



# DISINFECTION BYPRODUCTS

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# Presentation Topics

What are Disinfection Byproducts (DBPs)?

Health Effects

Sources and Formation

Analytical Procedures

Drinking Water Regulations

Small System Considerations

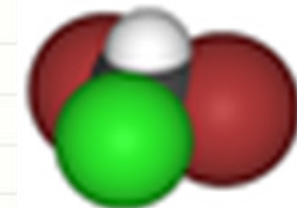
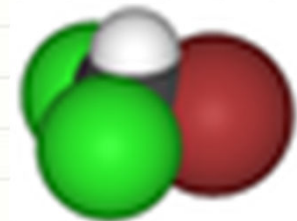
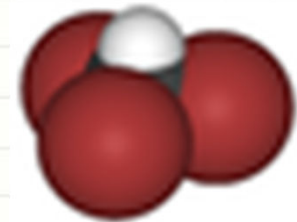
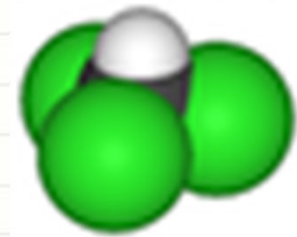
Future Concerns

# What are Disinfection Byproducts?

- Organic and Inorganic Compounds created by the disinfection of water
- Formed by reaction of a disinfectant with inorganic or natural organic matter (NOM) present in source water
- Regulated Classifications
  - Trihalomethanes
  - Haloacetic Acids
  - Oxyhalides

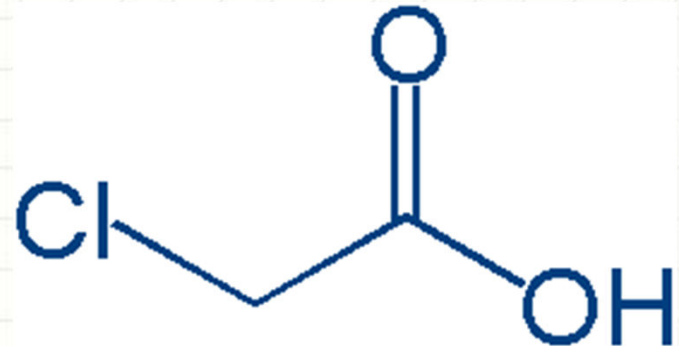
# Trihalomethanes (THMs)

- Four THMs
  - Chloroform
  - Bromoform
  - Bromodichloromethane
  - Dibromochloromethane



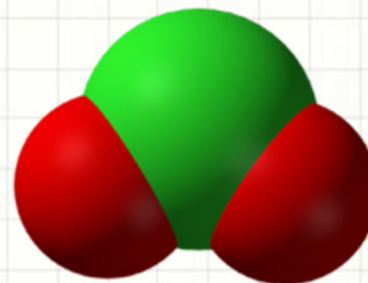
# Haloacetic Acids (HAAs)

- Five HAAs (HAA5)
  - Monochloroacetic acid
  - Dichloroacetic acid
  - Trichloroacetic acid
  - Monobromoacetic acid
  - Dibromoacetic acid

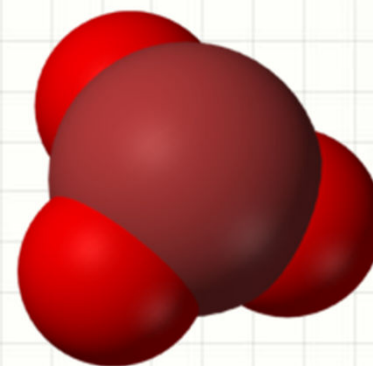


# Oxyhalides

Chlorite ( $\text{ClO}_2^-$ )



Bromate ( $\text{BrO}_3^-$ )



# DBP Health Effects

- Trihalomethanes
  - No short term health effects noted
  - Liver, kidney, central nervous system problems
  - Long term increase risk of cancer
- Haloacetic Acids
  - Short term exposure may cause pregnancy complications
  - Long term exposure associated with cancer

# DBP Health Effects

- Chlorite
  - Neurodevelopmental effects most concerning
  - No specific effects related to cancer
- Bromate
  - Gastrointestinal effects at short term, high level of exposure
  - Potential kidney effects at long term, high level exposure

