Complying with the Stage 1and 2 DBPR

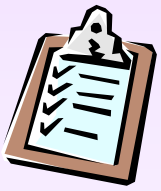
Anchorage, Alaska

October/November 2006

1

Outline

- Applicability
- Decision Tree Options
  - MCLs
  - MRDLs
  - Treatment Technique



Outline (cont)

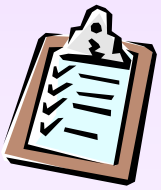
- Case Studies
  - Surface water, conventional plant, 50 MGD, TOC = 3.8 mg/L
  - Groundwater, disinfection only, 5 MGD, TOC = 8 mg/L
  - Surface water, softening plant, 50 MGD, TOC = 4.5 mg/L

Outline (cont.)

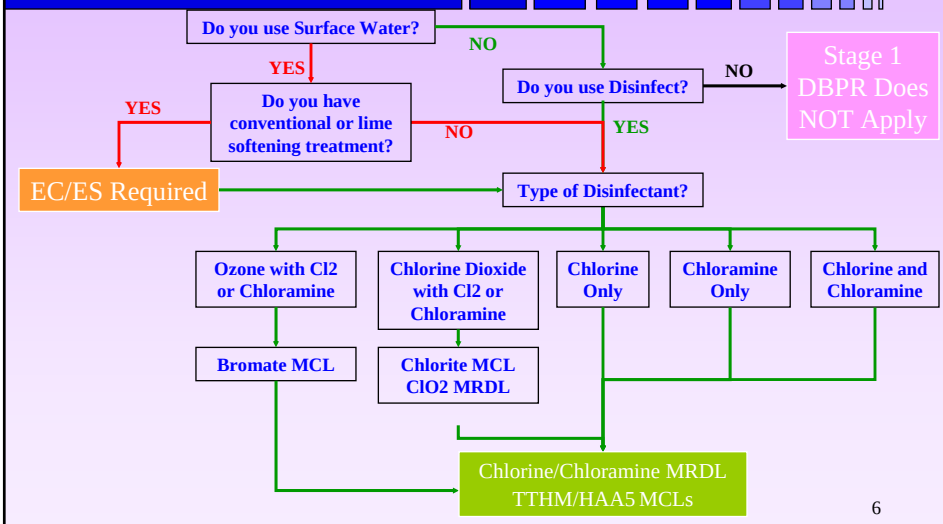
- Case Studies - Workshop
  - Groundwater, iron removal, 10 MGD, TOC = 2 mg/L
  - Surface water, direct filtration plant, 50 MGD TOC = 2.1 mg/L
  - Surface water, conventional treatment plant, 50 MGD, TOC = 10 mg/L
- Summary

Outline

- Applicability
- Decision Tree Options
- Major Elements/Strategies
  - MCLs
  - MRDLs
  - Treatment Technique



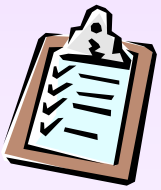
Stage 1 DBPR Applicability Chart



6

Outline

- Applicability
- Decision Tree Options
  - MCLs
  - MRDLs
  - Treatment Technique



Decision Tree Options: Four Major Elements of Stage 1 DBPR

Maximum Contaminant Levels

Treatment Technique

Maximum Residual Disinfectant Levels

8

Decision Tree Options: MCLs

Maximum Contaminant Levels Exceeded

Source	Treatment	Distribution
1) Change source/blend 2) Precursor management 3) Modify Chlorination 4) Seasonal Strategies	1) Optimize Coagulation 2) Change Point of Disinfectant Use 3) Change Disinfectant 4) Install Precursor Removal Technology 5) Seasonal strategies	1) Adjust residency time 2) Modify disinfection practice 3) Seasonal strategies

9

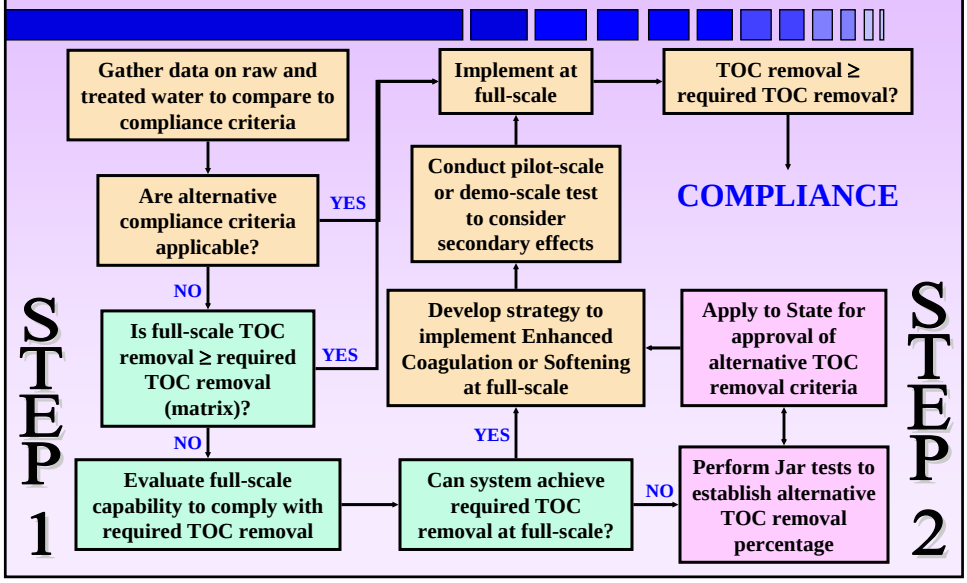
Decision Tree Options: MRDLs

Maximum Residual Disinfectant Levels Exceeded

1) Reduce dosage
2) Change disinfectant
3) Manage distribution system
4) Manage disinfectant demand

