Multiple Disinfectants Research

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Research Motivation

- Treatment optimization and robustness are keys.
  - With multiple disinfectants/oxidants, multiple water quality/operations goals (e.g. DBP control, disinfection, control of high turbidity events, algae bloom event, etc.) can be achieved without compromising treatment/operation performance.
- Redundancy is another advantage.
- Processes can vary seasonally depending on source water conditions.

Research Overview

Previous ClO_2 experiments (2001-2002)

- Focused on bromate control, includes control of other DBPs (chlorite/chlorate, THM/HAA formation) and operational issues (filter performance)

Future ClO_2 experiments (pending)

- Focus on high algal loading events and disinfectant synergy involving ClO_2

Bay Area Collaborative (2003-2006)

- Focus on disinfectant synergy involving UV, ozone, chloramines, and ClO_2 (Phase 1) and advanced filtration technologies such as MIEX (Phase 2) or membranes

Bromate Control with Chlorine Dioxide

(Peter Zhou, CCWD with Jeff Neemann, Black & Veetch)

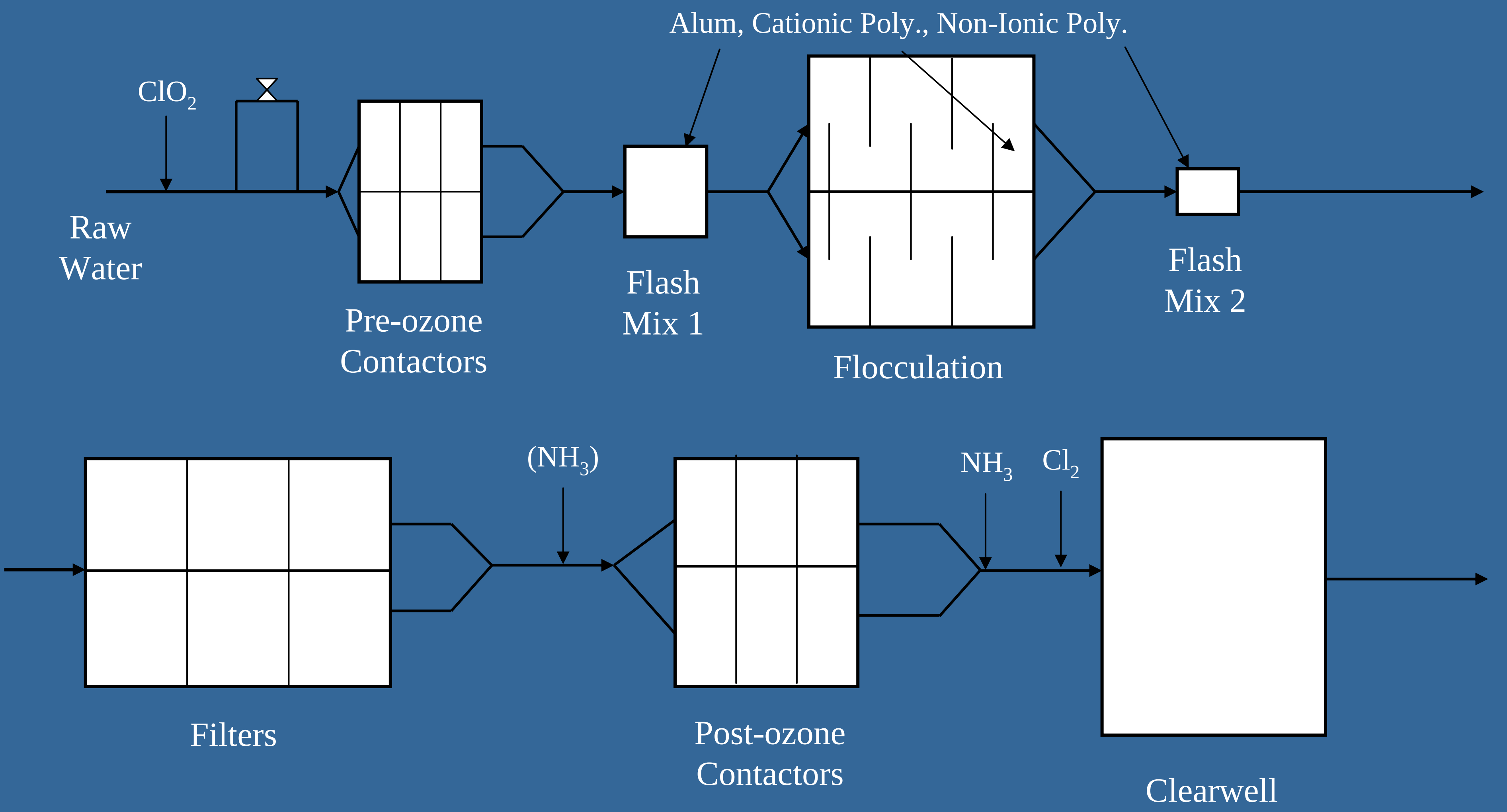
Determine the extent to which:

