

10142 - Chlorination Disinfection By-Products and Risk of Abruption Placenta

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Concern has been raised about the possible role of chlorination disinfection by-products (CDBPs) in the risk of fetal death, especially among stillbirths due to asphyxia-related causes such as abruption placenta. Administrative databases were used to create a cohort of 695,510 singleton live and stillbirth deliveries in municipalities served by public water supplies in Ontario Canada between 1990 and 1997. Approximately 8,000 cases of abruption placenta were identified in the cohort using the hospital discharge database. Abruption placenta cases ending in stillbirth were included to represent an added level of severity of the placental condition. These records were linked to municipal drinking water levels of trihalomethanes and haloacetic acids. Postal codes were used to identify the water treatment facility serving each subject. Average CDBP levels reported by the treatment facility for the 4-month period around conception were used to estimate individual exposures. The pattern of risks for total or individual trihalomethanes did not support an association with abruption placenta; however in stillbirths, the abruption placenta risk was elevated in all but the highest exposure level of chloroform (for 60-79 $\mu\text{g/L}$, RR = 2.15; 95% CI 1.4-3.4). Moderate increases in risk of abruption placenta were observed following exposure to total and di- (DCAA) and tri-chloroacetic acids (for DCAA levels $\geq 8 \mu\text{g/L}$, RR = 1.3; 95% CI 1.2-1.5); however, haloacetic acid risk estimates for abruption placenta cases ending in stillbirth did not follow the same patterns. This study is limited by the lack of individual data on consumption and activity patterns as well as potential confounders; however, the results observed in this large study warrant further investigation using more accurate exposure assessments.

10152 - Is Balkan endemic nephropathy restricted to the Balkans?

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A disease leading to end-stage renal failure, Balkan endemic nephropathy (BEN) is so named because it is presently known to affect only inhabitants of Romania, Bulgaria, and former Yugoslavia. Despite its limited geographic range, BEN is a significant public health threat. Several thousand people are known to have BEN, with about 50% of these patients also having associated renal cell carcinoma (RCC), in the Balkans. We suggest that the actual number of people worldwide both currently affected and at risk for BEN/RCC, however, may be considerably greater. The reason for this suspicion is based on the hypothesized etiology of BEN. While the causative agent has yet to be definitively identified, strong evidence suggests that toxic organic compounds in contaminated drinking water supplies are at least partially responsible for BEN/RCC's onset. The source of the toxic organic compounds in the Balkans is thought to be Pliocene lignite (very low-rank coal) deposits that serve as aquifers in alluvial valleys. According to this scenario, the toxic compounds are leached out of these very chemically reactive lignites, and household wells in rural villages tap into the contaminated ground water. In North America, regions with the highest rates of RCC-like cancers often correlate with the lowest-rank coal and lignite deposits. This apparent association warrants rigorous testing because many of these cancer cases may be preventable by avoidance of the causative agents once they are identified and confirmed. Although reliable health data in certain parts of the world are sometimes hard to obtain, we contend that other countries that have especially low-rank lignites, such as Turkey and Greece, should be considered for investigation to determine whether BEN- or RCC-like syndromes also occur there.

Pooled analysis of case-control studies on bladder cancer and chlorination by-products

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INTRODUCTION: Exposure to chlorination by-products (CBP) has been associated with an increased risk of bladder cancer. We pooled and jointly analysed the data of the case-control studies of bladder cancer with detailed information on trihalomethane (THM) exposure, as a surrogate of total CBP level, and estimated the bladder cancer risk for long-term THM exposure.

METHODS: The pooled database includes two studies from USA, and one from Canada, France, Italy and Finland, accounting for 3790 cases and 6075 controls. Inclusion criteria were availability of detailed THM exposure data and accessibility of original data. Primary data were combined using common definitions and coding schemes. Subjects under 30 and over 80 years old, and those with more than 2 years between diagnosis and interview were excluded. A common exposure window of 40 years prior to interview was defined. The statistical analysis was limited to subjects with known exposure for at least 70% of the exposure window. Cumulative exposure to THM (mg) was estimated by combining individual year-by-year average THM level in the exposure window (micrograms/litre) and daily tap water consumption (litres/day). Unconditional logistic regression was used and all odds ratios (OR) and 95% confidence intervals (95%CI) were adjusted for age, sex, centre, pack-years of smoking, ever worked in high-risk occupations, socio-economic status (years of education) and heavy coffee drinking. The current analysis is based on four of the six databases.

RESULTS: We found an overall increased risk for ever having been exposed to THMs (OR=1.31, 95%CI=1.02-1.68) and a dose-response pattern. OR for ever-exposed was slightly lower when including low-exposed subjects (0-10 mg THM) in the reference group (OR=1.22, 1.00-1.49). In relation to the latter reference group OR were 1.17 (0.93-1.47) for the exposure category >10 to 30 mg, 1.21 (0.97-1.52) for >30 to 200 mg, and 1.28 (1.02-1.59) for >200 mg. ORs were similar between never-smokers (OR=1.32, 0.78-2.45) and current smokers (OR=1.34, 0.90-1.98), and in both strata ORs were highest among subjects with the highest THM exposure. A similar pattern was found for men (OR=1.26, 0.96-1.66). Among women, an overall OR of 1.47 (0.73-2.95) was found for ever having been exposed to THMs compared to those never exposed. These results depended, however, on the definition of the unexposed group. Inclusion of women with very low cumulative exposure (<5mg or <10 mg) among the unexposed, substantially modified the results with ORs close to unity.