10

Decision Tree Options: Enhanced Coagulation/Softening Triggered



Alternative Compliance Criteria

(1) Source water TOC < 2.0 mg/L (annual average) OR

(2) Treated water TOC < 2.0 mg/L (annual average) OR

(3) Source water TOC < 4.0 mg/L, alkalinity > 60 mg/L (annual average) and

- annual average TTHM ≤ 0.040 mg/L and HAA5 ≤ 0.030 mg/L;

12

Alternative Compliance Criteria (cont.)

(4) TTHM ≤ 0.040 mg/L and HAA5 ≤ 0.030 mg/L (annual averages) and system uses only chlorine for primary and residual disinfection OR

(5) Source water SUVA ≤ 2.0 L/mg-m (annual average) OR

(6) Treated water SUVA ≤ 2.0 L/mg-m (annual average)

13

Additional Alternative Compliance Criteria for Softening Systems

(1) Softening that results in lowering treated water alkalinity to <60 mg/L

(2) Softening that results in removing at least 10 mg/L (as $CaCO_3$) of magnesium hardness

- Meeting any Alternative Compliance Criteria Results in a Performance Ratio of 1.0 for that Month

14

Enhanced Coagulation/Softening Requirements (cont.)

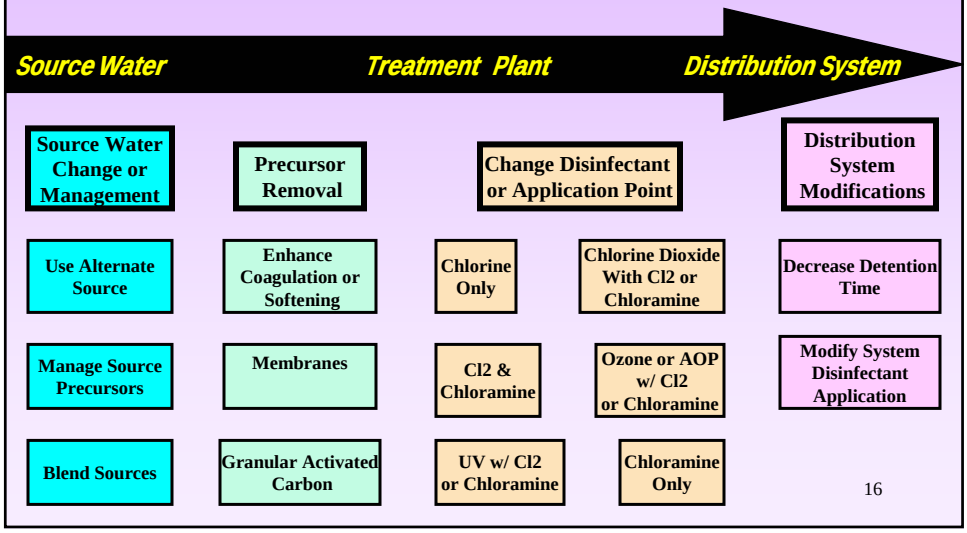
3x3 Matrix of Required TOC Removal

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L)		
	0-60	> 60-120	>120**
> 2.0 to 4.0	35%	25%	15%
> 4.0 to 8.0	45%	35%	25%
> 8.0	50%	40%	30%

** Softening Plants must meet the TOC reduction in far right column

15

Decision Tree Options: *DBPR Tool Kit*



16

Source Water

- Change, Abandon, and/or Blend
- Precursor Management
- Modify Chlorination
  - Point of Application
  - Cl_2 Dose
- Seasonal Strategies

Downsides?

17

Source Water

- Change, Abandon, and/or Blend
- Precursor Management
- Modify Chlorination
  - Point of Application
  - Cl_2 Dose
- Seasonal Strategies

Considerations for Change

18

Treatment

- Precursor Removal
  - Enhanced Coagulation or Softening
  - Membranes
  - Granular Activated Carbon
- Ozone With Biologically Active Filters

Downsides?

