%, 16% and 14% of the wells sampled respectively had detectable atrazine with about half located in the south central agricultural district. The statewide atrazine levels significantly declined from 1994 to 2001. The odds ratio of breast cancer for women who were exposed to atrazine concentrations of 1.0-2.9 ppb compared to women in the lowest exposure category (less than 0.15 ppb) was 1.1 (95% CI 0.9-1.4) after adjustment for known and suspected breast cancer risk factors. For those few women with exposure greater than or equal to 3.0 ppb the fully adjusted odds ratio was 1.3 (95% CI 0.3-5.0). Similar odds ratios were found for rural women living in the high atrazine use area of South Central Agricultural District.

The result of this study do not suggest an increased risk of breast cancer from exposure to low levels of atrazine in drinking water below the US EPA statutory action level of 3.0 ppb. The possible risk for women exposed to levels of atrazine at or above this level cannot be assessed as the study only had very small numbers of women in this exposure category.

Climate Change

Drinking water and potential threats to human health in Nunavik: Adaptation strategies under climate change conditions.

Martin, D., Belanger, D., Gosselin, P., Brazeau, J., Furgal, C. and Dery, S. (2007) Arctic, **60**(2); 195-202.

Nunavik is the northern part of the province of Quebec in Canada and is a sparsely populated territory of mostly Inuit residents who live in 14 coastal communities. These Inuit populations with their traditional fishing and hunting activities and resulting dietary habits are vulnerable to the risks associated with diseases transmitted by food and water. From 1990 to 2003 three weather stations in Nunavik observed sustained warming of nearly 0.37 degrees C per year. Climate change may have major impacts on water use and sanitary disposal practices in these communities and this may in turn affect the incidence of gastroenteric disease and perhaps other infectious diseases. Most Nunavik communities now have water treatment plants, however due to the difficulties of installing pipelines in permafrost areas water is usually delivered by truck to houses where it is stored in large tanks. Many residents also use untreated water from lakes, creeks and river in the summer or from melted snow in winter and spring. This study was undertaken in 2003 and 2004 to evaluate drinking habits that may increase the risk of disease for Nunavik residents in the context of climate change.

There were four Nunavik communities selected for this study. Two of them had already implemented technological and community strategies to improve the quality of drinking water and the other two were still distributing untreated water to residents at the beginning of the study in 2003. Semi-structured interviews were conducted with water resource managers, public health officials, elected representatives and an Inuit population sample in the four communities. The topics discussed were related to climate change trends and the resulting impacts on drinking water resources and human health. Investigators gathered information at drinking water treatment stations, at individual and collective water supply sites and at wastewater disposal sites. Water samples were collected during the Nunavik Health Survey in the fall of 2004. Samples were analysed for total coliforms (TC), *E. coli* (EC) and for enterococci (EI). Water was considered unfit for consumption when it equalled or exceeded 10 TC/100ml, 1 EC/100ml and 1 EI/100 ml. A limited number of samples from individual containers and raw water sources were also tested for presence or absence of *Cryptosporidium parvum*, *C. hominis* and *Giardia duodenalis*.

The main climate change impacts reported by Nunavik residents were earlier springs, longer and hotter summers than 30 to 40 years ago with less precipitation, colder and shorter winters with less snow, thinner ice covering on lakes and rivers, lower lake levels, decreased river flows and the drying up of small rivers and small lakes. Major shoreline erosion was also noted on certain rivers, higher turbidity of running water and a deterioration of raw water quality. In the four villages visited, 69% of the people consumed water from their domestic tanks and 31% of people obtained their water from lakes, creeks and rivers in the summer and from melting ice or snow in winter and spring.

There were 64 domestic tanks sampled and of these 21 contained more than 10 TC/100 ml, none exceeded 1 EC/100 ml and only one exceeded 1 EI/100 ml. None of the tank analysed contained free chlorine at the time of sampling. Participants obtained water from creeks, lakes and rivers from one to three times a week. Participants claimed the raw water was clearer and less contaminated than water from household tanks. They said the water was fresher and tasted better than tap water. For most of those interviewed, gastrointestinal symptoms were usually associated with tap water. When they had tap water problems they would look for water outdoors. It was mentioned that in spring, when the ice was starting to break up, the water taken outdoors tasted different and cases of diarrhoea were more frequent.

