Toxicology of Chlorinated Disinfection By-products

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Introduction

Personal

Disinfection of Drinking Water

- Chlorine
- Chloramine
- Ozone
- Ultraviolet Light

Disinfection Dilemma

- Raising chlorine concentrations produces higher levels of chlorination by-products
- Removing natural organic matter before chlorination reduces by-product levels
- The high cost of organic removal is a serious economic/political problem
- Chlorine concentration must always be maintained at an adequate level for disinfection until the by-product problem can be solved

Exposure and Toxicity

- Health Risk = Exposure x Toxicity
- Exposure = Water consumed x Concentration
- Toxicity = Maximum dose that is safe expressed as ug per kg body weight per day
- VOCs: Ingestion, Inhalation and Dermal absorption

Factors affecting CDBP levels

- Chlorine concentration
- Contact time
- Level of natural organic matter
- pH
- Bromide
- Temperature

Commonly found CDBPs - 1

- Trihalomethanes, $CH.X_3$
- Chloroform, $CH.Cl_3$
- Bromodichloromethane, $CH.Cl_2Br$
- Dibromochloromethane, $CH.ClBr_2$
- Bromoform, $CH.Br_3$

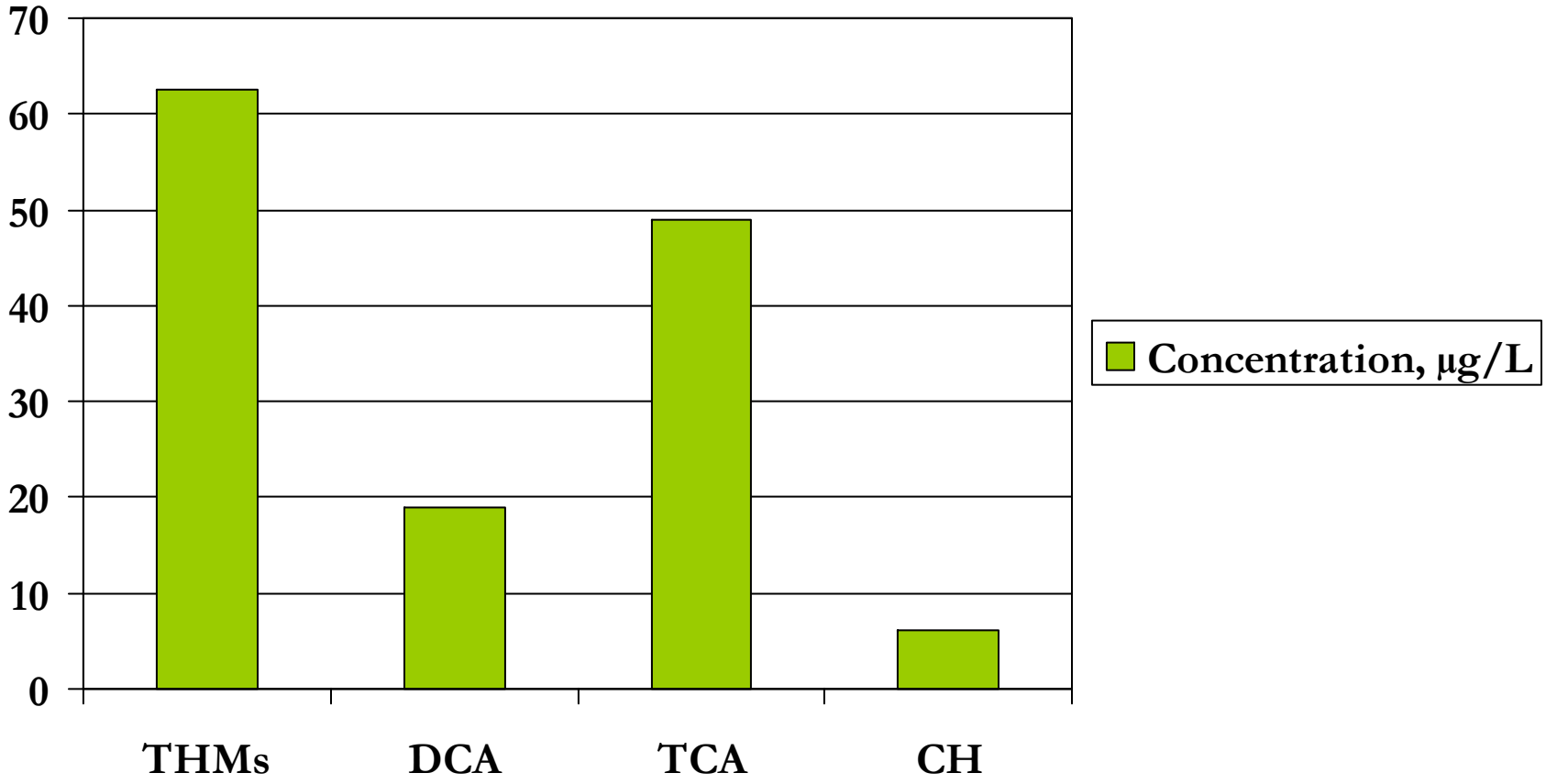
Commonly found CDBPs - 2

- Haloacetic acids, HAAs
- Monochloroacetic acid, MCA, $Cl.CH_2.COOH$
- Dichloroacetic acid, DCA, $Cl_2.CH.COOH$
- Trichloroacetic acid, TCA, $Cl_3.C.COOH$
- Brominated acetic acids (6 identified)