19

Treatment

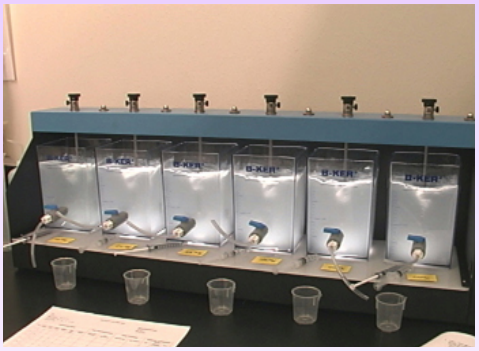
- Precursor Removal
  - Enhanced Coagulation or Softening
  - Membranes
  - Granular Activated Carbon

Considerations for Change

20

Enhanced Coagulation Considerations

- Do You Have a "Conventional" Plant?
  - Optimize Coagulant Dose
  - Coagulant Selection
  - Optimize pH
- Membranes
- GAC



21

Treatment Downsides

- Enhanced Coagulation
  - Corrosion
  - Sludge Production
  - Turbidity
- Enhanced Softening
  - Reduced Alkalinity/Corrosion
  - Sludge

22

Treatment Downsides

- Membranes
  - Cost
- Granular Activated Carbon
  - Cost
    - Initial
    - Replacement

23

Treatment

- Disinfectant Application Point
- Chlorine and Chloramine
- UV With Chlorine and/or Chloramines
- Chlorine Dioxide With Chlorine and/or Chloramine
- Ozone With Chlorine and/or Chloramine
  - With Biologically Active Filters (BAF)
- Chloramine Only

24

Treatment Downsides

- Disinfectant Application Point
  - Benchmark
- Chlorine and Chloramine
  - Nitrification
  - Nitrosodimethylamine (NDMA)
- UV With Chlorine and/or Chloramines
- Chlorine Dioxide With Chlorine and/or Chloramine
  - Chlorite & Chlorate
- Ozone With Chlorine and/or Chloramine
  - With Biologically Active Filters (BAF)
    - Bromate
    - AOC and Regrowth/Biofilms
- Chloramine Only

25

Distribution System

- Decrease Detention Time
- Modify Disinfection Practices
- Seasonal Strategies

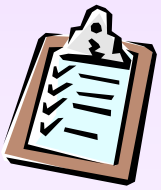
Downsides?

Benchmark

26

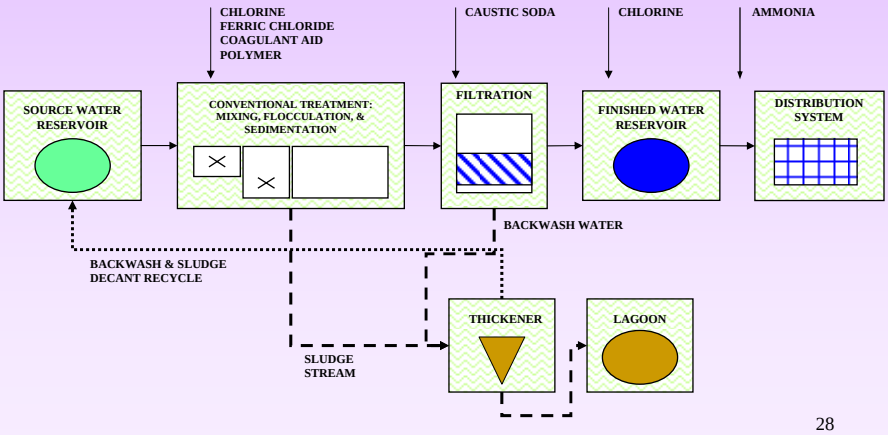
Outline (cont)

- Case Studies - Ensemble
  - Surface water, conventional plant, 50 MGD, TOC = 3.8 mg/L
  - Groundwater, disinfection only, 5 MGD, TOC = 8 mg/L
  - Surface water, softening plant, 50 MGD, TOC = 4.5 mg/L



Stage 1 DBPR Case Study #1

Surface Water Conventional Treatment: 50 MGD



28

Stage 1 DBPR Case Study #1

Surface Water Conventional Treatment: 50 MGD

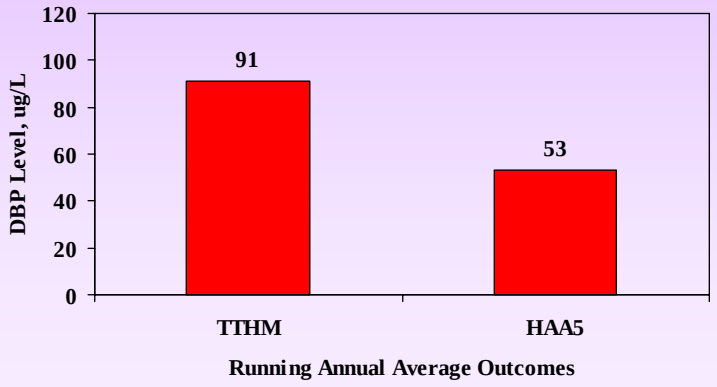
Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L)	3.8	2.2	6.1
Bromide (µg/L)	0.1	0.05	0.25
pH	7.6	6.9	8.4
Turbidity (NTU)	22	9	145
Temperature (^{o}C)	13	4.1	26
Alkalinity (mg/L)	65	42	88
UV-254 (/cm)	0.095	0.032	0.256
SUVA (L/mg-m)	3.6	1.8	6.0
Total Coliform (colonies/100mL)	340	110	980

29

Stage 1 DBPR Case Study #1

Surface Water Conventional Treatment: 50 MGD



30

Case Study #1: Observations

Surface Water Conventional Treatment: 50 MGD

- TOC Level Triggers Enhanced Coagulation (EC)
- TTHM MCL is Exceeded and HAA5 MCL is Close Even with Chloramines
- 20% Reduction of TTHMs Needed to Achieve Compliance
- Prechlorination Practiced