In September 2004 the principal water resource sources used by the residents were visited and water samples were analysed from six outdoor sites. Large quantities of TC were found at several sites, few EC and EI were found. The water stored in 20 individual containers was also analysed. The water had been taken from one of the six outdoor sites and was not refrigerated. Of the 20 containers, 16 contained more than 10 TC/100 ml, four exceeded one EC/100 ml and four contained at least one EI/100 ml. The water appeared to be more contaminated in these containers than the raw water. An absence of cleaning of these containers or ineffective cleaning between fillings may have contributed to the increased number of bacteria present. No *Cryptosporidium parvum*, *C. hominis* oocysts or *Giardia duodenalis* cysts were detected in samples from raw water from plastic containers in any of the four communities. The Nunavik Health Survey did detect these protozoa in other communities however.

Residents in the four villages used melt water in Winter and Spring from one to three times a week. Participants obtained water this way because it tasted better than tap water and also because it is a traditional practice. Melt water is considered cleaner than tap water because it does not run through pipes or sit in a domestic tank. Most people indicated they never had gastrointestinal problems after consuming melt water, however some people did report an association with illness.

The raw water collected from most of the sites visited was of good quality. Of concern was the fact that water from individual home storage containers was much more contaminated that the water at the collection sites. Residents need to be made aware of the importance of cleaning these containers properly between fillings. This region is going through major warming which is already affecting the water supply of the communities. The climate change adaptation strategies could be developed or improved in this area by: appropriate monitoring systems being established, wastewater disposal and municipal water systems being improved, nursing staff being involved in microbiological testing of the water at community sites, making the public aware of the risks related to consumption of raw water and gathering strategic health information during periods of the year when cases of gastroenteric disease are more frequent to see if there is a link between these disorders and water quality.

Disinfection Byproducts

Case control study of the geographic variability of exposure to disinfectant byproducts and risk for rectal cancer.

Bove, G.E., Jr., Rogerson, P.A. and Vena, J.E. (2007) International Journal of Health Geographics [Electronic Resource doi: 10.1186/1476-072X-6-18], **6:**18.

This study examined if there were geographic disparities in the probability of developing rectal cancer within a single water distribution system. The study was designed around case control data initially collected at the University of Buffalo as part of the Upstate New York Diet Study. Trihalomethanes data was supplied by Monroe County Water Authority and the Monroe County Health Department. There were 128 case participants chosen from pathology records from Monroe County, Western New York State, U.S. and 253 controls who were disease-free males between 35-90 years old also living in Monroe County chosen from control groups for studies from cancer of five other (unrelated) sites.

A combination of individual tap water consumption data and geographic-based exposure analysis of disinfection byproducts was used to provide estimates of the effects of ingestion of specific amounts of some DBPs on rectal cancer risk. Using THM data the mean value for each sampling point was calculated. The resulting values were then used in a method of interpolation, to provide a surface of THM values from which estimates for THM levels were extracted at the locations of cases and controls. The dietary and water intake information for cases and controls was collected between 1978 and 1986, and covered the 12 month period before diagnosis (cases) or interview (controls). DBP data were collected between 1998 and 2003. Odds ratios were estimated using logistic regression to assess the effects of estimated THM exposure on cancer risk with adjustment for alcohol, dietary beta-carotene intake, tap water intake and total caloric intake.

Firstly the effect of total THMs on increased risk of rectal cancer was examined. After adjusting for covariates there was no apparent significant effect of tap water consumption, THM level or THM intake per day on risk of rectal cancer. Next individual THM components were examined to assess whether they had an effect on risk. After adjustment for covariates, both bromoform level at the location of the case or control (OR 1.20; 95% CI 1.05-1.37) and bromoform consumption (OR 1.85; 95% CI 1.25-2.74) were significantly associated with increased risk of rectal cancer. Chlorodibromomethane was also marginally significant (OR 1.78, 95% CI 1.00-

3.19) as was bromodichlromethane (OR 1,15; 95% CI 1.00-1.32). Quartiles were created based on bromoform consumption estimates and after controlling for covariates, odds ratios were significantly increased in the highest quartile (1.69-15.43 microg/day) of exposure to bromoform (OR 2.32, 95% CI 1.22-4.39).

This study found that the levels of THMs in the water distribution system varied spatially which was partly due to variation in water age. There was also a geographic pattern found of increased risk of rectal cancer in areas with the highest levels of bromoform in the county.