- ClO_2 reduces pre & post ozone doses
- ClO_2 reduces bromate formation
- ClO_2 reduces THM/HAA formation
- Lower ozone dose → energy savings
- How much ClO_3^- is formed from ClO_2^- oxidized by O_3

CCWD Source Water Quality

- Sacramento-San Joaquin River Delta / Los Vaqueros Reservoir
- Water quality
  - Turbidity = 2-12 NTU
  - TOC = 2-5 mg/L
  - pH = 6.9-9.6
  - Average alkalinity = 75 mg/L
  - Bromide varied from <0.1 mg/L to **0.5** mg/L

Randall-Bold Treatment Plant



Bromate Formation at RBWTP

- Bromate formation profile through plant
  - Bromate formation closely related with ozone dose
  - Preozone is a primary contributor
  - Postozone provides minimal bromate formation
    (Ammonia added before post-ozonation)

- Historic Results
  - Varied from 5 to 69 ppb
- Potential problems complying with 10 ppb

Bromate Control Technologies

- pH adjustment
- Ammonia
- Chlorine dioxide
- Prechlorination
- Pre-chlorine/Pre-ammonia
- Split ozone addition

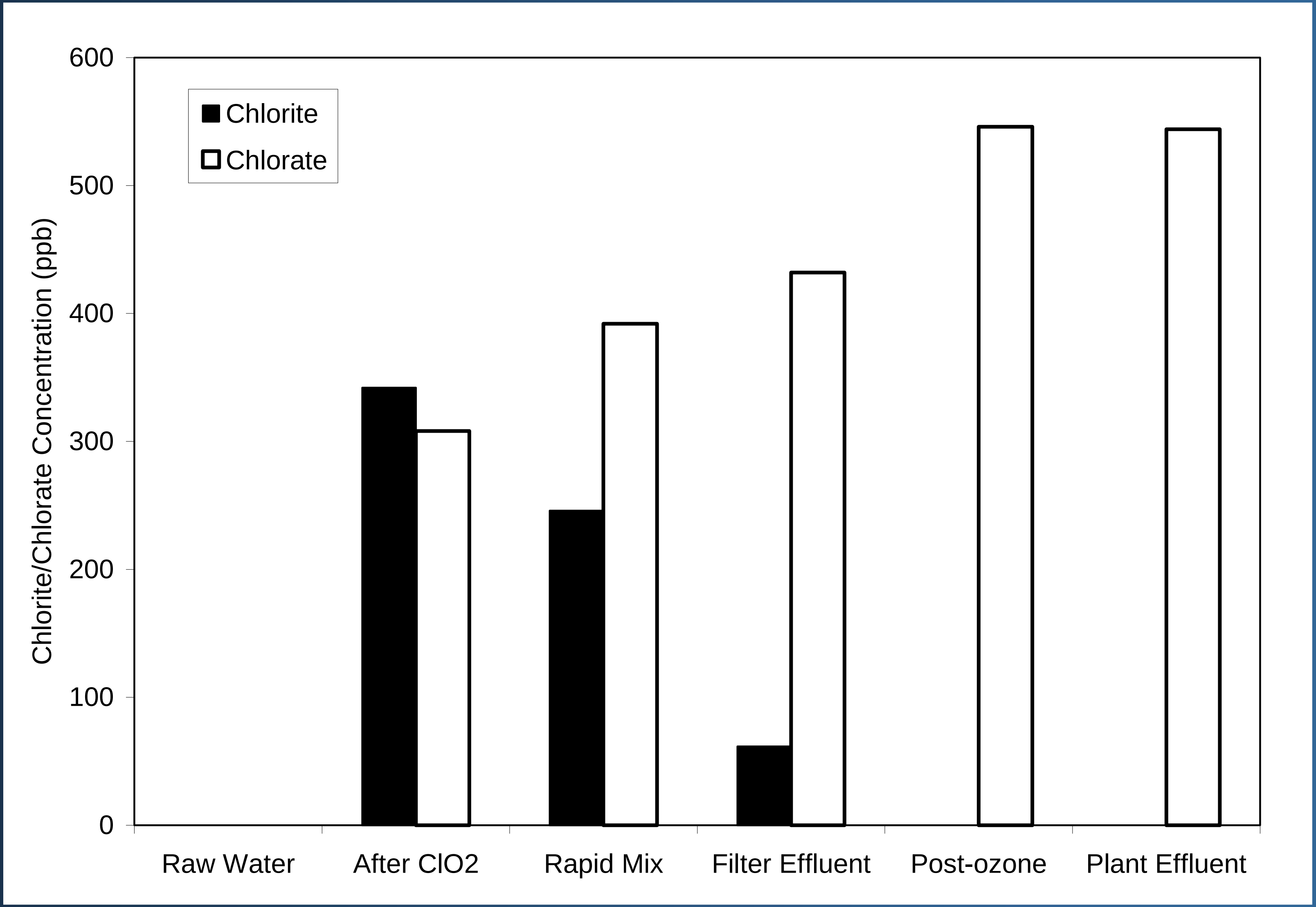
How is Chlorine Dioxide Helpful ?

- Reduce the ozone demand
  - Decrease ozone dose
- Increase ozone half life
  - Increases CT