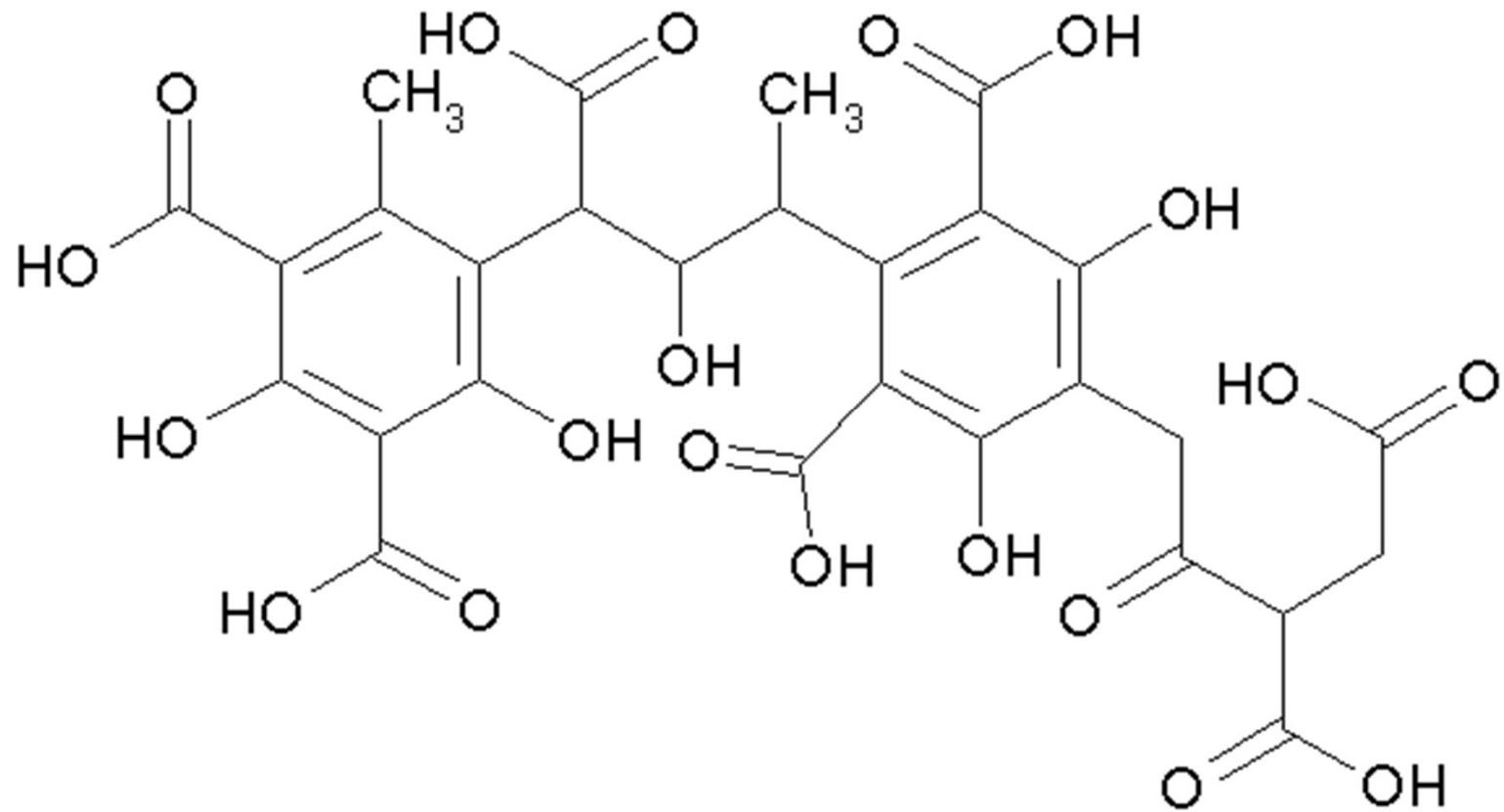
# DBP Precursors

- Inorganic precursors
  - Can be naturally occurring or anthropogenic
  - Bromine / Bromide
    - Natural occurrence in ground and surface water
    - Introduced via chlorination as contaminants
    - Reacts with Ozone to form Bromate ( $\text{BrO}_3$ )

