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New Cyanobacterial Toxin

An algal bloom in South Australia's Yorke Peninsula has led to the discovery of a new cyanobacterial toxin. The bloom in the Paskeville reservoir led to a health alert being issued for about 15,000 residents in 35 towns. Many visitors were also affected by the alert in the popular tourist area during the Easter holiday period. The incident began on Friday 14 April with a number of complaints from consumers about an unpleasant taste and odour in tap water. Tests detected the presence of MIB (2-methyl isoborneol), a cyanobacterial metabolite which although not considered toxic is often responsible for "musty" taste and odour in water supplies.

Investigations by SA Water revealed the source to be one of two shallow earthen storage reservoirs in Paskeville where filtered water was stored prior to chlorination and distribution. A cyanobacterial "mat" growing on the floor of the reservoir had broken up and become detached, resulting in algal fragments contaminating the water intake. The reservoir was removed from service and examination of algal samples showed the bloom to be a *Phormidium* species. This filamentous cyanobacteria commonly grows on the surface of submerged rocks in shallow clear water bodies, and has not been reported to produce toxins. It is generally not regarded as a concern in drinking water supplies. The local media were notified of the bloom and advised there were no health concerns. The South Australian Department of Human Services was also notified.

Despite the absence of reported toxin production by *Phormidium*, algal samples were collected by SA Water for toxicity testing by intraperitoneal injection in mice. These tests showed the material to be toxic, and a health alert was issued on Tuesday 18 April. Due to uncertainty over the identity of the toxin the South Australian Department of Human Services advised

consumers not to use tap water for drinking, making cold or hot beverages, washing or cooking foods, making ice or cleaning teeth. Bottled water was distributed free through supermarkets and local fire stations. Farmers were warned not to use tap water for livestock.

A program of mains flushing was commenced to clear the affected water from the distribution system. Due to the large area affected, it was several days before the all clear was issued to the last townships on Tuesday 25 April. According to local media, no instances of human illness or stock losses have been reported. Shortly after the incident the state government announced a \$9 million project to cover and line five major water storages including the Paskeville reservoirs. The project is part of a \$36 million Country Water Quality Improvement Program to be carried out in South Australia over the next 5 years.

Preliminary characterisation of the toxin has been carried out by the Australian Water Quality Centre and the University of Adelaide Department of Clinical Pharmacology (both participants in the CRCWQT). The toxin appears chemically distinct from the known major toxin classes (not a microcystin, nodularin, saxitoxin or cylindrospermopsin), and is somewhat less toxic in mouse tests than the most toxin microcystins. The effects are protracted, with injected mice generally surviving more than 6 hours and sometimes more than 24 hours before succumbing. Examination of internal organs shows no gross organ damage, but liver damage is evident on histopathological examination. It has also been established that the toxin is effectively inactivated by boiling and by water chlorination.

A similar protracted toxic effect from cyanobacteria has been reported previously for *Aphanizomenon flos-aquae*. In this case chemical characterisation of the toxin was not performed but it was reported that no gross organ damage was seen in mice, but liver and lung damage was evident on histopathological examination (1). Histopathological data from this toxin is now being compared with observations on the South Australian isolate.

The finding of a new toxin from an algal species hitherto regarded as innocuous raises concerns for water and health authorities. *Phormidium* growth on the bottom of shallow reservoirs is not unusual, and this species has been regarded as a nuisance organism only on the rare occasions when algal growth becomes detached and enters the water column. Now it appears that water authorities may need to consider testing for toxicity whenever *Phormidium* is identified, rather than assuming there are no health concerns.

(1) Underdal B. Nordstoga K. and Skulberg OM. Protracted toxic effects caused by saline extracts of *Aphanizomenon flos-aquae* (Cyanophyceae /Cyanobacteria). *Aquatic Toxicology*. **46**(3-4): 269-278, 1999.



E. coli Strikes Canadian Town

A major waterborne outbreak of *E. coli* O157 has struck the small town of Walkerton, Ontario, about 180km north of Toronto. As of 7 June, seven fatalities had been attributed to the outbreak, with four more deaths under investigation, and several people still in serious condition. The deaths have occurred mainly in the elderly, but also included a 30 year old man and a 2 year old child. More than 1,000 people are believed to have been ill, with over 400 attending the emergency department of the local hospital with severe gastroenteritis symptoms. Schools, childcare centres and many businesses in the town have been closed for the duration of the outbreak.

In contrast to the harmless *E. coli* strains normally found in the intestine of humans and warm blooded animals, the O157 strain produces a potent toxin (verotoxin) which causes cell damage, leading to the development of bloody diarrhoea (haemorrhagic colitis). The infection may also result in severe dehydration and kidney damage requiring dialysis treatment (Haemolytic Uremic Syndrome, HUS). Fatalities may occur particularly among young children and the elderly, and some survivors suffer permanent kidney damage which may require life-long dialysis or a transplant.

Toxigenic *E. coli* (including O157 and other related strains) are carried by 10-15% of healthy ruminants (including cattle, sheep, goats and deer). The bacteria may be transmitted to humans by consumption of raw or undercooked meats, or by contamination of foodstuffs or water supplies with faeces from infected humans or animals. Outbreaks have also been associated with recreational water bodies, and direct contact with animals. The infectious dose may be as low as 5 to 10 organisms, and the incubation period ranges from 2 to 8 days. The bacteria are readily killed by chlorination of drinking water.

No specific treatment is yet available to combat the infection, and recent research suggests that antibiotics and anti-diarrhoeal medication may increase the risk of HUS developing. The Canadian government has granted special permission for victims of this outbreak to be treated with an experimental drug called Synsorb Pk developed by a Canadian biotechnology company. The drug binds the verotoxin produced by *E.coli* O157 infection in the gut, preventing it from reaching the bloodstream and thus reducing the risk of organ damage. The drug is presently completing the final stages of a 4 year clinical trial and is scheduled for release later this year.

The Walkerton community of 4,800 residents is served by a groundwater supply drawn from several wells. It is suspected that one of the wells became contaminated with animal waste after heavy rainfall in the area on May 12. The chlorination system for the water supply had reportedly been performing unreliably for some time and new equipment had been ordered.

Water samples taken on Monday 15 May tested positive for *E. coli* and the results were reported to the local water utility on Thursday 18 May. A program of flushing and chlorination was commenced to clear the contamination. The first signs of the outbreak occurred on 19 May when a local paediatrician reported two cases of bloody diarrhoea to the public health authority. By Sunday 21 May cultures of faecal specimens had confirmed *E. coli* O157 as the cause of the illness. Meanwhile more cases of severe gastroenteritis were reported by doctors and the local hospital,

and on Sunday 21 May a boil water notice was issued by health authorities.

According to reports in Canadian newspapers, a police investigation is now underway into the actions of the Walkerton Public Utilities Commission which supplies water and electricity to the town. The utility has only nine employees, with two individuals primarily responsible for managing the water supply.

Allegations have been made that the utility did not report either the *E. coli* findings or the problems with chlorination equipment to public health officials even when directly questioned about the safety of the water supply. The Health Officer for the region has been quoted as saying he contacted the utility when the first cases of illness were reported on Friday 19 May and was assured that the water supply was safe and secure. These assurances were repeated when the utility was again contacted the following day.