  - Decrease ozone dose
- Other mechanism?

Bromate Control with Chlorine Dioxide (2002)

Condition	Ozone Dose (mg/L)	Bromide (ppb)	TOC (mg/L)	UV254 (1/cm)	Average Bromate (ppb)
Ozone only	2	160	2.0	0.085	24.7
0.5 mg/L ClO_2	2	180	2.1	0.095	14.3
1.0 mg/L ClO_2	2	180	2.1	0.095	**5.2**
0.7 mg/L Chlorite	2	180	2.0	0.085	**5.3***
pH 6.5	2	180	2.0	0.085	13.3
pH 6.0	2	180	2.0	0.085	**5.6**
0.25 mg/L NH3-N	2	210	2.0	0.087	19.7
0.5 mg/L NH3-N	2	210	2.0	0.087	16.9

Chlorite and Chlorate Production (July 2002)



Chlorite and Chlorate Production (July 2002)

Interaction of ClO_2 and O_3

1. Chlorite can oxidized with ozone and form chlorate
2. No chlorite in effluent.
   - Chlorate CA Action Level 800 ppm
   - Chlorite MCL 1 mg/L

Bromate Control with Chlorine Dioxide

(P. Zhou, CCWD and J. Neemann, B&V, 2003)

- ClO_2 reduces bromate formation from ozonation process
- pH adjustment to 6.0 was effective
  - Very high dosage plus subsequent caustic addition
- Ammonia addition was less effective
- Minimal chlorite leaving the plant and most is converted into chlorate and no perchlorate formed.
- No major impact to the RBWTP filtration processes.