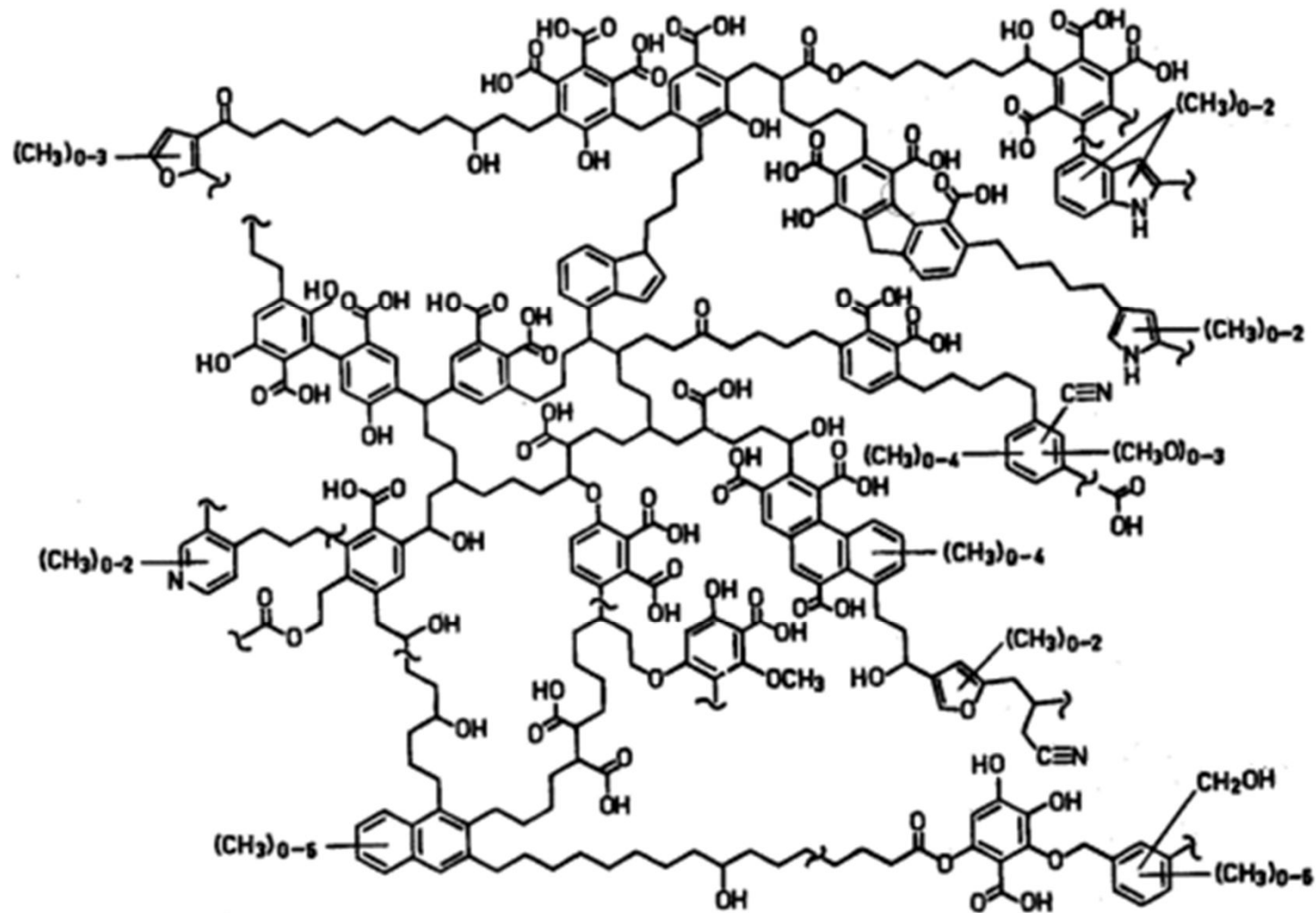
# DBP Precursors

- Organic precursors / Natural Organic Matter
  - Plants and organisms degrade, forming organic acids and other matter
  - Humic and Fulvic acids, ...
  - Large, complex structures break down into smaller molecules ultimately resulting in DBP formation
  - Time, Temperature, pH all factors in formation

# Humic Acid



# Fulvic Acid



# Analytical Procedures

- Trihalomethanes
  - EPA Methods 502.2, 524.2
  - Purge and Trap Sample Preparation followed by Gas Chromatography / Electrolytic Conductivity or Gas Chromatography / Mass Spectroscopy
  - Reporting Limits  $\approx$  0.5-1.0  $\mu\text{g/L}$

# Analytical Procedures

- Haloacetic Acids
  - EPA Method 552.2
  - Microextraction followed by Gas Chromatography / Electron Capture Detection
  - Reporting Limits  $\approx$  1-2  $\mu\text{g/L}$