31

Case Study #1: Observations

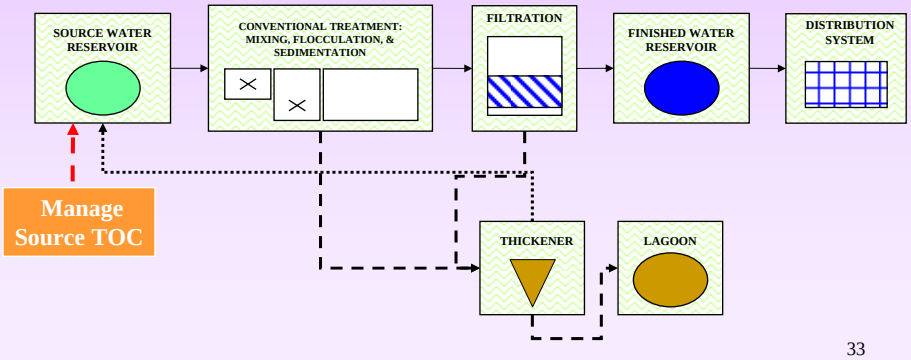
Surface Water Conventional Treatment: 50 MGD

- Relatively Low Alkalinity Water
- Periodically Elevated Bromide Levels
- Distribution System Water Quality Issues to be Considered with Chloramines:
  - Nitrification, dialysis patients, plumbing materials

32

Stage 1 DBPR Case Study #1

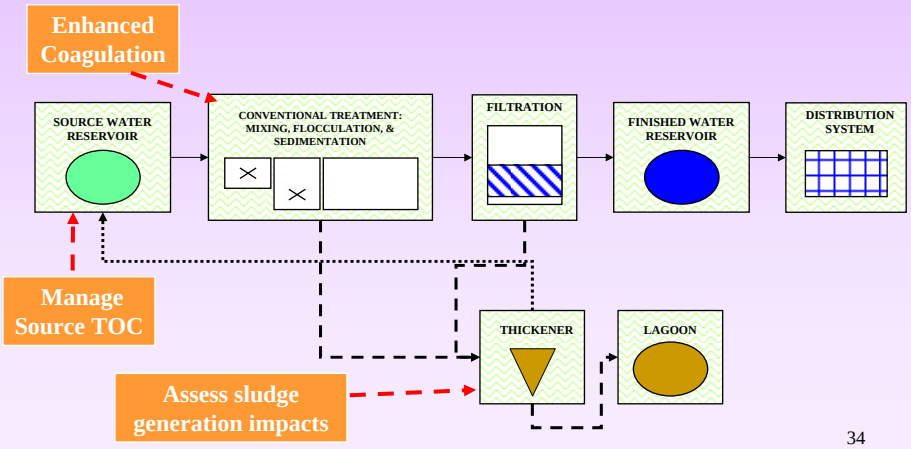
Surface Water Conventional Treatment: 50 MGD



33

Stage 1 DBPR Case Study #1

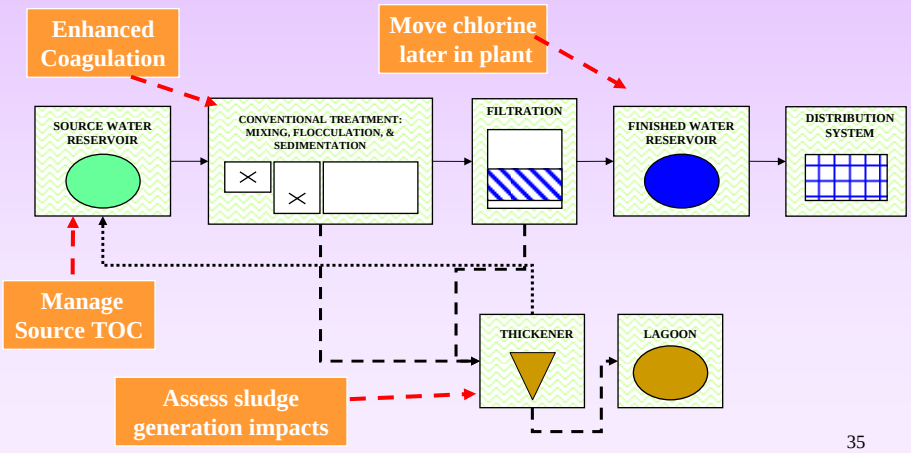
Surface Water Conventional Treatment: 50 MGD



34

Stage 1 DBPR Case Study #1

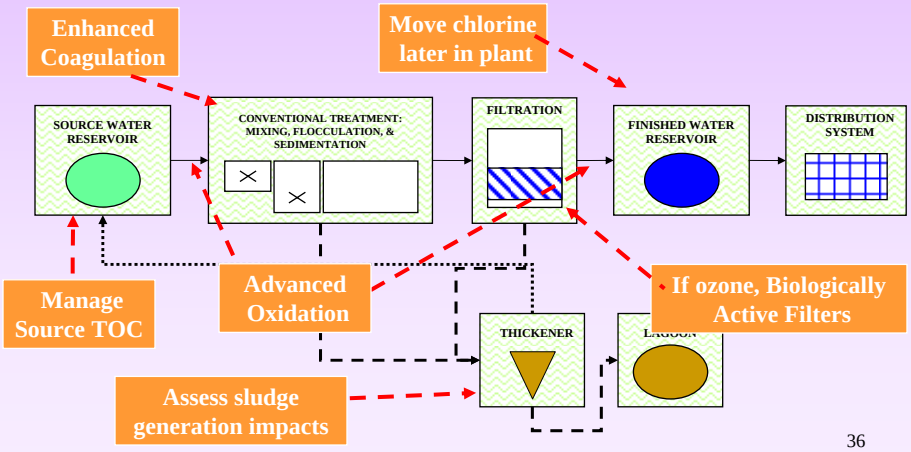
Surface Water Conventional Treatment: 50 MGD