CONCLUSIONS: Our preliminary results strengthen the hypothesis that long-term exposure to THMs at levels currently observed in many industrialised countries are associated with an increased risk of bladder cancer. Final results will be available for the presentation at the conference

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Paper topic: DRINKING WATER
Poster presentation

Abstract # 10268

INTAKE OF CARCINOGENIC SUBSTANCES IN DRINKING WATER

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Abstract

From the medical point of view the continued monitoring of drinking water (end of pipe) is a requisite and extremely important activity. It allows the monitoring of the content of substances harmful to health. In addition to regular monitoring of the basic parameters determined in the Drinking Water Act (Official Gazette of the Republic of Slovenia, 46/97, 52/97, 54/98 and 7/2000), it must be established whether drinking water contains any substances which are harmful to health and which are not subject to continued monitoring. These, of course, include carcinogenic substances. In line with the National programme for health ecology, in 1995, we began a monitoring programme for drinking water, which included, in addition to the measurements and analyses stipulated by law, measurements of the content of certain carcinogenic substances in drinking water.

Drinking water samples are taken three times a year from the nine regions into which Slovenia is divided for the purpose of preventive healthcare. Sampling points are determined in all nine regions and so is the day of sampling. Sampling is carried out according to sound scientific practice. Chemical analysis is carried out according to the same methods and using the same standards, thus making an evaluation of the results from all nine measurements possible immediately after the analysis.

In 1995, we started analysing the content of three carcinogenic substances, that is lead, arsenic and chloroform. In addition to those substances we began, in 1996, measuring the content of two pesticides (alachlorine and atrazine). From 1998 cadmium was also measured. We have now been measuring the content of all these substances as well as the metabolites of the pesticides concerned. The results of measurements and evaluation thereof will be presented by individual years as well as the comparison of values by individual regions.

In addition to the measurements, a preliminary estimate has been made of the intake by humans of the measured substances in drinking water. On the basis of the data obtained by the poll on the daily intake of water, the intake of the measured carcinogenic substances has been estimated. This provided an approximate assessment of the increase in health risk for the inhabitants of individual regions. The measurements results, a calculations of the annual quantities of consumed carcinogenic substances in drinking water and the increased health risk will presented. Possibilities for the elimination of these substances from drinking water will be put forward.

ISEA abstract2

PRD Williams, Exponent, Boulder
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Title: 10269 - Time-Series Evaluation of MTBE in California Groundwater versus Surface Water

Abstract:

Detections of the fuel oxygenate methyl tertiary butyl ether (MTBE) in drinking water have resulted in ongoing efforts to ban MTBE usage in the United States. In California in particular, MTBE is required to be phased out of gasoline by the end of this year. Much of the controversy over MTBE's impact on drinking water is driven by concerns that leaking underground storage tanks will affect local and regional groundwater supplies. Few attempts have been made, however, to differentiate between contaminated drinking water supplies served by groundwater versus surface water. Many detections of MTBE are also found in drinking water that is unlikely to ever reach consumers, and few detected concentrations exceed health or aesthetic-based standards. In this presentation, we provide the results of our analysis of groundwater and surface water monitoring data for MTBE provided by the California Department of Health Services (CDHS) from 1995 to October 2001. Specifically, we evaluate the data in several ways: (1) one-detection versus two-detection criterion, (2) all drinking water versus the subset of drinking water that is likely to reach consumers, (3) all detected concentrations versus detected concentrations greater than or equal to 5 ppb or 13 ppb, which are California's aesthetic and health-based MCLs. We find that surface-water sources have historically been at greater risk of MTBE contamination than groundwater sources in California, most likely due to the use of two-stroke engines in watercrafts on these waters. For example, MTBE was detected in about 1% and 0.3% of all groundwater sources reported in 2000, assuming a one-detection and two-detection criterion, respectively, but was detected in 4% and 1% of all surface-water sources reported for this same year. Detection frequencies for both groundwater and surface-water sources are even lower if only the subset of drinking water that is likely to reach consumers is considered, or if a 5-ppb or 13-ppb cutoff criterion is used. Some evaluations of the groundwater data also suggest a downward trend in the detection frequency for MTBE over the last few years, while all evaluations of the surface-water data indicate that the detection frequency of MTBE has decreased substantially since 1998. Over the last five years, average detected concentrations of MTBE were about 10 ppb or less in all groundwater sources, and 5 ppb or less in all surface-water sources, assuming a one-detection criterion. Our findings suggest that, regardless of water type or status, the detection frequency and detected concentrations of MTBE have been low and have not changed much over time. The number of new drinking water sources found to contain MTBE in California has also declined in recent years, and is likely to continue to decrease over time as recent government policies, such as the new tank upgrade program, become fully implemented.

10293 - Drinking Water Exposure Concentrations of Down-the-Drain Consumer Product Chemicals Using the GIS formatted ROUT model

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In order to estimate the total or aggregate human exposure to consumer product chemicals, potential human exposure via drinking water consumption is included in addition to direct exposure to these chemicals during product use. Typically, drinking water exposure assessments use the results from environmental exposure models, which estimate exposures to the environment in the immediate vicinity of single point discharges, either directly or after applying extra dilution factors. This presentation will demonstrate the approach P&G is taking to incorporate the unique spatial distribution of consumer product use and disposal and the numerous discharges across broad geographies to predict more accurately drinking water exposures. As discussed at last years meeting, the approach is based upon the P&G exposure model ROUT, which was developed in the late 1980s and has now been converted to GIS format. This model predicts the concentration of a user-specified chemical and five conventional water quality parameters (e.g., DO, CBOD, NBOD, and NH₃) for more than 500,000 river miles in the United States. The model was built using U.S. EPA river and municipal facility characteristics databases (e.g. Clean Water Needs Survey, Safe Drinking Water Information System, GAGE stream flows, Reach File 1 database, etc). The model starts at the headwater reach of each river system and models the additions from wastewater treatment plants, losses due to in-stream removal as well as the dilution and movement of the chemical downstream until the mouth or estuary is reached. The presentation will illustrate how the model has been used to identify areas of relatively elevated concentrations for further study and to better understand how consumer product use patterns and chemical properties contribute to elevated concentration distributions. The current version of the model estimates the distribution of raw drinking water concentrations from the concentration of chemical in those river reaches where the intakes are located. Finally, the planned improvements to the ROUT model that will provide better estimates of drinking water exposures including potential ways to incorporate removal of the chemical during drinking water treatment based on the type of treatment employed, and factoring in the relative contribution of surface water and ground water to the drinking water exposure are described. Finally, key lessons learned while making this approach reality are discussed.