Health investigators initially concentrated their investigation on the possibility of foodborne transmission, but by Sunday 21 May they had become convinced that the municipal water supply was the most likely source. A boil water order was issued and the Public Health Unit collected water samples for analysis. These samples were reported positive for *E. coli* on Tuesday 23 May. It is reported that only then did the Public Utilities Commission personnel inform health officials of the previous *E. coli* test results and the chlorination problems. Control of the town's water supply has now been handed over to the Ontario Clean Water Agency for a six month period while the investigation continues.

The outbreak is the first waterborne *E. coli* outbreak from a municipal supply reported in Canada, and has attracted intense national media attention. A number of legal actions on behalf of victims have been lodged with the courts, citing negligence on the part of various parties. The outbreak has also triggered alarm in other towns and among homeowners with private wells, and testing laboratories have reportedly been overwhelmed with requests for water tests.

Some commentators have charged that the Ontario governments cutbacks in funding for environment protection and the devolution of responsibilities to regional and municipal authorities led to a failure of public health protection. The Ministry of the Environment (MOE) budget has been reduced by 40% since 1995, and it has been alleged the ministry has adopted a “soft” approach to enforcement and prosecution. The closure of government owned water testing laboratories in 1996 has also drawn criticism, after it emerged that the private testing laboratory had no legal obligation to report *E. coli* detections to government officials.

The MOE has launched an internal investigation after admitting it failed to follow protocols to notify the regional Medical Officer of Health of several recent detections of total coliforms or *E. coli* in the Walkerton supply. These test results were reported voluntarily to the MOE by a different private laboratory which was performing routine tests for the Walkerton water utility. This laboratory ceased working for the utility only weeks before the current outbreak, and testing was taken over by a different private contractor.

In the face of mounting public pressure, Ontario’s Premier announced a full inquiry into the outbreak on 31 April. Opposition parties are calling for broad ranging terms of inquiry to cover environmental regulation and enforcement in relation to water quality protection, as well as an investigation of the Walkerton outbreak.



Update on NATA Accreditation for Protozoa Testing

Report by Tanya Orlova, NATA.

In 1998 Australian laboratories had been testing for the presence of *Cryptosporidium* oocysts and *Giardia* cyst for some years, and a number of tests procedures/techniques were developed for detection of these organisms in water. The National Association of Testing Authorities, Australia (NATA) was however not prepared to offer accreditation at that stage due to perceived lack of consensus on the technical validity and comparability of these methods.

The need for development of principles of accreditation for potentially parasitic protozoa was precipitated when high levels of these organisms were detected in the Sydney water supply in 1998, which in turn led to an inquiry by Peter McClellan QC (1). The final report of the Sydney Water Inquiry acknowledged the still developing state of science relating to *Cryptosporidium* and *Giardia*, especially in relation to water supplies, but it also stressed the need to restore public confidence in the water supply and recommended greater transparency in all stages of water quality monitoring.

One of the recommendations of the final report of the McClellan inquiry was that: “*Laboratories providing parasitic analysis should be accredited by the National Association of Testing, Australia (NATA) utilising an approach similar to that implemented by the US EPA*”.

The rather challenging task of developing guidelines for accreditation was overcome with the help of dedicated and enthusiastic professionals who provided NATA with their expertise and time. The working group of NATA’s Water Biology Technical Group includes :

- Dr Colin Fricker, Thames Water UK
- Dr Peter O’Donoghue, Queensland University
- Ms Tanya Orlova, NATA
- Mr Bret Robinson, Australian Water Quality Centre
- Dr Frank Schaefer, US/EPA
- Mr Ian Smalls, Consultant (Chair WBTG)
- Assoc Prof Duncan Veal, Macquarie University

It was agreed that :

- accreditation will be granted only for the detection and confirmation of *Cryptosporidium/Giardia*;
- accreditation criteria will acknowledge the range of current technologies, but introduce a rigour and consistency of approach through extensive requirements on ongoing quality control. Quality Control will cover all stages of the test procedure (i.e. concentration, purification, detection and confirmation) and include training and monitoring of staff;
- laboratory reports will provide information on relevant quality control as well as

test results, in respect to typical and current recoveries for a type of sample in question, thus providing an indication of uncertainty of determination;

- international expertise, accumulated in the USA and UK will be utilised in developing criteria of accreditation and initial assessments of the laboratories;
- proficiency program participation will be a compulsory component of this accreditation.

The members of the working group have visited 7 laboratories to discuss the principles of proposed criteria and to gather more specific information. On the basis of these visits, the working group developed a checklist that covers relevant technologies and quality control requirements. The checklist was circulated to laboratories and placed on NATA's website in November 1999. Accreditation will require total compliance with relevant sections of the checklist.

As agreed, the working group has also developed and implemented a plan for the provision of a regular proficiency program. Two preliminary rounds of this program were offered to laboratories in August 1999 and March 2000. Results of these rounds provided the basis for defining the performance acceptable for accreditation.

Satisfactory performance in proficiency is defined as follows :

- Satisfactory – Laboratories that do not report any extreme results (false positives and/or false negatives) or low recoveries for any sample tested in two consecutive rounds will be graded as "satisfactory".
- Questionable – Laboratories identified as having reported extreme results or low recoveries in one round of this program, will be graded as "questionable".
- Unsatisfactory – Laboratories identified as having reported extreme results or low recoveries in two consecutive rounds of this program, will be graded as "unsatisfactory". NATA accredited laboratories graded as unsatisfactory will become inoperative for this testing. These laboratories will need to perform to a satisfactory standard on two consecutive

rounds before their accreditation status for this testing is returned. Information on inoperative laboratories is available to the public.

The acceptable range for percentage recoveries, in the first instance was set at 10% - 110%. This range has the possibility of changing once the confidence levels based on a history of proficiency testing data has been established.

As usual, individual laboratory testing performance will be monitored for each round of this program. Laboratories that have reported an extreme result (false positive/false negative) or reported low recoveries, will be required to instigate investigative action to identify the cause. Details of this investigative action, and any associated corrective action, will be required to be reported in writing to NATA by a stated date. Laboratories' investigations will be reviewed and technical comments will be provided if required.

NATA's Water Technical Group will continue its input into the review of criteria to ensure the program's currency in light of ongoing technical developments and the performance of laboratories in the proficiency program.

One laboratory that voluntarily offered to be the first to be assessed against the checklist is now accredited. The rest of the visits are planned for July-September 2000. NATA is now planning its next year of accreditation and proficiency testing, including financial and program management cooperation with the Water Services Association Australia.

(1) Reports on the Sydney Water Inquiry can be found in Health Stream Issues 11, 12 and 13.



Workshop Report

Exposure Assessment for Disinfection By-Products in Epidemiologic Studies

8-10 May 2000, Ottawa, Canada.

This 2 1/2 day conference sponsored by Health Canada and the US EPA brought together over 70 participants from a wide range of fields including water analysis, toxicology, water system

management, risk assessment, public health and epidemiology. The aims of the workshop were:

- to develop better approaches in exposure assessment for future epidemiologic studies
- to provide insight on how better to interpret previously conducted studies
- to promote better understanding among disciplines of the needs of epidemiology for better exposure assessment tools

The workshop consisted of 4 half-day sessions of presentations with a question and answer session after each, plus a final morning of discussion led by a panel of experts. The main themes of discussion and outcomes are summarised here.

Tap Water Sampling, Analysis and Distribution Modelling

Speakers in this session emphasised the complexity of disinfection byproduct (DBP) formation and occurrence in water supply systems. The types and concentrations of DBPs formed depends on raw water composition (amount and nature of organic matter, bromide concentration), temperature, pH and the disinfectant used (chlorine, chloramine, ozone). The reactions leading to DBP formation continue as water moves through the distribution system, and some DBPs may also decompose due to chemical and/or microbial degradation. Even at a fixed point in a distribution system, DBP concentrations may vary markedly with time and water temperature.