35

Stage 1 DBPR Case Study #1

Surface Water Conventional Treatment: 50 MGD



36

Case Study #1: Compliance Strategy Observations

Surface Water Conventional Treatment: 50 MGD

- Reducing Chlorine Contact Time will Reduce Total Disinfection Performance
  - Check Profile and Benchmark
- Bromide Levels may Affect Ozone Retrofit Strategy
  - pH control to limit bromate formation

37

Case Study #1: Compliance Strategy Observations (cont.)

Surface Water Conventional Treatment: 50 MGD

- Bench and Pilot Test Should be Performed to Demonstrate Advanced Oxidation Techniques (ozone, chlorine dioxide, $KMnO_4$)
- Location of Advanced Oxidants Depends on Other Site-Specific Water Quality Issues:
  - Oxidation demand: organic and inorganic
  - Aesthetic water quality controls: T&O, nuisance algae
  - Effect of contact time

38

Case Study #1: Compliance Strategy Observations (cont.)

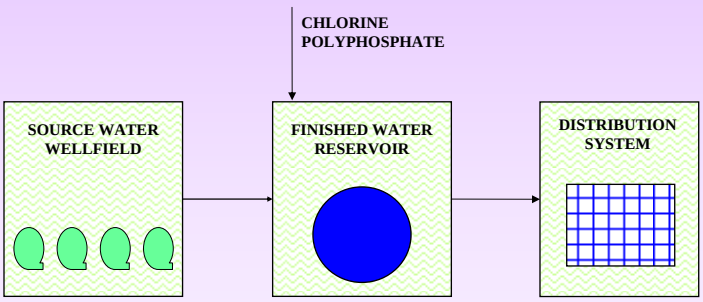
Surface Water Conventional Treatment: 50 MGD

- Location of Advanced Oxidants Depends on Other Site-Specific Water Quality Issues:
  - Compliance with MCLs for bromate or chlorite
  - Compatibility with other treatment objectives: corrosion control, filtration performance
  - Consideration of compliance with future rules

39

Stage 1 DBPR Case Study #2

Chlorinated Groundwater: 5 MGD



Chlorine dose designed to achieve 4-log virus inactivation

40

Stage 1 DBPR Case Study #2

Chlorinated Groundwater: 5 MGD

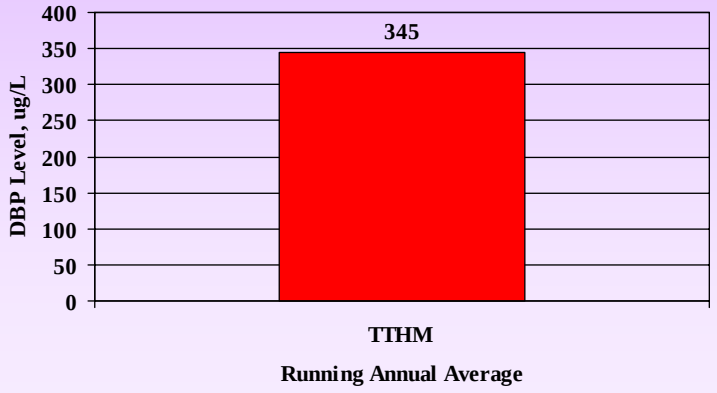
Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L)	8	6.2	12.4
Bromide (µg/L)	0.50	0.23	0.90
pH	8.1	7.6	8.9
Turbidity (NTU)	?	?	?
Temperature (^{o}C)	17	14	19
Alkalinity (mg/L)	260	175	310
UV-254 (/cm)	0.200	0.120	0.300
SUVA (L/mg-m)	?	?	?
Total Coliform (colonies/100mL)	3	ND	8
Radon (pCi/L)	4200	3600	5000
Arsenic (µg/L)	35	27	42
Color (pcu)	80	75	86

41

Stage 1 DBPR Case Study #2

Chlorinated Groundwater: 5 MGD



42

Case Study #2: Observations

Chlorinated Groundwater: 5 MGD

- Need to Collect HAA5 Data
- Multiple Well Sources Provide Source Water Blending Opportunities
- High TOC Groundwater
- Significantly Exceeds TTHM MCL
  - Inference is that HAA5 MCL is likely to be exceeded as well