10317 - DISEASE FROM THE TAP
Balancing Infectious Disease, Cancer and Costs in the US

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Drinking water is disinfected to prevent infectious disease. Disinfecting water costs money, and the by-products of disinfection may be carcinogenic and perhaps have other health effects. This confronts US public water utilities with both risk-risk and risk-cost tradeoffs.

We estimated the costs of waterborne infectious disease (WBID) in the US using published incidence estimates and data from cost-of-illness studies. We calculated that the annual WBID costs are about \$7 billion. New EPA regulations to control waterborne infectious disease have, on average, benefits many times their costs; indeed, reducing current waterborne disease levels by less than 5% yields a positive benefit-to-cost ratio.

To value damages from exposure to disinfection by-products (DBPs) in the US, we used attributable risk estimates and several alternative valuation methods. The cancer-related damages from exposure to DBPs range from \$1-16 billion/year, depending on the valuation approach used. With current data and methods, it is not possible to make an iron-clad economic argument for reducing exposure to carcinogenic disinfection by-products, but that reflects the uncertainties in the data and the conservatism of current benefit-cost methods; it is likely that benefits at least equal costs.

Under-spending for infectious disease control on the part of (mostly publicly-owned) water suppliers occurs largely because consumers are not likely to attribute their occasional bouts of stomach upset to the quality of their tap water. There may also be systematic under-investment in the development of new technologies to enhance drinking-water quality. Fixing those problems may require new institutional arrangements in this country.

10318 - Formation of Trihalomethanes in Beverages and Foods

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The trihalomethanes (THMs), one of the principal classes of disinfection by-products (DBPs), are classified as probable human carcinogens and exposure has been related to miscarriages and birth defects. Currently, exposure assessments have focused on the ingestion of THMs, which include CHCl_3 , CHCl_2Br , CHClBr_2 and CHBr_3 , in drinking water and to a smaller extent on inhalation and dermal adsorption. The consumption of foods containing THMs has been inadequately addressed. The available but limited data show that THMs and other DBPs are present in meat, dairy products, vegetables, baked goods, hot beverages and other foods. This paper investigates the formation of THMs while preparing beverages and foods using chlorinated drinking water.

A series of worse-case screening tests were conducted first to select food types for study. Selected beverages included: tea (instant tea, fermented tea leaves, unfermented tea leaves, herbal tea and decaffeinated tea); coffee (instant coffee, regular ground coffee and decaffeinated coffee); hot chocolate; and concentrated juices (orange and apple flavors). Foods included instant soups (chicken-noodle soup, miso-tofu soup and miso-seaweed soup); solid foods (rice, white noodle, pasta, corn, potato and spinach); and baby foods (baby cereal and formula). To prepare samples for analysis, distilled water (23 C or 100 C) was spiked with chlorine and used to prepare beverages and foods. Screening tests used chlorine at 6 mg/L, a reaction time of 5 min and headspace gas chromatography with electron capture detector to analyze the four THMs. Foods and beverages that formed significant THMs were selected for more complete analysis. DBP formation has been shown to depend on various factors. The more detail formation experiments used, for example, a range of chlorine concentrations (2~12.5 mg/L), tea concentrations (from 0.2 to 2 of the ratio of tea to water), steeping times (5~45 min), and bromide ion concentrations (0~250 $\mu\text{g/L}$). Regression models were used to characterize the relationships between THM production and each factor.

The screening tests showed that among the tested foods and beverages, tea formed the highest levels of THMs (chloroform= 2.7-67.0 ppb). THM formation in other foods and hot beverages was much lower, e.g., chloroform levels were 3-12.7 ppb, 0.4-3.0 ppb, 0~9.4 ppb, 0~0.7 ppb in coffee, instant soups, solid foods and baby foods, respectively. In the detailed tests, using tea, chloroform formation linearly increased with chlorine concentrations; higher tea concentrations decreased chloroform, likely due to increased consumption of chlorine present in tea leaving little free chlorine available to form THMs; steeping time and bromide ion concentration did not affect chloroform production. Other THM compounds (CHCl_2Br , CHClBr_2 and CHBr_3) were not significantly influenced by these factors.

Study results show that the production of THMs in tea and coffee can be considerable. Because two-thirds of water ingestion is through beverages, a large fraction of which is tea and other hot beverages, it is important that exposure assessments account for THM formation in hot beverages.