Other minor CDBPs

- Chloral Hydrate, CH, 6.1 ug/L
- Haloacetonitriles, HANs, e.g. Dichloroacetonitrile, 2.9 ug/L
- 1,1,1-Trichloropropanone, 2.7 ug/L

Typical CDBP concentrations



National Survey of Chlorination Disinfection By-Products in Canadian Drinking Water, Health Canada 1995.
www.hc-sc.gc.ca/hecs-sesc/water/pdf/eng_pt1.pdf

Toxicity review – Animal studies

- Controlled environment
- Accurate doses
- Ethics
- Species differences

Toxicity review- Human epidemiological studies

- No species differences
- Complex, highly variable environment/life-style
- Dose uncertain
- Ethical limitations

Epidemiological studies - Ecological

- Compare disease rates in different geographic areas
- Many possible causes of different disease rates
- Never conclusive, might give clues
- Inexpensive

Epidemiological studies – Case control

- Dose can be more accurately estimated
- Confounders can be controlled if known
- Very expensive – can be $millions
- Still not conclusive

Critical health effects

- Literature review of all toxic endpoints
- e.g. neurotoxicity, cancer, reproductive, immunological, etc.
- Endpoint that is shown at the lowest exposure level is chosen for quantitative risk assessment

Trihalomethanes (THMs)
Chloroform

- Chloroform causes kidney and liver tumours in rodents BUT now believed NOT to be due to an affect on DNA
- No evidence of human cancer despite extensive occupational exposure
- The tolerable daily intake (TDI) of 6.2 ug per kg body weight per day is derived from liver toxicity in a dog study
- THMs levels above 50 ug/L have been associated with bladder and colon cancer

Bromodichloromethane (BDCM)

- Major brominated THM
- Rodent tumours in the intestine, kidney and liver
- Probably genotoxic (i.e. changes DNA)
- Calculated cancer risk at a level of 16 ug/L is 10^{-5} (1 cancer per 100,000 people drinking the water for a lifetime of 70 yrs)
- Association between BDCM levels and stillbirth, retarded fetal growth and spontaneous abortion

Chlorinated haloacetic acids (HAAs)

- Not in current Canadian guidelines but coming soon
- Difficult to measure
- US EPA has regulated HAAs for many years
- Regulations based solely on animal studies since no human data available

Monochloroacetic acid (MCA)

- No evidence of carcinogenicity
- No evidence of genotoxicity
- Significant changes in body and organ weights in rats
- TDI of 3.9 ug per kg body weight per day

Dichloroacetic acid (DCA)

- Liver tumours in rats and mice
- Probable human carcinogen
- A level that gives a 10^{-5} cancer risk after a lifetime of exposure is achievable

Trichloroacetic acid (TCA)

- Liver tumours in mice
- Peroxisome proliferation casts doubt on relevance of mouse result
- Possible human carcinogen
- TDI of 32.5 ug per kg body weight per day based on liver toxicity in rats

Chloral hydrate (CH)

- Pituitary tumours in female mice were the only significant cancer effect
- Used as drug for a long time without any apparent cancer effect
- Possible human carcinogen
- TDI of 4.5 ug per kg body weight per day based on the incidence of proliferative lesions in the liver of male mice

Regulated levels - 1

- THMs, IMAC 0.1 mg/L (proposed MAC 0.1 mg/L based on an annual average of a minimum of quarterly samples taken at the extremities of the distribution system)
- BDCM, No current guideline (proposed MAC 0.016 mg/L based on an annual average of a minimum of quarterly samples taken at the extremities of the distribution system)

Regulated levels- 2

- HAAs No Canadian guidelines although a proposal from Health Canada is being prepared

- HAA5 (US EPA), MCL 0.06 mg/L (MCA, DCA, TCA, Bromoacetic acid and Dibromoacetic acid)

Chloral hydrate (CH)

- No current guideline
- Risk assessment gave a proposed MAC of 200 ug/L – well above levels seen in drinking water
- No guideline recommended

Conclusion

- CDBPs are a significant health risk
- Technological solutions are usually possible
- Need to balance the drinking water risks against other public health issues that require funding
- Adequate disinfection is the number one priority
- Health Canada Drinking Water Web Page www.hc-sc.gc.ca/hecs-sesc/water/index.htm