# Analytical Procedures

- Oxyhalides
  - EPA Method 300.1, 317.0
  - Ion Chromatography with Electrical Conductivity or Colorimetric Detection
  - Reporting Limits  $\approx$  1-5  $\mu\text{g/L}$

# DBP Regulations

- Safe Drinking Water Act
  - Statute, signed into law in 1974
    - Enacted under the Commerce Clause
    - To ensure the protection of public health
  - Grants EPA authority to:
    - Establish standards against harmful contaminants
    - Establish joint Federal-State system assuring compliance with standards
    - Protect underground sources of drinking water
  - Original form created primary (enforceable) and secondary (non-enforceable) standards

# DBP Regulations

- SDWA Evolution
  - Only a fraction of contaminants addressed
  - Standard-setting process proved slow
  - Amended in 1986
    - Required promulgation of MCLs and MCLGs
    - Added additional contaminants over three years
    - Mandated adding contaminants every three years
    - Included a provision for disinfection / filtration for SW or GWUDI systems

# DBP Regulations

- 1986 Amendment required regulation of D/DBPs
- Required control of pathogens already existed
- Created a risk-risk problem
  - Pathogens vs. Disinfection Byproducts

# DBP Regulations

- Negotiated Rulemaking Act, 1990
- Regulation-Negotiation Committee formed
- Met from November '92 to June, '93
- Purpose – to address balance between pathogens and DBPs
- Included stakeholders from drinking water industry
- Provided opportunity to participate

# DBP Regulations

- SDWA Evolution
  - Compliance with 1986 amendments proved challenging
  - Ambitious goals and formidable requirements
  - Amended again in 1996
    - Relaxed mandated additions to contaminant list
    - Required formal rulemaking process
    - Increased consideration of cost and overall risk reduction in setting standards
    - Added revolving loan program
    - Expanded source water protection

# DBP Regulations

- Three new rules emerged in 1998
- Based on Reg-Neg Committee Recommendations to control Pathogens/DBPs
  - Information Collection Rule
    - Generated data to drive future regulations
  - Enhanced Surface Water Treatment Rule
    - Required disinfection of surface waters
    - Primary target – Cryptosporidium
  - Disinfection Byproducts Rule
    - Requires PWS to control byproducts of disinfection
    - Minimize levels of residual disinfectant

# DBP Regulations

- Summary on Disinfection Byproducts
  - Total THM MCL established in 1979 under the Total Trihalomethane Rule
  - 1986 Amendment included disinfectants and disinfection byproducts (D/DBPs)
  - 1996 Amendments required rules to balance risk of pathogens against disinfection byproducts
  - 1998 Disinfection Byproducts Rule
    - Implemented in two stages
    - In conjunction with Enhance SW Treatment Rule

# Disinfection Byproduct Rule

- Stage 1 Rule
  - Established in 1998, applies to CWSs and NTNCWs utilizing chemical disinfectants
  - Different effective dates by system size
  - Updated MCL for Total THMs
  - Added MCLs for Total HAAs, Chlorite, Bromate
  - Established routine monitoring program based on system source water, size, treatment tech.

# Disinfection Byproduct Rule

- Stage 1 Rule
  - Includes MCL goals for individual THMs and HAAs
  - Included maximum residual disinfectant levels
  - Created a TOC removal requirement for certain systems
    - Applicable to SW or GWUDI systems using conventional filtration
    - Target reduction based on TOC and Alkalinity concentration

# Disinfection Byproduct Rule

- Stage 2 Rule
  - Promulgated in 2006, applied to water systems based on four, size determinant schedules
    - Schedule 1: >100,000 customers
    - Schedule 2: >50,000 and < 99,999 customers
    - Schedule 3: >10,000 and < 49,999 customers
    - Schedule 4: < 10,000 customers
  - Applicable to any CWS or NTNCWS using residual disinfectants
  - Includes revised MCLGs for various DBPs

# Stage 2 DBP Rule

- Initial Distribution System Evaluation
  - Required of all CWS and any NTNCWS serving > 10,000 people
  - Identifies locations with high DBP concentrations
  - Use data to characterize distribution system and determine sampling points for monitoring
  - Compliance will be based on locational running annual averages for each monitoring point
  - Can be addressed via four options

# Stage 2 DBP Rule

- Initial Distribution System Evaluation Options
  - Standard Monitoring
    - One year of increased monitoring
    - Frequency determined by source type and population
    - In addition to Stage 1 Data collected
    - Can be performed by any system