43

Case Study #2: Observations

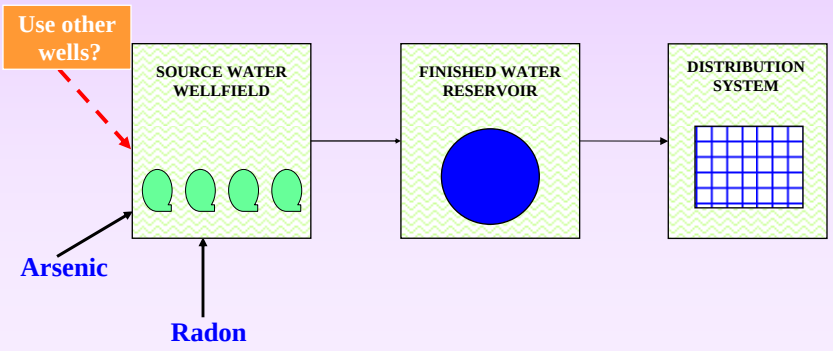
Chlorinated Groundwater: 5 MGD

- Arsenic MCL and Potentially, the Future Radon MCL
  - Compliance strategy should consider multiple objectives, not just DBPs
- High Alkalinity Water
- Highly Colored Water
- Significant Levels of Bromide

44

Stage 1 DBPR Case Study #2

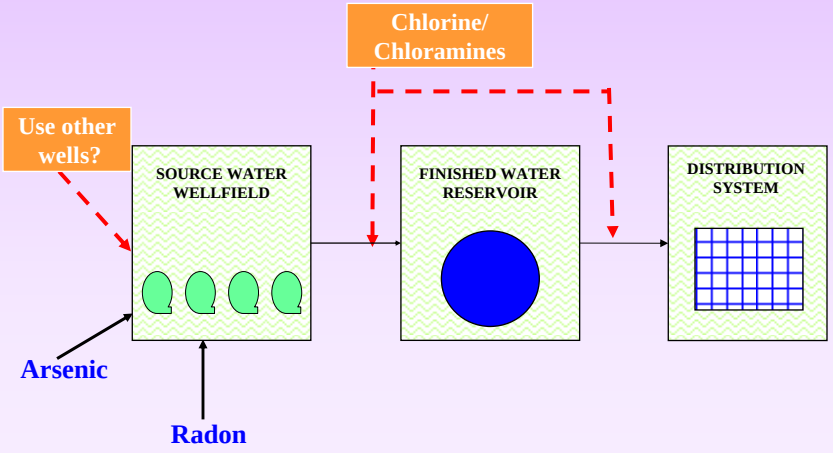
Chlorinated Groundwater: 5 MGD



45

Stage 1 DBPR Case Study #2

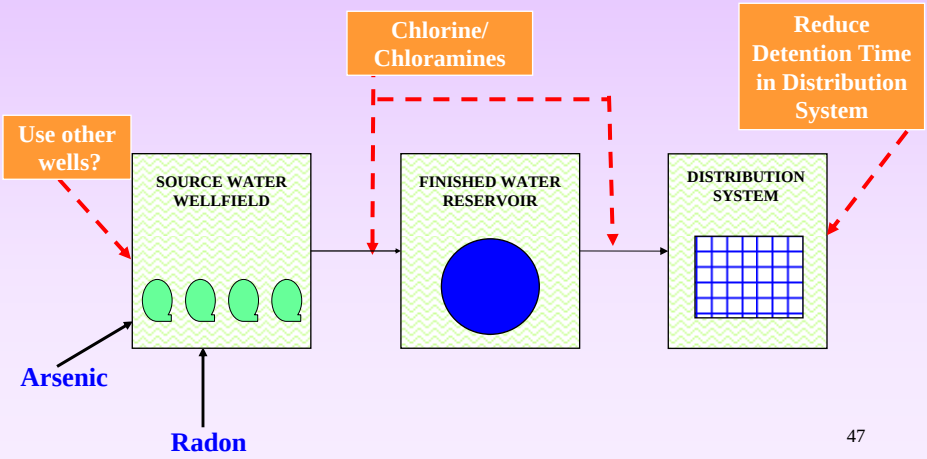
Chlorinated Groundwater: 5 MGD



46

Stage 1 DBPR Case Study #2

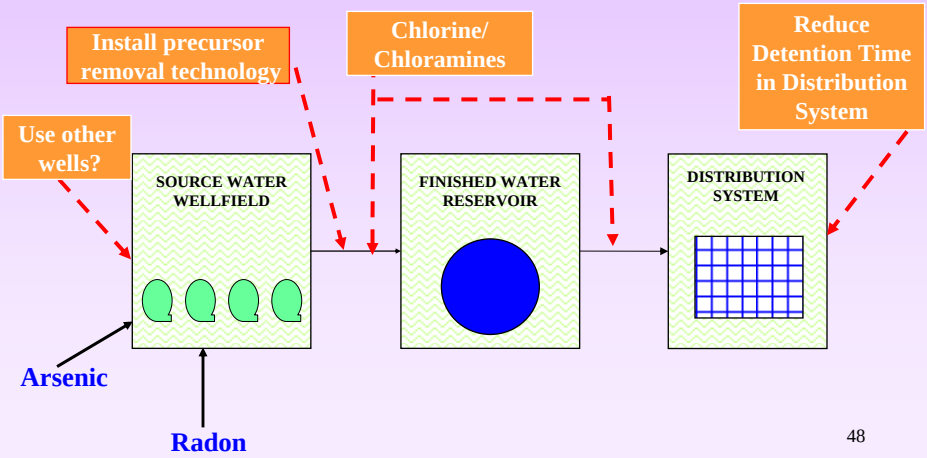
Chlorinated Groundwater: 5 MGD



47

Stage 1 DBPR Case Study #2

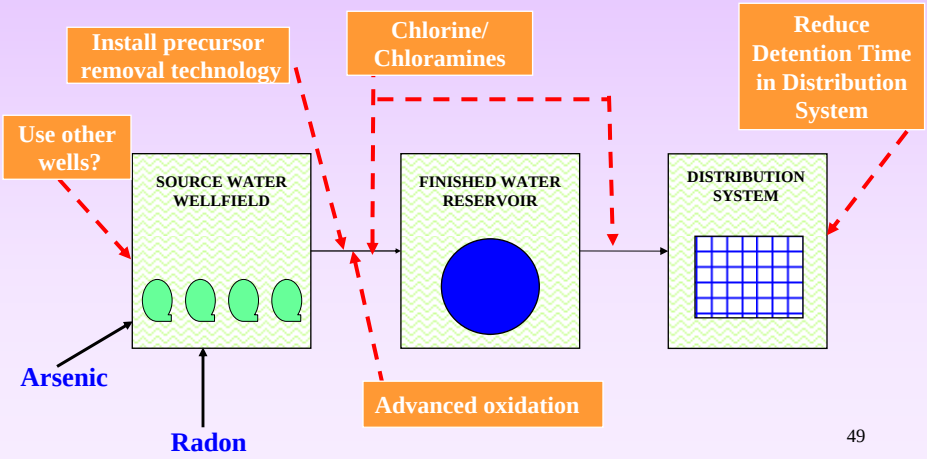
Chlorinated Groundwater: 5 MGD



48

Stage 1 DBPR Case Study #2

Chlorinated Groundwater: 5 MGD



49

Case Study #2: Compliance Strategy Observations

Chlorinated Groundwater: 5 MGD

- High Organic and Colored Source Water Could:
  - Limit the application of ozone or chlorine dioxide due to byproducts and costs