10327- DRINKING WATER QUALITY IN URBAN AREAS
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The quality of finished water and the technical problems associated with purification appear to be a function of the quality of raw water. In the surface waters were put in evidence heavy metals, pesticides, phenols, cyanide and different other microelements. Some times the inadequate water treatment may cause degradation of the drinking water quality. From interaction of some substances simultaneously existing in the water, as well as following disinfection by chlorine of water, are resulting many compounds, some of these being noxious or even carcinogenic. Distribution network constitute other potential source of chemical contaminants of finished water. METHODS. The objective of the present study 1999-2000 is the investigation of the water quality which is distributed to the population by the central water supplies station of district Iasi, Suceava, Neamt, Galati, Vaslui, Botosani. By an analytical, chemical, quality control program were investigated substances affecting the sources (raw water) delivered from point sources (phenols, metals, cyanide), from non-point sources (fertilizers, pesticides, heavy metals), substances resulting from treatment of water and substances arising from distribution system (Pb, Zn, Cd, Fe). The sampling and analysis were made according to the standardized techniques. RESULTS. The obtained data demonstrate that many of the surface sources are polluted by phenolic compounds-0.062 mg/L in Prut river, 0.035 mg/L in Danube river. Our investigations regarding microelements (Cu, Cd, Zn, Fe, Ni, Pb, Mn) shows that iron and manganese exceed MAC in drinking water delivered by some water works (Bucecea-0.445 mg/L for iron, 0.165 mg/L for manganese, Tiglina-0.613 mg/L for iron. Approximately 60 water samples (raw and drinking water) were analysed in order to determine the levels of following chloro-organic compounds-HCH and DDT and its metabolite DDD and DDE. The concentrations of DDT in drinking water were higher than HCH concentrations. The highest concentration of Al in tap water found – Sorogari 0.369 mg/L, Delea 0.2 mg/L, Tiglina 0.23 mg/L. In samples obtained from water supply systems there are 3-4 Benzopyrene and THM in low concentration. CONCLUSION. Our results have shown that, the water works do not retain some substances with risks for population health. By this reason the reconsideration of the projection, construction and the equipment for those stations so as they be able to retain the most of chemical substances and biological pollutants, must represent an important problem for authority in order to protect the health in urban areas.

10367 - THE QUALITY OF DRINKING WATER - DISAGREEABLE ODOR AND TASTE CHANGES - RELATED TO ALGAL BLOOMS IN THE WATER SOURCE OF TIRANA, THE CAPITAL OF ALBANIA

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The sanitary monitoring of the drinking water at the new treatment plant in Tirana City reported that the good quality of the drinking water and the lack of fecal contamination, were a direct result of not only the implementation of international recommendations, but also of the establishment of new national standards on water quality control.

On fall 2001, some disagreeable odor and taste changes began to occur. The treatment of the water through oxidation, coagulation, flocculation, sedimentation, filtration and the final disinfection did not remove the odor or the taste.

In addition to the routine monitoring controls performed by the public health laboratories, the Institute of Public Health and the Department of Biology at the Faculty of Natural Sciences did a joint control study for bacteriological and chemical indicators, also the phytoplankton examination.

The bacteriological quality of drinking water after the treatment plant, was within the national drinking water standards of the year 1998 respectively; E coli and Enterococcus indexes did not exceed the norms, even of the water of the origin; E. Coli 17/100 ml, Fecal Streptococcus 29/100 ml before treatment and 0/100ml after the treatment.

The residual chlorine was 0.5 mg/l, the turbidity was within 5.0 - 7.0 FTU before treatment and 0.1 FTU after treatment. The NH₄ - N 0.13 mg/l before treatment and 0.01 mg/l after treatment, P - total 3.2 mg/l before treatment and 0.05 mg/l after treatment. The phytoplankton examinations showed an algal blooms that were predominated by the diatome Cyclotella aff. commences Grunow. The highest level was about 3.130 000 C/liter in October.

Therefore, we concluded that the odor and the taste change were related to the degradation of the algae at the origin of the water, due to the fact that the lake water source was not protected from the human activity and animal husbandry. There is a population of about 6000 inhabitants near the water lake source who might have potentially caused a degradation of the water quality of the Source Lake.

It was recommended to employ powdered active carbon to the water of origin before treatment, also in order to clean of the pipelines and reservoirs of the aqueduct, the injection of high-pressure water, and disinfection.

Our survey demonstrated that human activities could be a very important source of environmental pollution that can result in the degradation of the quality of lake drinking water source, therefore posing a major risk for the health of the population.

Together with the additional treatment of the water it was also recommended, to restrict access to the immediate and secondary sanitary protection zones around the lake, and to increase the environmental awareness and education of the population in the zones close to the Source Lake.

10368 - Epidemiological investigation on chronic copper toxicity to children exposed via the public drinking water supply.

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Copper in drinking water has been associated with Non Indian Childhood Cirrhosis (NICC), a form of liver cirrhosis in childhood. This epidemiological study examines the exposition of infants to increased copper concentrations through drinking water from public water supplies in Berlin, Germany, and if this dietary copper intake can cause liver damage in early childhood. In total water samples from 2944 households with infants were tested for copper. In the 2619 collected composite samples taken independently of screening samples the mean copper concentration was 0.44 mg/l in the composite samples type 1 and 0.56 mg/l in type 2. Infants in households with copper concentrations above 0.8 mg/l and a defined minimum ingestion were recommended to undergo a paediatric examination. Nearly every of the 541 recommended infants were examined by a local paediatrician and of these 183 received a blood serum analysis, too. None of the infants had clear signs of a liver disease although a few serum parameters lay outside the accompanying reference range and abdominal ultrasound imaging gave slightly unusual results in five cases. Additionally no signs of a negative health effect could be found in the statistical analysis of the serum parameters GOT, GPT, GGT, total bilirubin, serum copper, or ceruloplasmin in relation to estimated daily and total copper intakes of the infants from tap water. No dose relation of serum parameters and estimated copper intakes could be established.

10489 - Assessing Exposure to Lead in Drinking Water Contaminated by Corrosion of Leaded Solder.