More than 200 halogenated and 400 non-halogenated DBPs are known to be formed by chlorination and new compounds continue to be identified. For many compounds, standard assay methods are not available and little or nothing is known of their biological effects. Information on the occurrence of DBPs is also very limited except for those where monitoring has been a regulatory requirement.

During discussions it was agreed that DBP sampling programs designed to fulfill regulatory requirements or operational management purposes are inappropriate for short term health studies (ie reproductive outcome studies). These programs may fail to cover the relevant exposure

window, and do not adequately capture the variability in exposure levels. For cancer studies where long term exposures are estimated, there may be significant inaccuracies due to variations in sampling and assay methods between different utilities and different time periods. Modelling of DBP concentrations in distribution systems is very complex, and site specific models must be used which incorporate relevant local parameters.

Surrogate Measures Of Exposure

This session examined the exposure measures used to date in epidemiological studies of cancer and reproductive effects, and discussed possible options for improvements in accuracy. Early studies considered only drinking water exposure but it is now recognised that inhalation and dermal routes of exposure may be equally significant or more significant than ingestion for many DBPs.

Fourteen studies of DBPs and reproductive effects have been published, with a range of pregnancy outcomes examined by different researchers. Exposure has been assessed in terms of water source (surface vs groundwater) or disinfection type (none, chlorine, chlorine dioxide, chloramine), or DBP measurement (usually only total THMs). Only a few studies have examined water consumption or water use behaviours in individual women, and most have used retrospective assessment of exposures and pregnancy outcomes.

Reproductive study designs are limited by the frequency of the outcome under study - for example stillbirths occur at a rate of 5 in 1,000 births, therefore it is not feasible to conduct a prospective study as this would require enrolling many thousands of pregnant women to achieve adequate statistical power. Only relatively more common outcomes such as spontaneous abortion, premature birth or low birth weight are feasible to study in an entirely prospective manner.

Exposure assessment in cancer studies requires long term measures, which should include a full residential and occupational history, but it is uncertain whether questionnaires about water consumption or showering behaviour 30 to 40

years in the past produce accurate answers. Given present knowledge about variation in DBP profiles in different water sources, exposure classifications in past studies should be reexamined. For example, reclassification of exposure on the basis of brominated THMs rather than total THMs may yield different risk estimates.

Biomarkers Of Exposure

The US National Academy of Science has classified biomarkers into 3 classes as follows:

- biomarker of exposure - an exogenous substance or its metabolite, or the product of an interaction between a xenobiotic agent and some target molecule or cell, that is measured in a compartment within an organism.
- biomarker of effect - a measurable biochemical, physiological or other alteration within an organism that, depending on magnitude, can be recognized as an established or potential health impairment or disease.
- biomarkers of susceptibility - an indicator of an inherent or acquired limitation of an organism's ability to respond to the challenge of exposure to a specific xenobiotic substance.

A number of potential exposure biomarkers for DBPs are under investigation. Attention has focused on detection of THMs and haloacetic acids in blood, urine or exhaled breath as these are the most abundant classes in drinking water, and also the most widely monitored by water utilities. The relative importance of the different exposure routes (ingestion, dermal, inhalation) depends on the chemical nature of the DBP (volatile /non-volatile, lipophilic /non-lipophilic).

Some substances formed during drinking water disinfection may also occur in foods or beverages, and some are produced as normal body metabolites. Such compounds are unsuitable as biomarkers as they are not specific for drinking water exposure. Compounds which are primarily absorbed by ingestion may be difficult to detect in biological fluids if they are rapidly metabolised on the first pass through the liver. It is feasible that lipophilic DBPs and their metabolites may be stored in adipose tissue, but it is difficult to verify this experimentally in human subjects. During

discussions it was also noted that DBPs which are grouped together in chemical classes (eg trichloroacetic acids) may have very heterogeneous biological properties in terms of absorption, metabolism and excretion.

Biomarkers may eventually offer a means to accurately estimate exposure and reduce misclassification in epidemiological studies, however at present considerably more work is required to characterise and validate these markers under well controlled conditions before they can be routinely used. New developments in analytical techniques are likely to improve the speed and sensitivity of DBP assays both in water and in biological fluids.

Exposure Modelling And Uncertainty Analysis

This session examined sources of error in exposure assessment, their potential effect on risk estimates, and modelling approaches to the problem. In epidemiological studies, non-differential exposure misclassification is generally assumed to reduce risk estimates towards the null value (ie assumed to underestimate the degree of risk), however reanalysis of published studies on reproductive outcomes has demonstrated that under some circumstances exposure misclassification can produce a spuriously high risk estimate.

A number of research groups are developing models of in-home exposure to DBPs using information such as room sizes, ventilation, hot water temperature, showering times, water flow rates etc. Such models are designed to simulate the microenvironment inside the home in order to predict DBP exposures by various routes. Exposure estimates from these models are being compared to reported behaviour as recorded in diaries, blood samples from participants, and data logging of water use in individual homes. Sensitivity analysis will indicate which are most important parameters in the models.

An overview of epidemiological issues emphasised the need to recognise real world limitations. While the aim must be to develop more accurate exposure assessments, we must be careful not to confuse detail with accuracy. This

is particularly relevant for cancer studies, where the long retrospective time frame imposes limitations on data collection. For example, a detailed water consumption /water use questionnaire covering 30 years may not necessarily produce accurate answers due to unreliable recall of the people involved. Perhaps the effort spent in such assessments is not justified by the resultant improvement in accuracy over "ecological" measures such as residential history - if an improvement is gained at all. The difficulty in separating DBP exposure from other potential risks is also important. Long term exposure to chlorinated water supplies correlates strongly with residence in urban areas, which in turn entails exposure to many urban pollutants which may impact on cancer risks.

Studies of reproductive effects have the opportunity to collect much more accurate exposure data, but again there is a need for some caution. It has been demonstrated that people show a distinct "digit preference" when recording showering times - if the showering time exceeds 5 minutes there is a tendency to round up times in 5 minute increments. Thus reported exposure times will tend to cluster in a way that does not reflect actual behaviour. When considering "exposure windows" for reproductive effects we perhaps need to consider the impact of differential survival of foetuses on recorded pregnancy outcomes as well as the time period when a particular type of defect may have arisen.

The priority for improvements in epidemiological studies must be to identify measures which can be reliably reported or assayed, and which enable us to distinguish between people with different exposure levels.

Summary Of Workshop Outcomes

Water Sampling And Modelling

Routine sampling programs conducted by water utilities for regulatory purposes are unsatisfactory for epidemiological studies. Future studies should incorporate water sampling programs to better assess DBP profiles in different areas of the distribution system. Epidemiological researchers should involve water utilities in the design of such programs to ensure an optimal sampling strategy

within the financial and other constraints of the study. Industry bodies (AWWA, CWA) could assist by developing guidelines to facilitate contact between researchers and utilities.