# Stage 2 DBP Rule

- Initial Distribution System Evaluation Options
  - System Specific Study
    - Requires extensive TTHM and HAA5 data
    - Can prepare hydraulic model with sufficient expertise

# IDSE Special Provisions

- IDSE Special Provision 1
  - 40/30 Certification
  - For eligibility, a system must, for 8 consecutive quarters:
    - Collected all Stage 1 DBP samples
    - All individual samples have TTHMs <0.040 mg/L, HAA5 <0.030 mg/L
    - No TTHM or HAA5 monitoring violations

# IDSE Special Provisions

- IDSE Special Provision 2
  - Very Small System (VSS) Waiver
    - Applicable for systems serving <500 people
    - Collected all eligible TTHM and HAA5 data
    - Does not depend on TTHM or HAA5 results

# Stage 2 DBP Rule

- Additional Information
  - EPA and State are not required to send notification that 40/30 certification or VSS waiver was approved
  - Systems must prepare a compliance monitoring plan for Stage 2
  - Plan must be completed before system is required to begin Stage 2 compliance monitoring
  - Continue Stage 1 monitoring until Stage 2 begins

# Current DBP MCLs

Regulated Contaminant	MCL (mg/L)	Methods
Total Trihalomethanes	0.080	EPA 502.2, 524.2, 524.3
Total Haloacetic Acids	0.060	EPA 552.1, 552.2, 552.3, 557, SM6251B
Bromate	0.010	EPA 300.1, 317.0, 326.0, 321.8, 302.0, 557
Chlorite	1.0	SM4500-CLO <sub>2</sub> , EPA 327.0, 300.0, 300.1, 317.0, 326.0, ASTM D 6581-00

*EPA 816-F-10-081 ([www.epa.gov/drink](http://www.epa.gov/drink))*

# Current DBP MCLGs

Regulated Contaminant	MCLG (mg/L)
Chloroform	0.070
Bromoform	Zero
Bromodichloromethane	Zero
Dibromochloromethane	0.060
Monochloroacetic Acid	0.070
Dichloroacetic Acid	Zero
Trichloroacetic Acid	0.02
Bromoacetic Acid	-
Dibromoacetic Acid	-
Bromate	Zero
Chlorite	0.80

# Current Disinfectant MRDLs

Regulated Disinfectant	MRDL (mg/L)	MRDLG (mg/L)	Method
Chlorine (as Cl <sub>2</sub> )	4.0	4.0	SM4500-Cl*, EPA 334.0, ASTM D 1253-08
Chloramines (as Cl <sub>2</sub> )	4.0	4.0	SM4500-Cl*, EPA 334.0, ASTM D 1253-08
Chlorine Dioxide (as ClO <sub>2</sub> )	0.8	0.8	SM4500-CLO <sub>2</sub> *, EPA 327.0

*EPA 816-F-10-081 ([www.epa.gov/drink](http://www.epa.gov/drink))*

# Future Concerns

- California Regulations
  - Draft DBP Stage 2 Regulation in progress
  - Anticipated late 2011 promulgation
  - Consistent with Federal Program
  - Minor differences
    - Chlorite: Tier 1 vs. Tier 2 notification
    - Similar to Chlorine Dioxide in Federal regulation
  - Continue adhering to Federal requirements

# Future Concerns

- Nitrosodimethylamine (NDMA)
  - Found typically in treated wastewater
  - Created under chlorine disinfection
  - Problematic on water reuse / recharge
  - Also linked to chloramine disinfection
  - Most common contaminant found by lab under UCMRII

# Future Concerns

- Hexavalent Chromium
  - Recent publicity through EWA study
  - Current MCL in CA for Total Chromium at 50 ug/L
  - Draft California PHG reduced to 0.02 ug/L
  - Can be created by oxidation of  $\text{Cr}^{+3}$