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Background: Leaded (Pb) solder used on domestic copper plumbing pipework, was identified as a source of lead contamination in the drinking water supply of newly completed houses in Scotland, despite a ban on its use. A survey of lead levels in the drinking water of 661 newly built houses throughout Scotland identified an average of 15% (C.I. 12.4% - 18%) with excess lead (more than 5 µg/l Pb) compatible with the use of leaded solder on the pipework. In houses less than one year old, 31.4% had lead levels compatible with the use of leaded solder compared to 10% for houses aged three years. Follow-up studies of the houses identified as having excess water lead levels were conducted. **Objectives:** (1) To assess the exposure to lead associated with the use of leaded solder on the domestic water supply pipework. (2) To determine if there was a correlation between water lead levels and blood lead levels of house occupants. (3) To determine if there was a correlation in the isotopic profile of lead in the drinking water supply and lead in the blood of house occupants. **Methods:** Water samples were collected from newly constructed houses previously identified as having excess lead levels in the drinking water supply. These were analysed for total lead content using standard laboratory methods. Blood lead levels were also determined using standard laboratory methods. Ratios of the 206-, 207- and 208-Pb isotopes were measured by inductively-coupled plasma mass spectrometry (ICP-MS) using a Perkin-Elmer Elan 600. **Results:** Water lead estimations for 62 houses were completed. The distribution of water lead results was positively skewed with a range of 0.5 µg/l to 264 µg/l. Seventeen samples had lead levels above the WHO recommended level of 10 µg/l. The ²⁰⁶Pb : ²⁰⁷Pb ratios ranged from 1.062 to 1.74 and were negatively skewed. Blood lead levels were obtained for 47 subjects and ranged from 0.01 µmol/l to 0.74 µmol/l. All samples had lead levels less than 1 µmol/l, the upper limit of "normal" for blood lead in Scotland. Evidence of a direct correlation between blood lead levels and water lead levels was poor. However, there was evidence that the isotopic composition of blood lead was associated with that of the drinking water (r = 0.46, p<0.001). **Conclusion:** Although occupants of houses where leaded solder had been used on the drinking water plumbing had normal blood lead levels, isotopic analysis confirmed that they had been exposed to lead derived from corrosion of the leaded solder. Isotopic analysis is therefore a useful tool in water lead exposure assessment. The potential for toxic levels of exposure to lead in drinking water must therefore be considered as a risk in houses where leaded solder has been used inappropriately.

10576 - Indicators of wastewater and land use impacts on public drinking water: Historical reconstruction of exposure on Cape Cod, MA

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Elevated incidence of breast cancer on Cape Cod, MA, is not adequately explained by established risk factors, suggesting that other factors such as exposure to environmental pollutants, particularly those that mimic estrogen, may be important. The Cape Cod Breast Cancer and Environment Study is investigating the possible association between breast cancer risk on Cape Cod and environmental exposures to a broad class of endocrine-disrupting chemicals (EDCs) and mammary carcinogens. In addition to using GIS technology to reconstruct historical exposures to these compounds from aerial and ground-based pesticide applications, this study is developing data resources to assess drinking water exposures to EDCs and mammary carcinogens. Drinking water for Cape Cod residents is supplied almost entirely by a shallow water table aquifer that is particularly vulnerable to impact from residential septage and commercial wastewater infiltration and agricultural pesticide applications. Approximately 80% of Cape Cod residents are served by eighteen public water supply systems that distribute water pumped from approximately 145 wells in this aquifer. Wastewater has been shown to contain high levels of EDCs, but these contaminants have not typically been measured in public water supplies. Thus, exposure assessment required development of proxy indicators of impact using available historical data. For each supply system, we calculated two annual impact scores for each system based on the volume-weighted concentrations of (1) nitrate and (2) total volatile organic compounds (VOCs) other than chloroform measured in each of the wells that contribute to these distribution systems. These scores were designed to reflect impact from septic system leachate and commercial/industrial wastewater in particular. Additionally, we developed scores for each district based on analysis of historical land use (residential, pesticide application, and commercial/industrial/waste disposal land uses) within each of the areal zones of contribution (ZOC) for these wells using GIS technology. The nitrate- and VOC-based scores were found to be uncorrelated at the scale of the individual well and at the district level, suggesting the possibility that these two indicators generally reflect different sources of contamination. When annual district-level scores for nitrate and VOCs were each grouped with regard to geographic proximity of the districts, distinct regional trends were observed, particularly for the nitrate-based scores. Additionally, nitrate scores were correlated with residential land use scores, and the degree of correlation increased as land use data more contemporaneous to the nitrate measurements were considered, in agreement with the relatively fast travel-time of nitrate in this aquifer. The spatial and temporal patterns observed from these indicators suggest the utility of this methodology for use not only in health studies, but also for use in land use planning for aquifer protection.

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Several studies point to an association between consumption of chlorinated by-products in drinking water and cancer mortality (mainly bladder, colon and rectum). In the city of São Paulo, Brazil, chlorination is the disinfectant process for drinking water. The water distributed to the population derives from 3 main hydrographic basins. There are differences in the amount of chlorine used in each treatment station due to the quality of the water of each basin, resulting in different concentrations of THMs for each area of distribution covered by a basin. Also, there is virtually no use of wells in the city. The objective of this study is to investigate if there is an association of cancer mortality with exposure to THMs in the city of São Paulo. Counts of annual deaths of bladder, colon, rectum and lung (control) cancers in the city of São Paulo in the last 5 years were obtained from the city's Death Notification Registry (PROAIM), which is considered to be complete, with less than 1% of missing data. Deaths were grouped according to the residence address, and then were distributed by the 3 basins. The Water Company of the State of São Paulo (SABESP) will provide THMs concentrations, for the last 10 years. Our preliminary results show that there is a difference among the cases of cancer for bladder, colon and rectum, but not for lung. As data on THMs is still incomplete, final results and limitations of our data will be presented at the Symposium.