Comment *The authors note their methodology assumes that recently measured DBP levels represent historical exposures for cases and controls. Rectal cancer has a latency period of 10 to 20 years or longer so the relevant exposure period for the cases in this study may have extended as far back the 1950s when exposure of the population to DBPs first began. Estimated exposures to DBPs in water were estimated from "usual dietary habits" reported for a single year and thus would not reflect any long term changes in consumption habits.*

Hepatitis A

Hepatitis A virus in surface water in South Africa: what are the risks?

Venter, J.M.E., van Heerden, J., Viver, J.C., Grabow, W.O.K. and Taylor, M.B. (2007) Journal of Water & Health, **doi: 10.2166/wh.2007.006**

There have been limited studies to determine the risk posed by hepatitis A virus infection after recreational exposure to polluted surface water sources. In South Africa hepatitis A is endemic and hepatitis A virus (HAV) has been found in surface river and dam (impoundments) water used for recreation and domestic purposes. This study determined the possible risk of infection constituted by HAV to individuals in different socio-economic communities who use the same surface water sources for domestic and recreational purposes. In order to quantify the possible risk of infection from HAV, a risk assessment approach was employed.

Over a three year period weekly water samples were collected from a dam and river in Gauteng, South Africa. The dam water is used as source water for a water purification facility as well as by the higher socioeconomic community for recreational purposes. The river and dam water is used by the lower socio-economic communities for domestic and recreational purposes. A mathematical model was used to assess the risk of HAV infection in this population exposed to contaminated surface water.

In all dam and river water samples analysed, somatic and F-RNA coliphages were detected. In the river water faecal coliform counts were found to range from 130 to 66,000 colony forming units (cfu) /100 ml with more than 99.99% of samples exceeding 200 cfu /100 ml. In the dam water samples faecal coliform counts ranged from 4 to 3100 cfu /100 ml, with counts less than 100 cfu /100 ml in 85.7% of the samples. In 6.5% of the dam samples counts for faecal coliforms exceeded 200 cfu /100 ml. The corrected mean concentration of HAV per litre of water was 2.13×10^{-3} and 1.99×10^{-2} for dam and river water respectively, estimated by cell culture. It may be that these values are a gross underestimate of the actual concentrations of HAV in the water as the cell culture is influenced by factors such as viral strain, cell type, incubation time and incubation temperature.

For those in the higher socio-economic the estimated daily risk of infection during recreational activity in the river water is 1.1 infection per 1,000 recreational users per day with a risk of illness of 0.41 illnesses per 1,000 users. For dam water recreational activity, the risk of infection is 0.12 per 1,000 users and the risk of illness is 0.053 illnesses per 1,000 recreational users per day. Those undertaking water sports such as swimmers and canoeists who may accidentally ingest water and are exposed to the river water on a daily basis have a 14.8% annual risk of becoming clinically ill from HAV infection if they ingest 100 ml per day. The annual risk of becoming clinically ill with HAV for recreational exposure to dam water is 1.9% if 100 ml of water is ingested per day.

Those in the lower socio-economic populations who use river water for drinking purposes have a daily risk of HAV infection of 220 per 10,000 consumers, with an annual risk of 100%. Communities using dam water for drinking assuming 2L per day, have a daily risk of infection of approximately 23 per 10,000 and an annual risk of 5,800 per 10,000 consumers.

The US EPA guidelines of an acceptable risk are one waterborne infection per 10,000 consumers per year for drinking water therefore the use of these untreated water for drinking purposes was unacceptable as greater than 50% of consumers per annum were at risk of infection. However in high density, low socio-economic communities where sanitation is inadequate, nearly 100% of children are infected with hepatitis A before the age of 10 years, and subsequently are immune to further infections. Therefore, since it is the lower socio-economic, predominately immune communities that utilise the water for drinking purposes, the risk are minimal for those over 10 years of age. The risk values found may be of concern to those that are very young (children less than 10 years), immunocompromised or non-immune who use these water sources for drinking. Applying the US EPA acceptable risk level of eight gastrointestinal illnesses per 1,000 swimmers/recreational water users to HAV, results in a minimal risk (0.053 to 0.41 illnesses per 1,000 recreational users per day) of developing clinical hepatitis A in the higher socio-economic, mostly non-immune, population using these waters for recreational activities. For those adolescents and adults from lower socio-economic communities, the risk of developing hepatitis A after recreational exposure to the same water sources is well within the acceptable limits suggested by the US EPA.