There is insufficient knowledge to identify a likely causative agent or agents for adverse health effects among the wide range of known and unknown DBPs, therefore a range of water quality parameters should be tested in addition to a select range of DBPs. These measurements will allow the estimation of levels of any particular DBP that is identified as being of concern in the future. Participants with experience in water analysis strongly recommended that the following parameters be measured:

- 4 THMs and 9 HAAs at the plant and in the distribution system.
- raw water and water treatment parameters - SUVA (specific ultraviolet absorbance), DOC, pH, temperature, bromide, chlorine dose, coagulant dose etc.
- distribution system parameters - pH, temperature, chlorine demand, free chlorine, conductivity or inorganic chemicals if applicable (useful to trace blending of water sources).

It would also be preferable to utilise standard assay techniques for water quality parameters to ensure comparability of results. It was noted that commonly used kits for measuring free and total chlorine were not very accurate.

Current hydraulic models were developed for operational purposes (eg managing disinfectant residuals, maintaining pressure), and are not good for modelling DBP formation and decay. Better models with more accurate information on water age and travel times are needed.

Target DBPs

Brominated compounds - there was considerable discussion during the workshop of emerging evidence that brominated DBPs may be of more concern on the basis of animal toxicology and human reproductive studies than their non-brominated counterparts. However concerns were also expressed that we should not focus too heavily on these compounds to the extent that we neglect others.

There is still insufficient evidence to ascribe a "causative" role to any DBP or class of DBPs, and indeed the existence of adverse health effects from chlorination DBPs is still unproven. We must exercise care in communications with the public on this issue. There is already an erroneous perception that other means of water disinfection (eg ozonation) produce no DBPs. The risks from bottled water are also unknown.

As more data accumulates on DBP occurrence it may be possible to define a subset of compounds that will provide adequate surrogates for the presence of others. Consideration also needs to be given to the biological characteristics of DBP when choosing what to measure – similarity in chemical structures does not necessarily imply similarity in metabolic properties.

Epidemiological Measures

Exposure assessment - we need to resolve how much detail and what degree of accuracy is needed for exposure studies. It is wasted effort to ask detailed questions about water use behaviours (eg drinking, showering etc) unless:

- the measured parameter is reported with reasonable accuracy
- the parameter varies significantly between individuals

It would also be useful if epidemiological studies used common questionnaires for exposure assessment (eg water consumption).

Data is lacking on home microenvironmental effects - for example overnight storage of water in the domestic hot water tank will significantly alter the DBP profile compared to the cold tap water supply. This information is needed for incorporation into models. Research to date has focused mainly on modelling THMs - work is needed on other DBPs also.

Biological samples - it would be desirable to develop a consensus protocol for collection and storage of biological samples (eg blood, buccal epithelial cells, bladder epithelial cells) for epidemiological studies in order to maximise the potential for future DBP or biomarker analysis. Some research has been done on potential gene-environment interactions and on potential

pathways of effect for DBPs. Future work would be aided by the collection of biological samples.

Study Designs And Location

There is a need to design studies to maximise differences in exposure - when choosing locations for health studies it may be preferable to first examine the range of DBP exposures in several locations then site the study to maximise contrasts. Other factors that might be considered are the quality of existing distribution system models and the extent of DBP monitoring. However when comparing different locations, influences such as socio-economic differences may affect the health outcomes being measured.

Natural experiments - consideration should be given to designing "before and after" studies in locations where a significant shift in DBP exposure is occurring due to changes in water treatment practices.

Cancer studies vs reproductive studies - different exposure assessment tools are needed for the two types of studies, and these two issues must be independently assessed. Evidence supporting one type of adverse effect cannot be inferred to support the other.

Characterisation of DBPs

Information is needed on DBPs from other exposure sources (for example food, beverages, occupational exposures), and those which are natural body metabolites. We need to identify which DBPs occur solely or primarily in drinking water in order to concentrate our research focus.

More work is needed to characterise large molecular weight DBPs. During discussions, it was noted that some toxicologists believe that high MW compounds are unlikely to be of concern in terms of health effects as they may not be readily absorbed or metabolised. However there is no consensus on what molecular weight cutoff might be used to define such substances, with estimates ranging from 800 to 2,000 or perhaps 5,000 Daltons. Additionally, substances which are present at levels of 10 microgram/L or less should not represent a risk unless they are markedly more toxic than any known substance.

The Coliform Debate

The debate was organised by Victorian Branch of the Australian Water Association in Melbourne on 9th May 2000. The meeting was chaired by Dr John Langford of the Water Services Association of Australia, and consisted of six presentations followed by a panel discussion and debate on the value of total coliforms as a water quality indicator. The proceedings began with Dr Melita Stevens, Principal Microbiologist for Melbourne Water Corporation who provided a brief history and background to coliforms for the benefit of the non-microbiologists.

The next speaker was Dr Michael Taylor, a senior adviser with the New Zealand Ministry of Health who gave an overview of the New Zealand approach to drinking water practice. *E.coli* is used as an indicator of faecal contamination in NZ, while total coliforms and heterotrophic plate counts are used to assess the effectiveness of disinfection. Turbidity is viewed as the best indicator of protozoal risks. Dr Taylor acknowledged that there is no direct relationship between indicator organisms and disease organisms, and no technology for direct monitoring of disease organisms at present. In his view *E.coli* is the best solution at the moment.

Mr Jeff Wright, CEO of the Sydney Catchment Authority questioned the importance of the total coliform test and expressed the view that it was time for a change. In many Australian water supplies, particularly in rural communities, total coliforms occur more frequently than specified in the relevant guidelines (WHO 1984 or NHMRC 1987). Reduction of coliforms could be achieved by raising chlorination levels, but rural communities often dislike high chlorination levels, and excess DBP formation may be a concern even though Australian guidelines for THMs are not as strict as European or US regulations. The use of alternate disinfection techniques such as UV or ozone in order to reduce total coliforms to near zero would require significant increases in capital, operating and mains cleaning costs especially for small communities.

Mr Martyn Kirk from the Disease Control section of the Victorian Department of Human Services noted that Victoria is the only Australian state with legal Regulations regarding water quality. These specify sampling, reporting and notification of diseases, but do not prescribe standards, although compliance with guidelines may be required in licensing agreements. The DHS require monitoring of total coliforms, and if an alert level of 50 cfu/ 100 ml is reached then re-sampling must occur and if this is confirmed the authority must take action. This action involves: identifying the organisms, speciation if possible, investigating the operations and rectifying any problems, then resampling and documentation for future reference. The DHS will continue to monitor total coliforms, particularly since it is easy and can be done at the same time as *E. coli* and this measure has international support.

Dr David Cunliffe of the South Australian Department of Human Services and the NHMRC Coordinating Group for Revision of the Australian Drinking Water Guidelines (ADWG) mentioned that the drinking water guidelines have both strengths and weaknesses and they require both the supplier and regulator to think, interpret and apply. South Australia has a reporting structure for the detection of total coliforms. If for example, a system shows total coliforms in absence of *E coli* then additional sampling is required which includes Enterococci. The results are interpreted as follows:

Coliform positive, enterococci negative = non-faecal source of coliforms

Coliform positive, enterococci positive = less recent faecal contamination implicated.

Modifications to Fact Sheets in the ADWG are being proposed to incorporate the new defined substrate technology for *B*-galactosidase detection (eg the Colilert test), and to recognise that total coliforms may not signify faecal contamination in the absence of faecal /thermotolerant species.

The final speaker was Associate Professor Nick Ashbolt, from the University of NSW and a member of the WHO Guideline Expert Group. He advocated a whole system approach to water quality management using a number of

parameters to monitor for source water contamination, efficiency of treatment and distribution system integrity. While total coliforms have a role to play, they neither indicate faecal contamination or pathogen presence, and the time lag to obtain a result makes them an unsuitable trigger for rapid operational response. Physico-chemical parameters should form the basis for real-time monitoring of critical control points in system operation. For assessing health risks the focus should be on *E. coli* or the thermotolerant species.