10754 - DRINKING WATER HARDNESS AND MYOCARDIAL INFARCTION IN THE STOCKHOLM HEART EPIDEMIOLOGY PROGRAM (SHEEP).

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Objectives: A decreased risk for myocardial infarction (MI) has been related to the hardness of drinking water, particularly high levels of magnesium, but the evidence is still uncertain, especially in relation to the total individual intake from the water. We studied the association between MI-risk and the average daily intake of drinking water constituents in a sub-set from a large Swedish population-based case-control study 1992-1994 (SHEEP).

Methods: The study comprised 570 MI-cases in the ages of 45-70 years, and 753 population controls matched on age, gender, and hospital catchment area. A postal questionnaire provided information on a large set of potential risk factors for MI, including physical and psychosocial work environment, social factors, and different life-style factors. Individual data on magnesium, calcium, sodium, and hardness of the drinking water was collected up to two years preceding diagnosis for the subjects with an address connected to the local water distribution system (88%), and afterwards for those using private well-water. The mean daily dose of drinking water constituents was calculated by multiplying the water-work protocol data, or the result from the analysis of well-water, with the questionnaire data on amount of tap water consumed per day for each subject.

Results: After adjustment for the matching variables, smoking, hypertension, socioeconomic status, job strain, body mass index, diabetes mellitus, and physical inactivity, the odds ratio (OR) for MI was 0.88 (95% CI 0.67–1.15) among those with a magnesium intake from their drinking water above the median, i.e. >1.86 mg/day. Restriction to fatal cases resulted in a slightly lower estimate (OR 0.80, 95% CI 0.40–1.61). Analyses using multiple categories of exposure showed no sign of exposure-response. The ORs for hardness, sodium and calcium were also slightly below one, but none of the estimates were statistically significant and there was no exposure-response relation present. Considering only the drinking water quality during one year prior to infarction seemed to reduce the ORs slightly. In general, only men had estimates below one, and the association appeared stronger when excluding subjects using private wells. However, including data on other modes to consume the water in the dose calculation, e.g. as coffee, tea or soup, resulted in estimates slightly above one, indicating no association when considering total dose of magnesium or calcium from the drinking water.

Conclusion: In conclusion, our data could not support previous findings of an association between drinking water hardness, magnesium or calcium when considering total daily individual dose from the drinking water. However, potential misclassification of exposure should be recognized, as well as low mean levels and limited ranges in exposure.

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Background & Methods: A cross-sectional investigation was conducted to examine whether nutritional and metabolic factors are associated with skin lesions caused by chronic ingestion of drinking water arsenic. The study was conducted in Chiu Chiu, a small village located in the dry desert environment of northern Chile. This is a unique population because all residents shared the sole drinking water supply which was contaminated with high levels of naturally occurring arsenic (735-762 ug/l). After an extensive search, eleven families were selected who had the longest residence in this village. Each family consisted of father, mother, and two children. Of the 44 participants studied, 5 were found with arsenic-induced skin lesions (4 fathers, 1 daughter). In a previous publication we reported that the skin lesions were found despite adequate dietary intake of fruits, vegetables, and meat. For further investigation, blood samples were obtained from each participant and assayed for micronutrients and selected biochemical indicators of nutritional status. Here we present some findings for methionine (a methyl donor for arsenic methylation), selenium (potentially antagonistic to arsenic), and the antioxidants carotene and lycopene.

Results: The average concentrations of the blood nutrient indicators are compared between adult male cases (n=4) and adult male non-cases (n=7), and between families with one or more cases (n=16; 4 families) and families with no cases (n=28; 7 families).

Table: Comparison of selected blood nutrients

	Cases	Non-cases	Case families	Non-case families	Reference range
Methionine (umol/l)	26.5	26.5	22.2	23.5	6-40
Selenium (umol/l)	1.53	1.67	1.56	1.40	1.2-1.9
β-carotene (ug/dl)	166	128	184	158	2-80
Lycopene (umol/l)	19.5	35.4	14.2	26.4*	3-55

There is no evidence of differences between cases and non-cases, nor between case families and non-case families, for either methionine or selenium. β-carotene levels are higher than the U.S. reference range of 2-80 ug/dl in all groups due to heavy carrot consumption in this village whose livelihood is based on growing carrots. Interestingly average lycopene concentrations were lower in cases than non-cases, and also lower in case families than non-case families (p=0.04).

Conclusions: These findings indicate that arsenic causes skin lesions in persons with adequate blood methionine and selenium concentrations, and in persons with high blood carotene levels. The lower lycopene concentrations in cases and their families than in non-cases and their families require further study, in view of the small number of participants and the multiple comparisons involved.

10836 - Radium in Drinking Water and Osteosarcoma
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There has been considerable discussion of whether the cancer potency slope for radium isotopes in the low dose range can be characterized from epidemiologic data drawn from community exposures. The issue is of particular interest in New Jersey because a band of the Kirkwood-Cohansey aquifer, the drinking water source for much of the southern half of the state, contains relatively high levels of naturally occurring radium (Ra), primarily the Ra-224, 226, and 228 isotopes. Only two previous population-based studies of drinking water exist. We conducted an exploratory study of community water systems in the southern part of the state, using the address at the time of diagnosis from the New Jersey State Cancer Registry. Where applicable, we divided systems into subsystems, based on level of radioactivity, system architecture and pumpage. One exposure metric accounted for systems that were above the 5 pCi/L USEPA maximum contaminant level (MCL) for combined radium-226 and 228 and/or above the gross alpha MCL of 15 pCi/L, as measured within 48 hours of sampling. The second metric was based on the combined cancer potency of the three isotopes, expressed as equivalents of radium-228 (using Federal Guidance 13, 1999). The number of individuals classified as exposed ranged from 125,000 to 275,000, depending on metric and cut-point used, while the unexposed population was approximately 1,000,000 to 1,300,000. Overall incidence in areas receiving drinking water above either the radium or gross alpha MCL was 70% higher than in areas below both MCLs. Among males the rate ratio (RR) was 3.3 (95% CI 1.6-6.0). When we categorized exposure estimates according to total radium cancer potency, the resulting overall incidence among those exposed at ≥ 4 pCi/L and 2.0-3.9 pCi/L was 40% and 80% higher, respectively, than those whose tap water had less than 0.5 pCi/L. For males in areas receiving water with ≥ 4 pCi/L and 2.0-3.9 pCi/L, compared to those receiving <0.5 pCi/L, the RRs were 3.1 and 3.7, respectively. The risks calculated from these observations are within an order of magnitude of that predicted by USEPA by linear extrapolation from the radium dial painter and medical treatment cohorts.