This study is the first risk assessment study to examine the risk of infection by HAV in surface water for different socio-economic communities in South Africa. The results of this study suggest the possible risk of infection posed by HAV however the data cannot be applied universally and models need to be modified or adapted to take into consideration the microorganism being assessed and the local or national demographics and socio-cultural behaviour.

Metals

Elevated lead in drinking water in Washington, DC, 2003-2004: The public health response.
Guidotti, T.L., Calhoun, T., Davies-Cole, J.O., Knuckles, M.E., Stokes, L., Glymph, C., Lum, G., Moses, M.S., Goldsmith, D.F. and Ragain, L. (2007) Environmental Health Perspectives, **115**(5); 695-701.

In 2002, lead levels in treated water supplied by the District of Columbia Water and Sewer Authority (DCWASA) began to rise. The increase in lead concentrations occurred following the change from chlorine to chloramine water disinfection treatment on 1 November 2002. The change in disinfectant was made for reasons of compliance with the pending Disinfection Byproducts Rule. The rise in lead levels was abrupt thereafter and at its peak in early 2004, the 90th percentile value for homes sampled was 59 ppb. The lead action level (LAL) stipulates that the 90th percentile of samples cannot exceed 15 ppb, but during this period 68% of homes exceeded 15 ppb on the first draw sample and some exceeded 300 ppb.

Lead service lines are still present in a wide range of older housing types in the District of Columbia. The change in disinfection from chlorine to chloramines altered the leaching of lead from the interior surface of lead service lines and caused lead levels in tap water to rise. Other sources of lead from within households may have included solder in joints between copper pipes, older faucets, and certain types of water meters. In 2003 the DCWASA implemented plans for families living in homes with lead lines or testing above the LAL including: advisories, specific advice to limit exposure, filters, replacement of private segment of lead service lines on their property at cost, replacement of public segments of all lead service lines, low-cost financing to replace private parts of lead service line and free water testing, Lead levels were reduced in the distribution system by adding a commonly used passivating agent to the water. Health advisories associated with the elevated lead levels were lifted in January 2006. The aim of this study was to evaluate the public health implications of the high lead levels by examining blood lead levels in children.

A blood lead screening program to supplement the existing clinical screening program in the District of Columbia was started on the 3 February 2004 and was discontinued on the 2 August 2004. Two groups were identified, the "target population", which included children 6 months to 6 years of age and women who were pregnant or nursing and the "outside the target population" which included all others for who testing was requested. Elevated blood lead levels were defined as those greater than 10 microg/dL, the level of concern adopted by the Centers for Disease Control and Prevention. The homes of all of those with elevated blood lead levels were investigated by the District of Columbia Department of Health (DC DOH).

There were 6,834 persons screened for blood lead level. Of these subjects, 2516 were within the target population; 2,342 children less than 6 years of age, 96 pregnant women and 78 women who were nursing. Of the 2,342 children in the target population, 65 (2.8%) had blood lead levels greater than10 microg/dL but all except one had levels less than 45 microg/dL, a level that may be associated with clinically symptomatic lead poisoning. Not all of the target group with elevated blood lead levels were children, two were nursing mothers. None of the 96 pregnant women had elevated blood lead levels. Most of the children who had elevated blood lead levels (70.8%) did not live in homes with lead service lines. The home investigations of those with elevated blood lead levels revealed that in most cases at least one source of lead exposure other than drinking water, usually peeling lead paint and dust, could be identified.

Of those children less than 6 years of age who had blood lead levels less than 10 microg/dL, the blood lead level (mean ± SD) for the 344 children who lived in homes with lead service lines was 3.28 ± 2.05 microg/dL compared with 2.60 ± 1.69 for children living in homes without lead service lines, a statistically significant difference (*p* less than 0.05). Of those 4,318 residents who were outside the target population, 4 had blood lead levels greater than 25 microg/dL, the level of concern for adults. Two of these residents had lead service lines and two did not.

Of the 2,482 children less than 6 years of age who were tested for blood lead levels in 2004, first draw water lead concentrations were available for 107. A correlation analysis was performed on this data set and there was no correlation found ($r^2 = -0.03142$). A data set was obtained from the DC WASA which included 71 children with blood lead levels of greater than or equal to 10 microg/dL for which paired blood lead levels and water concentrations were available. A correlation analysis was also performed on this data set and there was no correlation ($r^2 = -0.0856$ for individuals, $r^2 = -0.05639$ for all data points and $r^2 = -0.09728$ for all addresses).