  - Force high disinfectant residuals in distribution system
- Bromide levels could affect use of chlorine or ozone even after precursor removal

50

Case Study #2: Compliance Strategy Observations

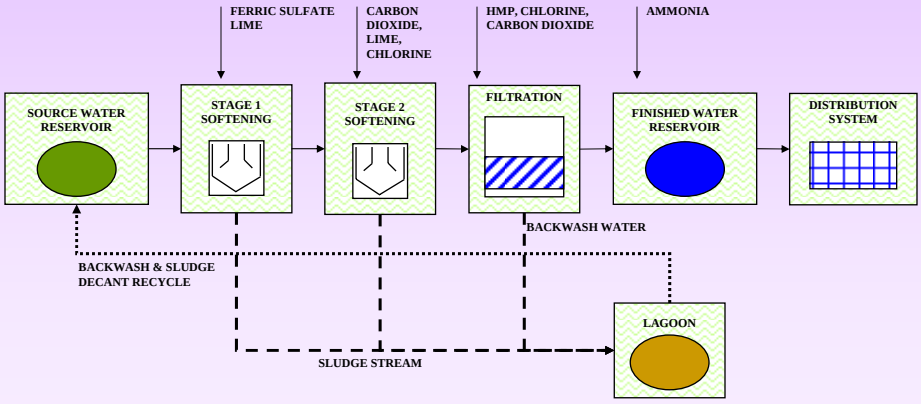
Chlorinated Groundwater: 5 MGD

- Arsenic and Radon MCLs may Require System to Install Treatment
  - Arsenic control technologies (membranes, anion exchange, activated alumina, coagulation) also benefit DBP precursor control
  - Aeration for radon control raises the pH and may aggravate DBP formation (TTHMs, bromate)
  - Ozone, if feasible, may benefit radon removal

51

Stage 1 DBPR Case Study #3

River Water 2-Stage Softening: 50 MGD



52

Stage 1 DBPR Case Study #3

River Water 2-Stage Softening: 50 MGD

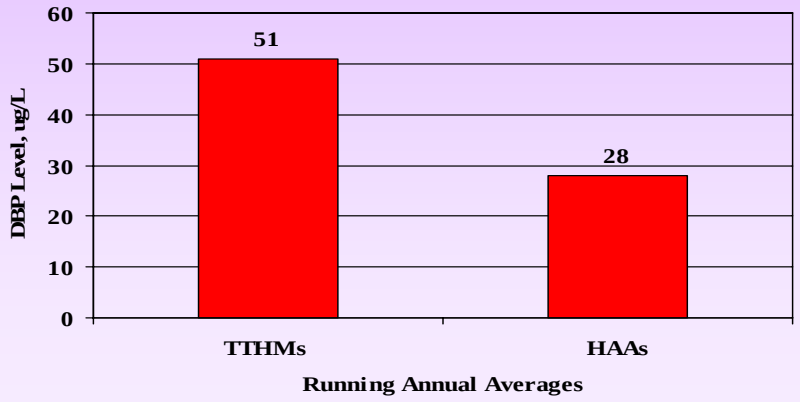
Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L)	4.5	2.8	7.1
Bromide (µg/L)	0.08	.05	0.12
pH	7.6	7.2	8.4
Turbidity (NTU)	12	3	50
Temperature (^{o}C)	12	5	22
Hardness (mg/L)	160	110	255
Alkalinity (mg/L)	175	134	240
UV-254 (/cm)	?	?	?
SUVA (L/mg-m)	?	?	?