The panel discussion and debate followed. The panel consisted of the invited speakers plus Prof Nancy Millis, Ms Jo O'Toole and Dr Daniel Deere. The chairman posed a number of questions to the panel which were representative of the major issues associated with the use of total coliforms as indicators for Australian Water supplies.

Dr John Langford concisely summarised the pros and cons of the debate:

- Total coliforms are a group of organisms defined by a test method and were originally chosen because they are ubiquitous, easy to measure, survive longer than *E.coli* and are easy to kill by chlorination. Their absence in water supplies was once considered to indicate very low disease risk, but it is now clear that they correlate poorly with risk from some pathogens (notably the chlorine resistant protozoa).
- Total coliforms may have some use as a measure of treatment efficiency, but only as part of a comprehensive set of measurements. It is better in reality to measure chlorine residual directly and use total coliforms as a validation tool.
- For legal regulation of water quality, regulators are better off looking to a HACCP based approach for microbiological risk management. Microbiological measurements should be used for verification only.
- Total coliforms are not very useful for validating the integrity of distribution systems, and represent a poor indicator of regrowth and ingress. More effort needs to be put into finding replacement methods that the water industry and health regulators can have confidence in.

Conference Announcement

CRYPTOSPORIDIUM – FROM MOLECULES TO DISEASE

International Conference on *Cryptosporidium*

8-11 October 2001

Fremantle, Western Australia

SCIENTIFIC PROGRAM

- Day 1 Cryptosporidiosis – Aetiology, Pathogenesis And Chemotherapy
- Day 2 Epidemiology And Species Differentiation
- Day 3 *Cryptosporidium* And The Environment
- Day 4 *Cryptosporidium* - Outcomes For The Future

This conference is sponsored by the CRC for Water Quality and Treatment, the Water Services Association of Australia, and the Australian Society for Microbiology. Further details will be published in Health Stream at a later date. The conference organisers may be contacted at: conwes@congresswest.com.au

News Items

Court Rules Against USEPA on Chloroform

The US Court of Appeals for the District of Columbia has ruled against the EPA in a case concerning the MCLG (minimum contamination level goal) for chloroform. The case was brought by the Chlorine Chemistry Council on the basis that the EPA had violated the Safe Drinking Water Act by failing to use the "best available peer-reviewed scientific evidence" in setting the MCLG for chloroform.

In 1998 the EPA had proposed an MCLG of 0.3 mg /L for chloroform on the basis that the scientific evidence supported a safe threshold level of exposure for this compound. However the MCLG was later revised to zero in the face of public and political criticism. The MCLG is not an enforceable standard but rather provides a target for water utilities to aim for. MCLGs are defined under the US Safe Drinking Water Act as levels "at which no known or anticipated adverse

health effects occur, allowing for an adequate margin of safety". The regulatory level or MCL (maximum contaminant level) is set equal to or above the MCLG taking into account practical considerations of cost and available technology.

In a decision issued on March 31 the Court found the adoption of the zero MCLG for chloroform by the EPA to be "arbitrary and capricious and in excess of statutory authority" and therefore vacated the rule.

Water Account for Australia

The Australian Bureau of Statistics has released a report detailing water supply, use and consumption by various sectors of the Australian economy from 1994 to 1997. Despite being the driest inhabited continent, Australia ranks second in the world in terms of water use per capita with 1 million litres of fresh water used per person. Agriculture, including forestry and fishing, accounted for over 70% of consumption, while household water use was responsible for 8%. About 52% of water is supplied via mains infrastructure while the rest is extracted directly from the environment. The report can be obtained from the ABS (Catalog No. 4610.0).

www.abs.gov.au

UK Concern Over Drugs In Water

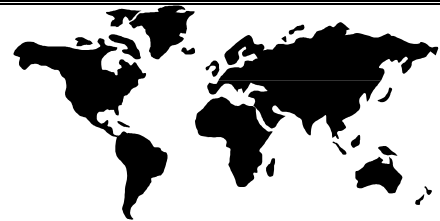
The UK Environment Agency is assessing the need for new regulations covering pharmaceutical compounds in sewage effluent, following an expert review of the issue. Evidence of drug residues and their metabolites in effluent and drinking water sources has been presented at recent conferences in Brighton and San Francisco, and there are concerns over the impact of such chemicals on aquatic ecosystems. Some scientists have speculated that residues from pharmaceuticals and personal care products may be responsible for mass die-offs of aquatic organisms, or interference with breeding cycles.

Legionnaire's Outbreak in Melbourne

An outbreak of Legionnaire's disease in Melbourne Australia has affected at least 100 people and caused two confirmed deaths, with a third fatality also under investigation. The source of the outbreak appears to have been the cooling system at a recently opened aquarium which attracted up to 4,500 local and international visitors each day. All cases had visited the area between April 11 and 25. Some infections occurred in people who had been near but not inside the building, suggesting that external drifts of water droplets from cooling towers may have been responsible.

Circulation Report – Issue 18 June 2000

Circulation for this issue of Health Stream is 3393 copies, with readers in 50 countries.



Australia	2844	Germany	29	Malaysia	50	Slovak Republic	3
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Austria	4	Hong Kong	23	Morocco	3	Sri Lanka	2
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From the Literature

Arsenic

Arsenic in drinking water and bladder cancer

Steinmaus C, Moore L, Hopenhayn-Rich C, Biggs ML, Smith AH. *Cancer Invest* (2000) **18**(2) p174-82.

This article reviews the major epidemiological evidence linking ingested arsenic to bladder cancer and the controversy which surrounds the research. The largest studies conducted into the effects of ingested arsenic and bladder cancer have been on populations in the southwest coast of Taiwan. These studies have shown large degrees of association and clear dose-response trends as well as consistency among investigators. However this data has been questioned for a number of reasons. It has been suggested that arsenic may not be the only cause of these cancers and humic acid-like substances found in high levels in artesian wells may be responsible for some portion of the effects seen.

The Taiwanese findings have not been supported by toxicological tests on animals and the studies were of ecological study design and based on large group averages rather than on direct exposure of individuals. Four recent studies have provided substantial support for an association between bladder cancer and ingested arsenic. None of these studies were conducted in areas with humic substances present and two of the studies used a retrospective cohort design looking at individuals rather than grouped data. Although the results have not been supported by tests on animals this may reflect the variability of arsenic metabolism among different species.

The US drinking water standard for arsenic was set in 1942 at 50 µg/l, at a time when little was known about the effects of ingested arsenic. EPA risk estimates suggest that the current standards needs to be substantially lowered in order to avoid cancer risk. Several of the EPA risk assessment processes have been questioned and a new standard in the United States is being delayed. The WHO has already lowered their recommended standard to 10 µg/l.

The dose-response relationship especially at low or moderate doses is still unclear. Several studies are being undertaken in the US at present to investigate the risks of ingested arsenic at doses under 100 µg/l. These studies however will take years to complete and in the mean time thousands of people are being exposed to levels of arsenic that may be associated with cancer risk.

Genetic biomarkers are currently being used to provide information into the mechanistic and susceptibility issues of arsenic carcinogenesis. The micronucleus (MN) assay and the comparative genomic hybridization assay are a few of the genetic biomarkers being used to study arsenic toxicology. The MN assay has provided evidence of genetic damage occurring in the bladder at arsenic exposures near the current US standard and may help to make clear the dose-response relationships at low doses. The authors suggest the most appropriate action at present may be to use the WHO recommendation of 10 µg/l until further research is completed.