There appears to have been no identifiable public health impact from the elevated lead levels in the drinking water in Washington, DC in 2003 and 2004. This may be a reflection on the effectiveness of measures to protect the residents such as compliance with recommendations to filter water. The screening program did reveal the actual situation of a continuing problem with sources of lead in the homes, specifically lead paint. This study cannot be used to correlate lead in drinking water with blood lead levels directly for various reasons: it is based on ecological data instead of individual exposure assessment, the protocol for measuring lead was based on regulatory requirements rather than estimating individual intake, there were interventions introduced to mitigate the effect, exposure from drinking water was confounded by other sources of lead in older homes, the period of potential exposure was not uniform among houses, and actual exposure was variable for individual residents.

MTBE

A re-evaluation of the taste and odour of methyl tertiary butyl ether (MTBE) in drinking water
Suffet, I.H. (2007) Water Science & Technology, **55**(5); 265-73.

Methyl tertiary butyl ether (MTBE) is a gasoline additive which is used to reduce smog formation. MTBE is very soluble in water and can contaminate groundwater if underground gasoline storage tanks leak. MTBE is considered mainly a taste and odour problem and not a toxicity issue at the levels found in drinking water. The basis for clean-up of MTBE problems is the odour threshold concentration (OTC). There is currently no consensus regarding an OTC-based drinking water standard in the US. Out of nine studies which have been completed on the OTC of MTB, eight have the OTC near or above 15 microg/L. One study however in by Campden Food and Drink Research Association in 1993 showed the OTC of MTBE to be between 0.04 and 0.06 microg/L which is much lower than the other studies. An accurate and scientifically defensible OTC is needed since the level of clean-up required for MTBE contamination will determine the cost of clean up. This 1993 study (examining a very low range of MTBE concentrations) was repeated using the same laboratory as the original study using quality assurance methods to determine whether the original study was scientifically valid and is reported here as the Campden (2004) study. A study by Stocking et al (2001) on MTBE odour threshold was also repeated by Campden as one quality assurance test of the laboratory and is reported here as Campden (2003).

The ASTM Method Standard E-679-91 was used by the Stocking et al (2001) and the Campden (2003) study to determine the OTC by an untrained consumer panel. This method states that the panel threshold is the geometric mean of the best-estimated thresholds of the individual panellists. Expert panellists who have been trained should represent the more sensitive proportion of the general population. The thresholds for odour or flavour determined by an expert panel should be more reproducible than those determined by untrained consumers.

The values in the Stocking et al (2001) study ranged from 2 to 100 microg/L with a geometric mean of 15 microg/L. The odour threshold detection level for consumer in the Campden (2003) study was 52.7 microg/L which represents the average threshold of approximately 56% of the consumers. Only 60% of the consumer population were able to detect MTBE at the highest concentration tested (100 microg/L). It was found that the panel in the Campden (2003) study was not as sensitive as the panel in the Stocking et al (2001) study. The Campden (2003) consumer panel determination of the odour detection of MTBE however was within the error range of the Stocking et al (2001) study result of 15 microg/L. The OTC for the Campden (2003) study was found to be 18 microg/L. The Campden (2003) study had good quality assurance and is a valid data set.

Review of the Campden (1993) study showed that there was insufficient quality assurance as no chemical analysis was completed to verify the MTBE concentrations that the panel tasted. The Campden (2004) study which included the same range of low MTBE concentrations also incorporated a number of quality checks including the chemical determination of MTBE concentrations after every dilution. The results showed no clear evidence of flavour or odour detection thresholds with the percent of panellists reporting a positive result being unrelated to the concentration being tested. It was concluded that the dilution series of the test solutions for the study were mainly at sub-threshold levels because of the inconsistencies found in the data and the high detection of the water blanks.

This comparison of studies showed that the Campden (1993) study cannot be used as a valid OTC study for MTBE and should not be used for setting drinking water or clean-up standards. The remaining studies with adequate quality assurance all agree that the OTC is at or above 15 microg/L. MTBE levels for drinking water and clean-up standards should be based on an OTC at levels shown in the Stocking et al (2001) and Campden (2003) consumer studies.

<u>Nitrate</u>

Nitrate in drinking water and risk of death from bladder cancer: an ecological case-control study in Taiwan

Chiu, H.F., Tsai, S.S. and Yang, C.Y. (2007) Journal of Toxicology & Environmental Health Part A, **70**(12); 1000-4.