# Future Concerns

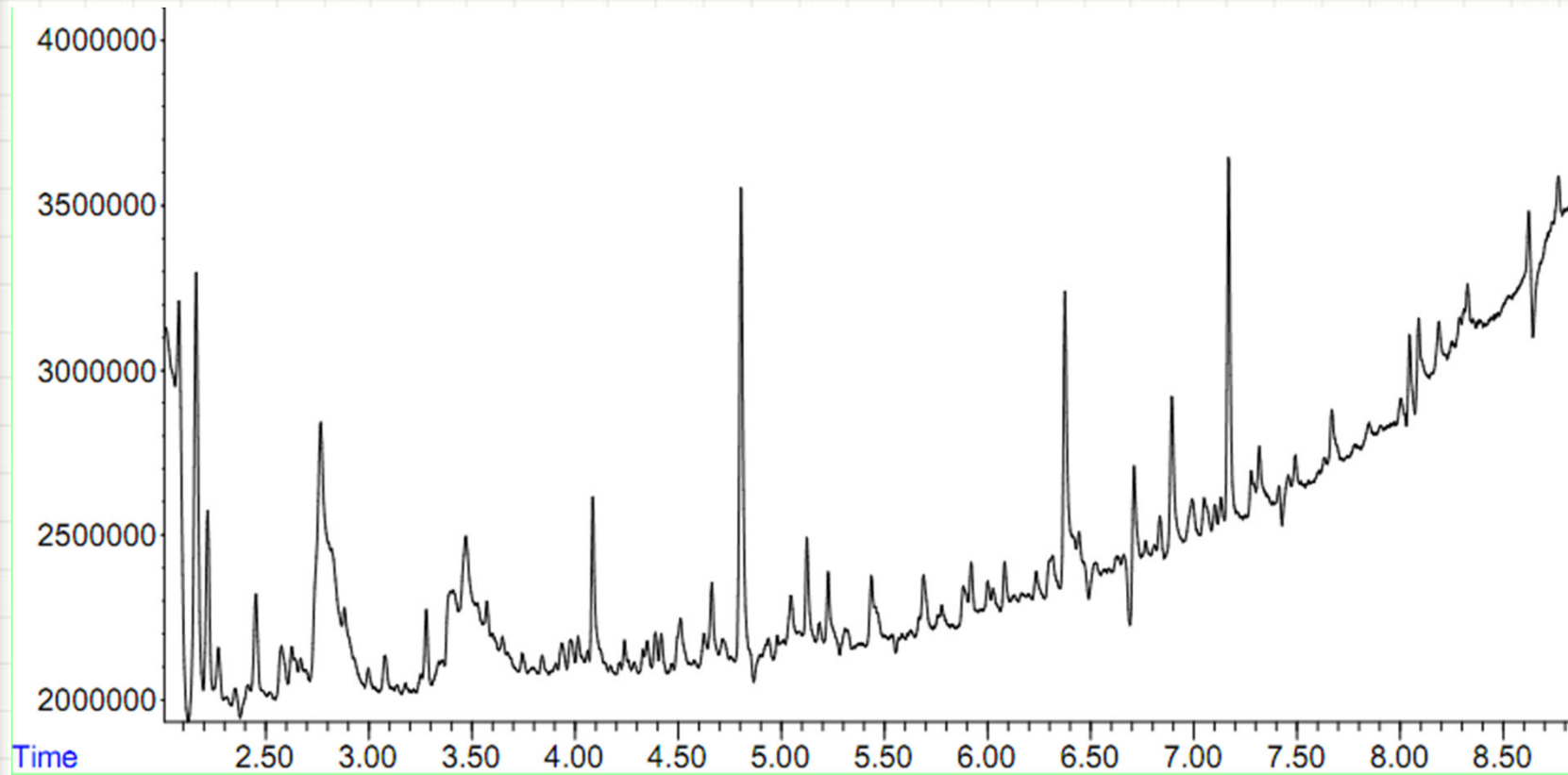
- Hexavalent Chromium
  - EPA is recommending increased monitoring
  - Quarterly or semiannual, source dependent
  - To understand fate of  $\text{Cr}^{+6}$  or transformed  $\text{Cr}^{+3}$  ...
    - Intake / Well – Collect samples of untreated water
    - DS Entry Point – For treated water, collect at entry
    - Distribution System
      - Collect samples consistent with DBP sampling
      - Collect subset of 10 or fewer at locations used for Stage 1 and 2 DBP Rule sampling
      - Systems not treating, collect at TCR sampling points

# Future Concerns

- Other Byproducts
  - Regulated DBPs are a surrogate for all others
  - Thousands of additional byproducts
  - More than 600 have been identified
  - Over 60% of TOX in drinking water composed of unknown organic halides

*(Susan D. Richardson, US EPA, National Exposure Research Laboratory, Formation and Occurrence of Disinfection Byproducts)*

# Unspecified halogenated material



**Laboratory De-ionized Water, 200-fold Concentration**

# Closing Thoughts

- Keep up with regulatory developments
- Work closely with district engineers
- If problems found, provide solutions
- Act on plans unless told otherwise
- Expect today's unknowns to be future issues at levels below current concerns
- Address treatment plans with future in mind

# Questions?

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