Clues and uncertainties in the risk assessment of arsenic in drinking water.

Buchet JP, Lison D. *Food Chem Toxicol* (2000) **38**(Suppl 1) pS81-S85.

This paper also discusses the evidence for cancer risks associated with arsenic, and the need for better data on health effects at low and moderate exposures. The authors note that although arsenic has been defined as an indirect genotoxic agent with several possible modes of action, it is also accepted that each of these modes has a threshold or non-linear dose response relationship.

They conclude that new data is need to better assess daily doses including the measurement of As in food and other potential sources using more sensitive and specific analytical techniques. Attention must be paid to other cancers beside skin cancer such as lung, liver, kidney and bladder. Current epidemiological surveys combined with studies on As pharmacokinetics and metabolism should help to better assess the risk of As in drinking water.



Cholera

Climate and infectious disease: Use of remote sensing for detection of *Vibrio cholerae* by indirect measurement.

Lobitz B, Beck L, Huq A, Wood B, Fuchs G, Faruque ASG, et al. Proc Nat Acad Sci USA (2000) **97**(4) p1438-43.

This study was undertaken to gather data needed to develop a cholera prediction model that would monitor ocean parameters, using remote sensing data and provide an early warning of conditions that might be associated with a cholera outbreak. Public domain remote sensing data of the Bay of Bengal was compared with cholera case data from Bangladesh from 1992-1995. The International Centre for Diarrhoeal Disease Research provided weekly cholera case data. Remote sensing data included sea surface temperature (SST) and sea surface height (SSH).

The analysis demonstrated a relationship between SST and SSH levels and cholera outbreaks. The dependence on SST is attributed to increased growth of plankton harbouring the causative organism *Vibrio cholerae* in warm water temperatures. The association with high SSH values is attributed to tidal intrusion of plankton into inland rivers, as much of Bangladesh is only slightly above sea level. The majority of Bangladesh residents consume untreated water, providing the conditions for outbreaks when cholera-carrying plankton are present. Other factors such as salinity are also important influences on cholera toxin production.

The relationships between cholera outbreaks and SST and SSH identified in this study will be combined with plankton distribution patterns and used to predict cholera outbreaks. This predictive model for cholera is currently under development for the Bay of Bengal and could then be extended to other regions of cholera outbreaks.



Cryptosporidium

Cryptosporidia on dairy farms and the role these farms may have in contaminating surface

water supplies in the northeastern United States.

Sischo WM, Atwill ER, Lanyon LE, George J. Prev Vet Med (2000) **43**(4) p253-67.

The aim of this study was to quantify the prevalence of cryptosporidia in dairy cattle, to assess the risk factors for *Cryptosporidium parvum* prevalence in calves and to determine the risks for *Cryptosporidium* contamination of surface water by dairy-production units.

The study area was a major watershed comprising 12,812 km² and the source of drinking water for a metropolitan area in the northeastern United States. The watershed contained a small concentrated dairy industry. Eleven dairy farms participated in the study and sampling was scheduled at approximately 4-week intervals for 6 months, beginning December 1997.

Cryptosporidium was detected on 10 of the 11 farms. The highest prevalence was in 0-3 week-old calves with 15% shedding cryptosporidia. Of the 16 on-farm water samples collected no *Cryptosporidium* was detected and of the 49 on-farm slurry samples only one had *Cryptosporidium* present. There was an 8% prevalence of cryptosporidia in water at the upper boundaries of study farms and a 2% prevalence at the lower boundaries.

There was a positive association between cryptosporidia shedding in calves and calf bedding changed more than 12 times per year and contact between calves. A negative association was found between increasing age and shedding oocysts. There was an association between frequent spreading of manure and cryptosporidia in the farm-water system. There was also an association between higher cumulative total rainfall during the 5 days prior to and including the sampling days and a decreased probability of detecting *Cryptosporidium* oocysts in the stream. No animal or barnyard management features were associated with detecting cryptosporidia in farm-impacted streams.

In this study the animals showed a low prevalence of cryptosporidia although most farms had

cryptosporidia present. Calves in the study farms were managed in a way to prevent their manure from directly contacting surface water; this was reflected in the lack of positive lower boundary waters in the study. This study gives support to the use of manure-storage facilities and strategic spreading of manure to reduce the possible contamination of surface waters.

Advice on the response from public and environmental health to the detection of cryptosporidial oocysts in treated drinking water. PHLS Advisory Committee on Water and the Environment.

Hunter PR. *Commun Dis Public Health* (2000) **3**(1) p24-7.

New water quality regulations in the UK that came into force in June 1999 require water companies to carry out risk assessments to establish if there is a significant risk of cryptosporidial oocysts getting into finished water supplied from each water treatment works. Water leaving the relevant treatment works must be continuously sampled and analysed daily for cryptosporidial oocysts. It will be a criminal offence to not comply with the standard. During 2000 the monitoring arrangements required by the regulations will be in position and local health authority consultants in communicable disease control (CCDCs) along with local authority environmental health officers (EHOs) will be informed by water companies about the detection of cryptosporidial oocysts.

This paper gives brief advice to CCDCs, EHOs and others on the action they should consider if informed of the detection of oocysts in their communities' drinking water supplies. These guidelines were developed by a working group of the PHLS advisory committee on Water and the Environment. The new sampling method for cyptosporidial oocysts required by the regulations is more sensitive than that used previously and therefore CCDCs and EHOs should be aware that this is likely to lead to more oocysts being detected.

The authors outline the need for incident planning and communication protocols between CCDCs

and EHOs and local water companies. They recommend that in each instance, a health risk assessment should be carried out to determine the appropriate public health response. This may be no action, advice to special groups, enhancing surveillance, provision of an alternative water source or issuing advice to boil water.

Sydney's 1998 water quality crisis.

Clancy JL *J AWWA* (2000) **92** (3) p55 – 66.

This paper discusses the water contamination events which occurred in Sydney Australia from July to September 1999. High number of *Cryptosporidium* oocysts and *Giardia* cysts were reportedly detected in the water supply during this period, leading to three separate boil water advisories in nine weeks. A number of experts (including the author) were involved in the investigation of the incidents and presentation of evidence to the subsequent government inquiry.

Current analytical methods for protozoa detection and reviewed, and the sequence of events in Sydney, the investigation, and the outcomes of the inquiry are described. The author's conclusions differ from those of the inquiry on two points:

- *that there were significant concentrations of Giardia cysts and Cryptosporidium oocysts in the Sydney drinking water supply during the crisis* – the author believes that inadequate laboratory quality control measures throw doubt on the findings of protozoa, and that deterioration in quality control as the incidents progressed may have led to cross contamination in the laboratory.

- *that a protozoan monitoring program should have clear links to public health and operational decisions* - the author argues that many complex technical and administrative issues surrounding protozoa detection preclude the use of monitoring as a measure to protect public health. Watershed protection and treatment process optimisation are advocated as the best strategy to reduce public health risks. There is also a need for regulatory agencies worldwide to publicly acknowledge that protozoa monitoring is not a practical option for predicting water quality.



Disinfection by-products

Inhalation exposure to THMs from drinking water in south Taiwan.

Lin TF, Hoang SW. *Sci Total Environ* (2000) **246**(1) p41-9.