Nitrate in drinking water may come from numerous natural and synthetic sources which include wastewaters and agricultural and urban runoff. Nitrate may be a procarcinogen and interact with amines and amides in the stomach and gut to form a variety of N-nitroso compounds (NOC) via a nitrosation process. NOC compounds are potent animal carcinogens, inducing tumours at multiple organ sites. There have been several studies to support a direct relationship between nitrate intake and endogenous formation of NOC. Nitrates in drinking water may contribute to nitrosation and it has been proposed that nitrate intake may be used as a surrogate for exposure of target tissues to NOC. Epidemiological studies examining the association between nitrate in drinking water and cancer risks have produced contradictory results. Given that nitrosation may not only occur in the gastrointestinal tract but also in the bladder, this study aimed to determine whether nitrate exposure in drinking water correlated with occurrence of mortality attributed to bladder cancer in Taiwan.

There were 322 municipalities in Taiwan included in the study. Data was obtained from the Bureau of Vital Statistics of the Taiwan Provincial Department of Health on deaths of Taiwan residents from 1999 through 2003. The case groups consisted of all eligible bladder cancer deaths occurring in people aged 50 to 69 years. The control group consisted of all other deaths excluding those deaths associated with genitourinary diseases and deaths previously reported to be associated with nitrate or NOC exposures. Control subjects were pair-matched to cancer cases by gender, year of birth and year of death. The Taiwan Water Supply Corporation supplied information on levels of NO_3-N in each municipality's treated drinking water supply. Four water samples representing each season were collected from each waterworks and analysed. Of the 322 municipalities, 70 were excluded because they had more than one supply of drinking water, leaving 252 municipalities. The municipalities of residence for all cancer cases and controls were assumed to be the source of the subjects' nitrate exposure via drinking water.

There were 513 bladder cancer cases with complete records included in the study. The mean nitrate concentration in the drinking water of bladder cancer cases was 0.52 mg/L (SD = 0.47). Controls had a mean nitrate exposure of 0.43 mg/L (SD = 0.45). When exposure was classified into three categories, the ORs for bladder cancer deaths were significantly higher for the two groups with high levels of nitrate in their drinking water. The adjusted ORs for bladder cancer death for those with water nitrate levels between 0.19 and 0.45 mg/L were 1.76 (95% CI 1.28-2.42) and for those with nitrate levels of 0.48 mg/L or more the ORs were 1.96 (95% CI 1.41-2.72). There was a significant trend found towards an elevated risk of death from bladder cancer with increasing nitrate levels in drinking water (χ^2 for trend =14.88, *p* less than .001).

This study shows a significant positive association between nitrate levels in drinking water and risk of death from bladder cancer. Further studies which include a more detailed estimate of individual intake of nitrate from both food and water are needed, and information on potential confounders such as smoking needs to be included in such studies. Given that bladder cancer has a latency period of about 20 years or more, past exposures of several decades duration need to be assessed.

Taste and Odour

The anatomy of odour wheels for odours of drinking water, wastewater, compost and the urban environment

Suffet, I.H. and Rosenfeld, P. (2007) Water Science & Technology, **55**(5); 335-44.

In the fields of drinking water and air pollution, odour wheels are used to evaluate and classify the character and intensity of odours. If the primary chemicals producing the odour are known, a potential remedial treatment can be defined from the odours reported. Odour wheels are based on sensory panel testing with the goal to identify odour problems and the chemicals causing those problems, conducting odour quality control monitoring and developing discussion about odour problems with the public. The aim of this paper was to define how to develop an odour wheel to describe any odour problem from drinking water to animal production odours.

Odour wheels are based on flavour profile analysis (FPA) sensory panel testing to define the odour characteristic and related odour intensities. The intensity or strength of each odour character is reported on a seven-point scale. In a drinking water wheel characteristics might include a musty odour (weak intensity = 4), a grassy odour (very weak intensity = 2) and a chlorinous odour (very weak intensity = 2). Expert odour panels may then be able to express the response to their particular community such as “The water has a musty, slightly grassy character from an algae growth in the reservoir”. or “The water is safe to drink with a slight chlorinous odour indicating proper disinfection”.