Disinfectant Synergies with Chlorine Dioxide and Ozone

- Potential to achieve higher log inactivation together than individually
- Synergies shown with ozone as the primary disinfectant and chlorine and chloramines as secondary disinfectants (B. Marinas, 2003)
- No evidence yet that ozone and chlorine dioxide can produce disinfectant synergies – but potential exists due to the distinct inactivation mechanisms
  - Pre-ozone with chlorine dioxide may allow chlorine dioxide mechanism to act more effectively

Bay Area Collaborative Research

Scope

- Examine variable water of Delta (daily, seasonal, locational) and impacts on treatment
- Focus on DBP control/reduction and increased disinfection potential
- Technologies to be tested include applications of multiple disinfectants and advanced filtration

Bay Area WTPs

Contra Costa WD	Direct filtration, conventional ,Ozone, Chlorine Dioxide, GAC
Santa Clara Valley WD	Conventional, (Ozone, GAC under construction)
Zone 7	Conventional, membranes
Alameda County Water District	Conventional, pH-adjusted pre-Ozone, GAC
Diablo WD	Direct filtration, Ozone, Chlorine Dioxide, GAC
Solano County Water Agency	Conventional, Ozone, GAC
City of Napa	Conventional
City of Antioch	Conventional, GAC
City of Fairfield	Conventional, Ozone, GAC
City of Martinez	Conventional, Ozone, partial GAC
City of Pittsburg	Conventional, Chloramine Primary Disinfection, GAC
City of Vallejo	Conventional, Ozone, GAC

Bay Area Collaborative Research

Phase 1: Disinfectant synergies, use of multiple disinfectants

UV Combinations

UV with NH_2Cl

UV with ozone and NH_2Cl

UV with ClO_2

UV with ozone and Cl_2

UV with Cl_2

Ozone Combinations with Preoxidants

NH_2Cl, ozone, NH_2Cl

ClO_2, ozone, Cl_2

ClO_2, ozone, NH_2Cl

$KMnO_4$, ozone, Cl_2

$KMnO_4$, ozone, NH_2Cl

Bay Area Collaborative Research

Phase 2: Treatment combinations including GAC, MIEX, and coagulation followed by MF and/or UF to reduce TOC

GAC Combinations	
GAC, Cl_2	ClO_2, ozone, GAC, NH_2Cl
GAC, UV, Cl_2	GAC, UV, NH_2Cl
MIEX Combinations	
MIEX, ozone, NH_2Cl	MIEX, ozone, Cl_2
Membrane Combinations	
NH_2Cl, PAC, UF/MF, NH_2Cl	GAC, UF/MF, Cl_2
Ozone, GAC, UF/MF, NH_2Cl	NH_2Cl, GAC, UF/MF, NH_2Cl
MIEX, Ozone, UF/MF, NH_2Cl	NH_2Cl, GAC, UF/MF, Cl_2
UF/MF, Cl_2, UV	UF/MF, UV, NHCl

Bay Area Collaborative Research

Scale of Research

Disinfectant Combinations (Phase I and II)	bench testing
	4 gpm pilot
UV Pilot to Demonstration Scale Options (Phase I)	7 gpm pilot
	200 gpm (demo)
Distribution System Testing (Phase I and II)	4 gpm pilot
GAC (Phase II)	4 gpm pilot
MIEX (Phase II)	2-10 gpm pilot
PAC with UF/MF (Phase II)	10-15 gpm pilot

Bay Area Collaborative Research

Schedule

Finalize experimental plan	Summer 2003
Complete experimental set-up, site preparation	Fall 2003
Begin Phase 1 experiments	Winter 2004
Begin Phase 2 experiments	Winter 2005
Complete experiments	Spring 2006