In south Taiwan the raw water used for a number of drinking water treatment utilities comes from polluted rivers and reservoirs. As a result trihalomethane (THM) concentrations in drinking water are generally elevated because large amounts of chlorine are added during water treatment. This study estimated exposure to THM via inhalation using a two part model.

An empirical THM formation model was used to predict THM concentration in drinking water based on raw water quality parameters collected in Kaohsiung, Taiwan. The input water quality parameters for this model included UVABS, TOC, temperature, pH, chlorine dosage, reaction time and ammonia nitrogen. The THM concentrations obtained from the formation model were used as input parameters for exposure models of three scenarios that were considered to contribute most to inhalation exposure. The models used were exposure during shower, during pre- and post-cooking activities and exposure during cooking processes. Inhalation exposure for the three scenarios was estimated using a risk analysis and simulation software.

The results using the models showed that the mean inhalation exposure of THMs for showering, pre- and post-cooking and cooking activities were 26.4, 1.56 and 3.29 µg/day respectively. The total mean inhalation exposure was 30.7 µg/day and this is comparable with that for ingestion of 47.9 µg/day. This indicates that inhalation is an important pathway for THM exposure from drinking water.

A multiple-purpose design approach to the evaluation of risks from mixtures of disinfection by-products.

Teuschler LK, Gennings C, Stiteler WM, Hertzberg RC, Colman JT, Thiyagarajah A, et al. *Drug Chem Toxicol* (2000) **23**(1) p307-21.

The risk to human health from low-level exposure to a complex mixture of disinfection by-products (DBPs) is of concern with studies suggesting possible systemic or carcinogenic effects. A multiple-purpose design approach to investigating the toxicity of DBP mixtures was developed by combining laboratory experimental designs with statistical models. The aims were to: estimate the human health risk from low-level multi-chemical DBP exposures, to assess various additivity assumptions as useful defaults for risk characterisation, and to calculate the health risk estimates for different drinking water treatment options. This paper uses data on liver endpoints in female CD-1 mice to illustrate the multiple-purpose design approach. The studies provide dose-response data for specific mixtures of four THMs which are chloroform, bromoform, chlorodibromo-methane and bromodichloro-methane, also for single chemicals and all possible binary combinations.

Dose-levels and mixing ratios were selected as useful for the development of three statistical methods: statistical testing of departures from dose-additivity, interaction-based hazard index and use of a proportional-response method. Initial results suggest that dose-additivity is a reasonable risk assessment assumption for DBPs. A complementary series of experiments are being carried out in medaka, a small Japanese fish (*Oryzias latipes*) which is under evaluation as an alternative species for use as a possible screening assay for mixtures.



Fluoride

Fluoride in drinking water and cancer mortality in Taiwan.

Yang CY, Cheng MF, Tsai SS, Hung CF. *Environ Res* (2000) **82**(3) p189-93.

This paper examines the association between cancer mortality and naturally fluoridated water supplies in 299 municipalities in Taiwan. The study was restricted to those municipalities in which at least 75% of the municipality population was served by municipal water supplies.

Two groups within the population were identified; those 10 municipalities with the highest naturally fluoridated water supplies (NFM) and those 10 with unfluoridated water supplies (UFM). Each NFM was matched with one UFM with the same urbanisation level. The Bureau of Vital Statistics provided information on number of deaths and midyear population by sex, age and calendar year during 1982 and 1991. For the years 1982, 1991 average annual cancer mortality rates per 100,000 population were calculated for males and females for each municipality in the two fluoride groups. The mean age-standardised mortality rates for cancer sites were calculated for all NFMs and UFM.

The two groups were reasonably similar in regard to several socioeconomic indicators and urbanisation levels. In UFM fluoride levels in water were less than 0.01 mg/L, in NFM levels ranged from 0.24 to 0.28 mg/L. For both NFMs and UFM cancer rates were generally similar in both males and females, except in the case of female bladder cancer mortality which was significantly higher in NFMs. This bladder cancer finding is considered as possibly a chance result by the authors who state that it seems biologically implausible for fluoride to affect only one sex and the result may have occurred due to multiple comparisons carried out in the analysis. The results overall do not show an association between fluoridation of water supplies and increase in cancer mortality. However the fluoride levels in the drinking water of the NFM group was quite low compared to artificial fluoridation which is normally about 1 mg/L.

Lead

A Practical Model for Estimating Total Lead Intake from Drinking Water.

Clement M, Seux R, Rabarot S. *Wat Res* (2000) **34**(5) p 533-42.

This paper describes the development of a practical model for estimating lead exposure of residents living in a given area based on the nature of the water supply and the configuration of the household plumbing system.

Sites were selected to study which had varying risks of contamination due to lead pipes. Water supplies were grouped into three classes of risk according to the water's lead dissolving capacity; low, average and high (based on pH and alkalinity). Water samples were taken from kitchen taps. Lead concentration in water after a given period of stagnation in piping systems was measured as well as during flow. Once water samples were obtained a proportional sampling tap was installed. When this tap was opened, 5% of water used for drinking or cooking purposes was collected in a sampling bottle.

To form a predictive model the lead concentration in standing and flowing water must be calculated, information required to do this includes: the pH and alkalinity of the water, the lead piping characteristics of the household plumbing and the stagnation time. The mean daily concentration of lead in drinking/cooking water can then be calculated by using the information on daily consumption of cooking/water for each household during stagnation and flow times and established contamination rates during these two phases.

This model was applied to the three representative water classes assuming different lengths of lead piping of 5m to 40m with internal diameters of 20 or 30mm. For high risk water the model showed that the limit for lead concentration recommended by WHO ($10 \mu\text{g l}^{-1}$) was reached for five metres of household lead piping. For low risk water the recommended limit is reached for pipes ten metres and longer.

Radon

Health risks due to radon in drinking water.

Hopke PK, Borak TB, Doull J, Cleaver JE, Eckerman KF, Gundersen LCS, et al. *Environ Sci Technol* (2000) **34**(6) p921-6.

Radon has been identified as a public health concern when present in drinking water, and has the potential to produce adverse health effects including lung cancer. As a result of the 1996 amendments to the Safe Drinking Water Act, the EPA contracted with the National Academy of

Sciences to undertake a risk assessment for exposure to radon in drinking water. This paper summarises the review and assessments conducted by the NAS committee.

Setting a standard for radon in drinking water has been difficult because ^{222}Rn efficiently transfers from water into indoor air and produces a risk from the inhalation of its decay products. This risk is however small as compared to radon in most homes that is present because of migration of soil gas. Radon in water is thought to only contribute a small amount to indoor radon concentration, however the risk posed by radon released from water is estimated to be larger than the risks posed by other drinking water contaminants that have been subject to regulation such as disinfection by-products. Radon in water also poses a direct ingestion risk.

The committee estimated a lifetime risk of lung cancer for a mixed population of smokers, non-smokers, men and women, resulting from the air exposure to radon from a waterborne radon concentration of 1 Bq m^{-3} to be 1.3×10^{-8} . The lifetime risk of stomach cancer from ingestion for the same water concentration was estimated to be 0.2×10^{-8} . There was insufficient scientific information to estimate the risks to susceptible populations such as infants, pregnant women, elderly, seriously ill, etc. The lifetime risk of lung cancer from the same water concentration could be calculated however for smokers and was estimated to be 3.2×10^{-8} for male smokers and 1.29×10^{-8} for female smokers.

The committee noted that while US occurrence data on radon is of good quality, a large degree of uncertainty exists in risk estimates due to lack of knowledge about inter-individual variability.