The first complete drinking water taste and odour wheel was presented in 1995 and upgraded in 1999. The drinking water wheel has developed more as specific chemicals have been identified as the cause of odour problems. The drinking water odour wheel has 8 confirmed classes listed under four headings of the sources of the odour problems: natural products, Industrial products, Aerobic oxidation products, and Anaerobic degradation products. Odour wheels are based on the best available knowledge at the time and therefore evolve with scientific advancement. As well as drinking water odour, other wheels have been developed for wastewater, compost and urban odour.

These odour wheels are starting to form the basis for the evolution of odour quality data with a link to the chemical cause. This paper shows that wheels for such odour problems as sludge odours from waste treatment or farm odours from animal husbandry can be classified and evaluated, and it is hoped that this will assist in the minimisation of odour problems.

<u>Water Consumption</u>

A study of the association between children's access to drinking water in primary schools and their fluid intake: can water be 'cool' in school?
Kaushik, A., Mullee, M.A., Bryant, T.N. and Hill, C.M. (2007) Child: Care, Health and Development, **33**(4); 409-15.

There are both short and long-term consequences of dehydration. It is particularly important that children have adequate water intake as they have immature thirst mechanisms, relatively high fluid losses and higher activity levels than adults. There is data to show that children drink less than half of their recommended daily fluid intake and that the quality of what children drink is of concern as well. The “Water is Cool in School” campaign was launched in the UK in 2000 with the aim to raise awareness of the health benefits of drinking water and improve children’s access to drinking water. This study aimed to determine whether children’s access to drinking water at school was associated with their fluid intake and also to study the relationship between increased water access and consumption of alternate fluids; whether the promotion of drinking water was correlated with frequency of visits to the toilet and teachers’ views on children’s drinking behaviours in the classroom.

Children were recruited for the study from six primary schools in the urban area of Southampton on the South coast of England. There were 145 children recruited from Year 2 (aged 6-7 years) and 153 from year 5 (aged 9-10 years) classes. Schools were recruited according to class room policy with respect to access to drinking water in the classroom. There were therefore 47 year 2 and 40 Year 5 children who were studied in a ‘free access’ environment, where water was permitted on the desk at arm’s length; 39 Year2 and 52 Year 5 children were studied in a ‘limited access’ environment, where water was available in the class (e.g. located in a water cooler) but the child was required to actively request or seek a drink, and lastly there were 59 Year 2 and 61 Year 5 children who were studied in a ‘prohibited access’ setting, where drinking was not permitted in the class. All schools allowed children to drink freely out of the classroom and allowed consumption of drinks other than water.

Children were studied by a single observer in groups of 10 over a full school day. All fluid containers used by children during the school day were weighed and the volume of fluid consumed calculated. Intake of water from water fountains was estimated from mean ‘gulp’ volume and the number of gulps. Visits to the toilet were recorded for each child. Teachers were given a questionnaire about their beliefs about children’s access to water in school.

Only 29% of children achieved a minimum desired fluid intake. It was found that free access to water bottles throughout the school day was associated with a significantly higher total fluid intake in both age groups. Total fluid intake was found to be significantly higher in Year 2 free access schools (geometric mean 293 mL, range 104-953 mL) compared to prohibited access schools (geometric mean 189 mL, range 0-735 mL, *P*=0.046) and in Year 5 free access schools (geometric mean 489 mL, range 88-1200 mL) compared with prohibited access schools (geometric mean 206 mL, range 0-953 mL, *P*=0.001) and in free access versus limited access schools (geometric mean 219 mL, range 0-812 mL, *P*=0.003). There were 81% and 80% of all children in prohibited and limited access schools who consumed below the minimum recommended fluid intake over the school day respectively compared with 46.5% in free access schools.

Year 5 children consumed more flavoured drinks than Year 2 children, and free access to drinking water was associated with a decrease in consumption of flavoured alternatives compared with prohibited access (*P*=0.019). There were 34.6% of all children who did not use the school toilets at all during the school day and there was no trend found between water access and frequency of toilet visits. Most teachers supported the view that children should have free access to drinking water in class and believed there would be both educational and health benefits in such a policy. They also believed that encouraging drinking in class would increase children's frequency of toilet visits.

The primary school children in this study had poor fluid intake at school. Primary schools need to promote water consumption in school as children with free access to water in class consume fewer flavoured drinks which are often high in calories and colourants, and are less likely to suffer dehydration than children in class rooms where drinking water is prohibited. Also children who drink less fluid crave more high fat foods which may precede the development of Type II diabetes. Promoting water consumption may also help to arrest the current epidemics of childhood dental decay and obesity.

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