- Specific Expertise:

  Formation, Occurrence, Modeling, and Control of Disinfection By-Products (DBPs)

  Natural Organic Matter (NOM) Characterization and Removal

  NOM and Bromide (Br^-) Profiles through Water Treatment Processes/Process Trains

  Distribution System Modeling of Chlorination DBPs

- Utilities: Research and Consulting

  Metropolitan Water District
  Los Angeles Department of Water and Power
  Los Angeles County Sanitation District
  East Bay MUD
  Contra Costa Water District
  Orange County Water District
  Irvine Ranch Water District
  Alameda County Water District
  Santa Clara Valley Water District
  City of Phoenix
  Tucson Water
  Denver Water Department
  American Water Works Services Company
  Compagnie Generale des Eaux
  Lyonnaise des Eaux
  World Health Organization
  International Bottled Water Association

- Genesis, Transport, and Fate of DBP Precursors through the Delta

  NOM (TOC) and Br^- Occurrence: Spatial and Time Variations

  Source of Br^- (Salt Water Intrusion)✓

  Sources of NOM: Inflows (Allocthonous) vs. Algae (Autochthonous) vs. Agricultural Drains

  Transport/Flow Paths of Br^- and TOC to Water Treatment Export-Points

- Co-Occurrence of Br^- and NOM

  Reactivity of NOM within Delta; Labile (e.g., Biodegradable) vs. Refractory

  Character of NOM: Beyond TOC (e.g., UVA_{254}, SUVA); Reactivity with Disinfectants

  Cannot Separate Br^- from TOC; the Inorganic and Organic DBP Precursor are Linked

- NOM-Br^- Interactions

  Br^-

  Oxidized by Cl_2 or O_3 to HOBr/OBr^- (Br_2); Intermediate to BrO_3^-; Bromination of NOM

  Br^- is Conservative through Coagulation, GAC

  Transformation of Br^- by Oxidation (O_3); Potential Removal of Br^- by Membranes

  Water Quality Conditions (e.g., pH and temperature)

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- NOM-Br^- Interactions - Continued

  Ozonation DBPs

    BrO_3^- vs. TOBr (higher vs. lower pH)

  Tradeoffs: Disinfection vs. DBP Minimization

    CT vs. DBPs; Microbial vs. Chemical Risk

  Tradeoffs: Other Alternative Disinfectants; ClO_2: ClO_2^-

- Br^- Control

  Source Control

    Segration of Delta Water Intended for Export from Salt Water Intrusion ✓

  Removal of Br^-

    NF Membranes

  Control of BrO_3^-

    Minimization by Acid (✓) or Ammonia Addition

  Removal of BrO_3^-

    Ferrous Iron Coagulation or NF Membranes

  Minimization of THM-Br, HAA-Br (pH effects?)

- NOM Control

  Source Control: (On-Site) Treatment or Diversion of Agricultural Drainage; Algae Control

  (Centralized) Removal by (Enhanced) Coagulation, Membranes, GAC, or O_3-GAC

- Future Developments/Factors

  More Restrictive MCLs for DBPs (BrO_3^-, THM/HAA Species)?

  More Rigorous Disinfection (CT) Requirements?

  Health Effects Studies on Brominated DBPs?

  What is an Acceptable Level of Br^-?

    Model Projections: e.g., $BrO_3^- = f(Br^-, \text{etc.})$; $Br^-_{LIMIT} = f(BrO_3^-_{MCL})$

      Past Projections: All TOC is Equal; no DBP (THM or HAA) Species

    National Average: $Br^- \approx 70$ ug/L

      10 ug/L of BrO3- = 6.3 ug/L of Reacted Br^-
      Br^- Conversion into THM-Br (≈ 20 %) and HAA_5-Br (≈ 10%):

- Research Needs:

  Source-Specific (e.g., SPW) DBP Models

  NOM Inventory of Delta: Amount and (General and Reactive) Properties

  Framework for Additive Risk Model Applicable to DBP Mixtures