10964 - Gastroenteritis in the elderly during the 1993 Milwaukee cryptosporidiosis outbreak

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The elderly are a population at elevated risk for infections. It has been recognized for many years that the elderly have an higher incidence, morbidity, and mortality, from infections than younger people, resulting in longer hospital stays and higher hospitalization costs. Changes in immunity and gastrointestinal function occur with aging, leading to increased susceptibility to enteric infections. Contaminated drinking water is a well-documented route of transmission for *Cryptosporidium*. Water disinfection via chlorination does not inactivate the parasite, making filtration an essential barrier in protecting public water supplies.

In the spring of 1993, Milwaukee experienced an outbreak of waterborne cryptosporidiosis associated with a breakdown in the water filtration process at the South Plant. In our prior studies, we have demonstrated that the increased rates of 'unspecified' gastrointestinal infection in Milwaukee were significantly associated with increased public drinking water turbidity. During the outbreak period, this linkage between drinking water turbidity and infection was strongest at a time lag of seven days in children, and at eight days in adults. These times lags correspond to the typical incubation period for *Cryptosporidium*. We hypothesized that the elderly population of Milwaukee would have been more susceptible to infection by *Cryptosporidium* than non-elderly adults, and that this would be evidenced by a difference in the characteristic time lag period between drinking water turbidity and infection during the epidemic.

We examined gastroenteritis in the elderly, and its relationship to drinking water turbidity during the 1993 Milwaukee waterborne *Cryptosporidium* outbreak, using HCFA database. To examine the association between GI infections and drinking water quality, we generated time series of daily counts of GI events and regressed it to the time series of effluent turbidity at the south water treatment plant. We performed the analysis using a generalized additive model with a nonparametric "loess"- smoother for exposure at a given lag and a set of linear autoregressive components. To visualize the lagged relations between exposure and outcome, we produced three dimensional surfaces, which reflect the changes in GI daily rates associated with changes in exposure measurement over time periods typical for the cryptosporidiosis incubation period. We estimated and marked the time lag period with the highest impact on this temporal exposure response surfaces (TERS).

Gastroenteritis related emergency room visits and hospitalizations, and age in the elderly, were significantly related ($p=0.002$) before the epidemic. Time-series analysis indicates that outbreak-associated gastroenteritis in the elderly had a shorter peak time lag period (5 days) than either children or all adults (7 and 8 days, respectively), consistent with a shorter incubation period in the elderly. Using simple assumptions about incubation periods and time-series analysis, we have found that the magnitude of secondary transmission in the elderly may have approached the magnitude of primary transmission. We concluded that the elderly are a sensitive subpopulation at increased risk for gastroenteritis in general, and for *Cryptosporidium* in particular.

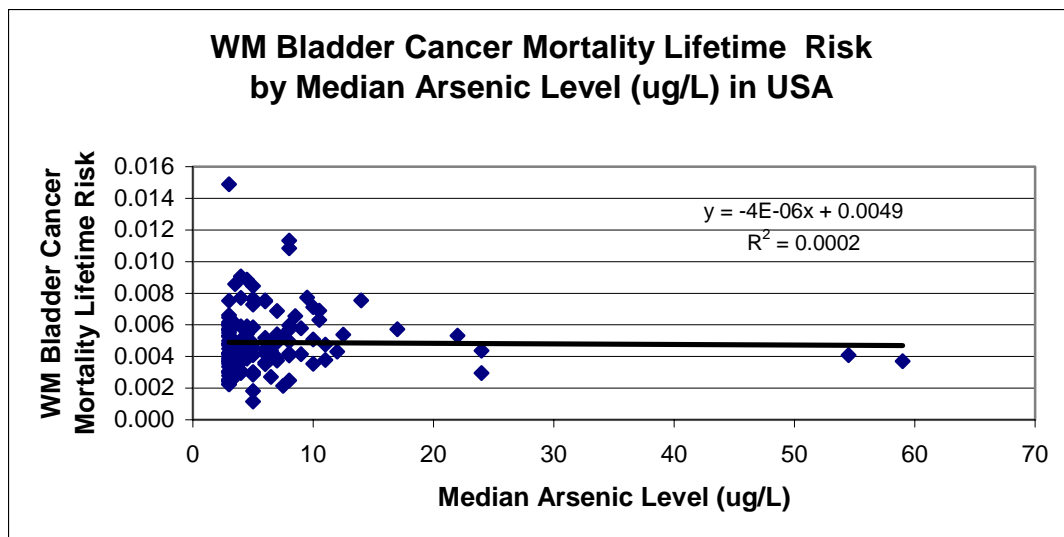
10999 - Examination of the NRC Bladder Cancer Risk from Arsenic in Drinking Water Estimate, using US data with 75 million Person-Years of Observation

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The NRC (2000) estimate for bladder cancer risk from arsenic in drinking water is based on the data from the Blackfoot Disease Endemic area of SW Taiwan where increased risks of bladder cancer mortality were found in villages with 400 (+) ug/l arsenic in their drinking water. Those data have been adjusted and analyzed in order to predict the arsenic in drinking water bladder cancer risk in the United States where drinking water arsenic levels may go as high as 50 ug/l but are generally in the 3-12 ug/l or lower range. We now present US data on bladder cancer mortality (1950-1979) in 133 US counties known to depend on ground water as their drinking water source (per state departments of the environment) and with ground water median arsenic concentrations of 3 ug/l or greater (US Geological Survey). The bladder cancer mortality for these 133 US counties, which includes a population of 2.5 million white males (1960 census), has been observed for 30 years (1950-1979) by the National Cancer Institute for a total observation of 75 million person-years of observation.