Comment The 1996 Safe Drinking Water Act Amendments allow states to implement multi-media risk reduction measures for radon. Depending on the relative contribution of water and non-water sources to indoor air radon levels, states may choose to reduce radon in the water supply (thus reducing risk on a community wide basis) or to utilise other measures to reduce radon levels in individual homes (thus targeting

the portion of the community with highest risk). While this flexibility will allow the most cost-effective method to be chosen in each jurisdiction, it has raised many concerns over equity and public perceptions that different groups may be exposed to different risks. The authors note that a careful public education program is needed to provide perspective on the risks, benefits and costs of each approach.



Water Quality

Microbiological standards for water and their relationship to health risk.

Barrell RAE, Hunter PR, Nichols G. Commun Dis Public Health (2000) **3**(1) p8-13.

Microbiological examination of water is undertaken to monitor and control the quality and safety of various types of water including: potable waters, treated recreational waters and untreated waters used for recreational purposes. As it is impractical to screen samples for all possible pathogens; indicator organisms are used as surrogate markers of risk. The most common tests done on water are for coliforms and *Escherichia coli* but the use of enterococci and *Clostridium perfringens* is increasing.

This article describes the microbiological standards that are law in the United Kingdom and the guidelines for drinking water and bathing water. Recent and pending changes to regulations are described, and the relationship between the microbiological quality of water and risk to human health is also examined.

Linking public health and the health of the Chesapeake Bay.

Burke TA, Litt JS, Fox MA. Environ Res (2000) **82**(2) p143-9.

The watershed of Chesapeake Bay covers 64,000 square miles and is home to 136 million people. While the region's economy is growing the Bay is increasingly threatened by the changing regional environment. It is estimated that wastewater from industry and sewage treatment makes up 20% of the water entering the Bay at any one time. In

recent years, reports of illness related to *Pfiesteria* raised concerns about the impact of pollution on human health.

The authors propose a framework for a “public health report card” to track the relationship between pollution and health to compliment ongoing research and ecological monitoring systems. Analysis of pollution problems in the context of the framework would help identify knowledge gaps, and assist in priority setting for public health and surveillance efforts.

Relationships between levels of heterotrophic bacteria and water quality parameters in a drinking water distribution system.

Carter JT, Rice EW, Buchberger SG, Lee Y. *Wat Res* (2000) **34**(5) p1495-1502.

Levels of heterotrophic plate count (HPC) bacteria in the water distribution system are commonly used to assess water quality. This study aimed to compare bacteria counts using plate count agar (PCA), R2A agar (low-nutrient media) and TSA-SB (tryptic soy agar with 5% sheep’s blood) in water and biofilm, and also to quantify pigmented bacteria in water and biofilm and to identify relationships among these bacteria and standard physical and chemical water quality parameters.

From July to November 1997 water quality samples were collected from a variety of location representing different flow conditions in the water distribution system in Milford, Ohio. HPC bacteria numbers from the different plating media did not correlate well, and the expected inverse relationship between HPC counts and free chlorine levels was seen only with R2A medium.

The percentage of pigmented bacteria was not found to be correlated with standard physical and chemical parameters of water quality, but statistically significant associations were found between physical and chemical parameters and levels of HPC bacteria, in particular counts calculated using R2A media. These data may be useful to water utilities in the operation and maintenance of their water distribution systems.

Natural protection of groundwater against bacteria of fecal origin.

Conboy MJ, Goss MJ. *J Contam Hydrol* (2000) **43**(1) p1-24.

Groundwater quality studies in Ontario, Canada have shown that drinking water wells differ in their bacterial contamination levels with some being consistently clean over a 5 year survey period while others are consistently contaminated. This study was undertaken to identify the characteristics that make some wells susceptible to microbial contamination and give others natural protection.

In 1997, 300 wells from the Ontario Farm Groundwater Quality survey were re-sampled to determine the effectiveness of various indicator organisms and to assess the vulnerable well locations. In June 1997, 150 wells were also sampled in the Goromonzi rural district of Zimbabwe, which has a very different geology and dominant soil type than the sites in Ontario.

In Ontario the analysis showed that manure spreading, especially on a daily basis, can increase the risk of well water contamination. The high-risk wells were found to be mostly located on sites with older limestone/dolostone bedrock and clay or clay loam soil. Sandy soils seemed to offer some protection to groundwater resources as sands become unsaturated much more quickly than clay soils. Shale and hardpan layers, which are impermeable in nature, may also offer protection.

In Zimbabwe the soils and geological setting did not offer much protection from contamination. Deeply weathered joints and fractures in the underlying rock may be the reason for this.

Shallow dug or bored wells in locations where the soil profile was shallow or the water table was high were most susceptible to contamination. Dug or bored wells were more affected by soil and geological setting compared to drilled wells. Apart from soil type and geological setting, the condition of the well, location of contaminants and farm management practices were all important in determining well water quality.

List of Articles

Chemical contaminants

The epidemiology of chemical contaminants of drinking water.

Calderon RL. Food Chem Toxicol (2000) **38**(Suppl 1) pS13-S20.

Cyanobacteria

Cyanobacterial toxins: Removal during drinking water treatment, and human risk assessment.

Hitzfeld BC, Hoger SJ, Dietrich DR. Environ Health Perspect (2000) **108**(Suppl 1) p113-22.

Disinfection by-products

Estimation of water utility compliance with trihalomethane regulation using a modelling approach.

Rodriguez MJ, Serodes J, Morin M. Aqua (Oxford) (2000) **49**(2) p57-73.

Gastroenteritis

Outbreak of viral gastroenteritis due to sewage-contaminated drinking water.

Hafliger D, Hubner P, Luthy J. Int J Food Microbiol (2000) **54**(1-2) p123-6.

Parasitic food-borne and water-borne zoonoses.

Macpherson CNL, Gottstein B, Geerts S. Revue Scientifique Et Technique De L Office International Des Epizooties (2000) **19**(1) p240-58.

Foodborne and waterborne infectious diseases - Contributing factors and solutions to new and reemerging pathogens.

Prier R, Solnick JV (2000) Postgrad Med **107**(4):245.

Water quality

An overview of biofilm formation in distribution systems and its impact on the deterioration of water quality.

Mooba MNB, Kfir R, Venter SN, Cloete TE. Water SA (2000) **26**(1) p59-66.

Top quality drinking water treatment through low investment and operation costs.

Geering F. Aqua (Oxford) (2000) **49**(1) p35-47.

Microbiological water purification without the use of chemical disinfection.

Gerba CP, Naranjo JE. Wilderness Environ Med (2000) **11**(1) p12-6.

Water as consumed and its impact on the consumer - do we understand the variables?

Bates AJ. Food Chem Toxicol (2000) **38**(Suppl 1) pS29-S36.

Population-based dietary intakes and tap water concentrations for selected elements in the EPA Region V National Human Exposure Assessment Survey (NHEXAS).

Thomas KW, Pellizzari ED, Berry MR. J Exposure Anal Environ Epidemiol (1999) **9**(5) p402-13.

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Whilst every effort is made to reliably report the data and comments from the journal articles reviewed, no responsibility is taken for the accuracy of articles appearing in Health Stream, and readers are advised to refer to the original papers for full details of the research.

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The CRC for Water Quality and Treatment also produces the quarterly newsletter **Water Quality News** featuring current affairs, highlights from all 4 research programs of the CRCWQT, and information about other CRCWQT activities.

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