Overall, the lifetime risk of bladder cancer mortality for white males is seen to be 0.005 (1/200) and no increase with increased level of arsenic in the drinking water is observed. Linear regression shows a slope indistinguishable from zero, revealing no evidence of an arsenic-dependent risk in this exposure range. The R-squared is 0.0002, and the slope (lifetime increased risk per 1 ug/L arsenic exposure) is $-4 E-06$ with 95 % confidence limits of $-5 E-05$ to $+4.2 E-05$. The NRC predicted risk of $4.6 E-05$, based on extrapolation and adjustment from the southwest Taiwan data, is outside of the range that is consistent with the US experience shown here in the 75 million person-year study. New toxicological studies provide explanations as to why the increased bladder cancer

risk from certain villages in SW Taiwan is not predictive of the US experience with arsenic in the drinking water and bladder cancer mortality.

11015 - Development and Application of a Two-Compartment Model to Estimate Dietary Intake for Disinfection By-Products. James Raymer, Ye Hu, and Gerry Akland. RTI International, Research Triangle Park, NC 27709

A variety of organic compounds in tap water are produced as a result of the disinfection process. The use of chlorine-containing chemicals for disinfection produces many chemicals, or disinfection by-products (DBPs), including trihalomethanes, haloacetonitriles, and haloacetic acids (HAAs), among others. Ozonation with secondary disinfectants, such as hypochlorite, yields many of the same compounds, although at lower concentrations. Human ingestion exposures to DBPs occur not only as a result of drinking disinfected water, but also as a result of tap water used in the preparation of foods and beverages in the home. Work underway at RTI is designed to improve our understanding of the contamination of foods as a result of cooking in water containing DBPs.

A two compartment model has been developed to characterize the uptake of HAAs from drinking water into foods during food preparation in the home. The HAAs studied were chloroacetic acid, bromoacetic acid, dichloroacetic acid, trichloroacetic acid, bromochloroacetic acid, dibromoacetic acid, bromodichloroacetic acid, chlorodibromoacetic acid and tribromoacetic acid. Parameters for the model were estimated based on laboratory experiments in which foods were cooked in water that was spiked or not spiked with DBPs. These parameters were the first order absorption rate constant for water to food (K_{wf}), the first order absorption rate constant for food to water (K_{fw}) and the elimination rate constant. Earlier work had demonstrated the decomposition of certain DBPs with increased cooking time. Thus, duration of cooking is an important consideration and must be incorporated into the model. Using the two compartment model, we mathematically characterized and simulated most common food preparation processes, including soaking/rinsing (rinsing of vegetables and chicken before cooking), stewing, cooking and draining without rinsing (vegetables, spaghetti), cooking and rinsing (spaghetti), and soaking and cooking (dried beans). Elimination rate constants ranged from 0.01 hr^{-1} for dichloroacetic acid, chloroacetic acid, dibromoacetic acid and bromochloroacetic acid to 10 hr^{-1} for bromodichloroacetic acid, chlorodibromoacetic acid and tribromoacetic acid. Through these simulations and characterizations, we were able to hierarchically categorize foods into different groups according to the amount consumed, food/water partition coefficient, food preparation processes and the duration of cooking. The simulations thus far have pointed to additional parameters that should be studied to increase our confidence in the model, including the impact of cooking time on DBP uptake. It is anticipated that the two-compartment model and food characterizations will serve as a solid base for future population exposure estimation studies and will assist in the determination of the high risk sub-populations and the food categories and cooking practices that have the greatest impact on human exposure.

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11037 - Determinants of fluoride intake among children

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Drinking water fluoridation is adopted in many communities as an important means of dental caries prevention. Many studies in the past relied on ecological design to compare fluoridated vs. nonfluoridated areas. In order to assess the patterns and determinants of individual fluoride intake among children, we studied 82 and 80 students in the 3rd grade in fluoridated and nonfluoridated areas, respectively. Dietary history was obtained by 24-hour recall method to assess fluoride intake. Fluoride levels were measured in individual home's drinking water, and children's and their mothers' early morning urine samples. Total water intake was 1.05L/day on average. In fluoridated and nonfluoridated areas, fluoride levels in drinking water at home were 0.53 and 0.09ppm, and average daily fluoride intakes via drinking were 0.16 and 0.08mg/day, respectively. Correlation between children's and mothers' urine fluoride levels was 0.44($p<0.001$). Correlation between fluoride intake and urine fluoride levels was 0.245($p<0.01$). Sex, parents' age, occupation, and education were not associated with fluoride intake. In the fluoridated area, children from the higher economic class had lower urine fluoride levels (0.38 vs. 0.48mg/g creatinine, $p<0.05$). This difference appeared mainly because they drank less water and drank more milk, compared to children from the lower economic class. We conclude that individual assessment of fluoride exposure and adjustment for potential confounders are important to study the effect of drinking water fluoridation.