53

Stage 1 DBPR Case Study #3

River Water 2-Stage Softening: 50 MGD



54

Case Study #3: Observations

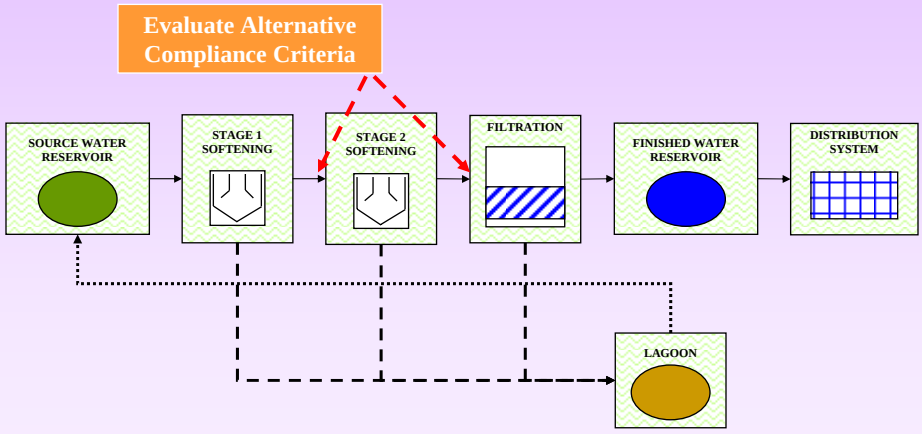
River Water 2-Stage Softening: 50 MGD

- Complies with the DBP MCLs and Disinfectant Residual MRDLs
- Average Magnesium Hardness is 16 mg/L
- TOC Values Indicate Enhanced Softening Required
- Low Bromide Source Water
- SUVA Data Needs to be Collected, Including Treated Water SUVA Values

55

Stage 1 DBPR Case Study #3

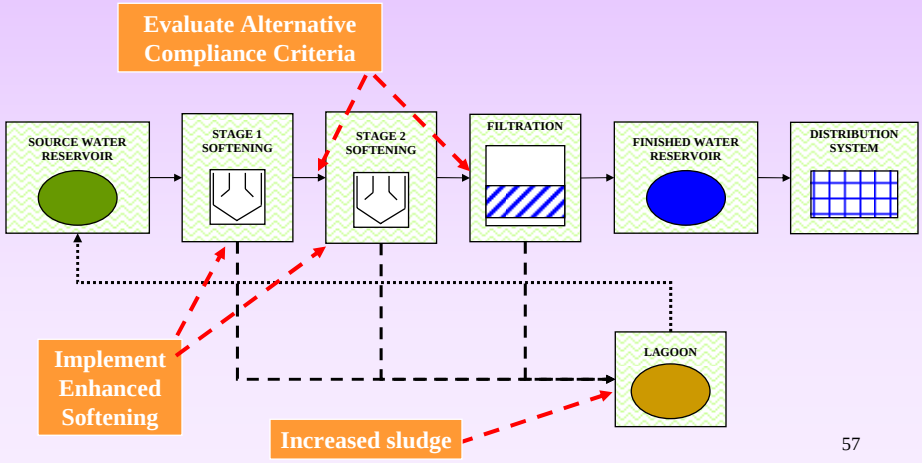
River Water 2-Stage Softening: 50 MGD



56

Stage 1 DBPR Case Study #3

River Water 2-Stage Softening: 50 MGD



57

Case Study #3: Compliance Strategy Observations

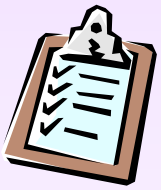
River Water 2-Stage Softening: 50 MGD

- Source and Treated Water Monitoring Should be Initiated to Evaluate the Plant's Ability to Meet Alternative Compliance Criteria
- Jar Testing will be Necessary to Determine Potential Compliance with the Treated Water SUVA Alternative Compliance Criteria
- Lime Dosages for this Plant Minimally Could Be:
  - 100 mg/L $Ca(OH)_2$: Reduce alkalinity to ≤60 mg/L
  - 135 mg/L $Ca(OH)_2$: Remove 10 mg/L magnesium

58

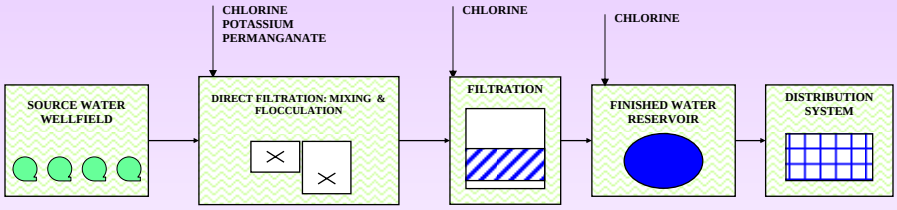
Outline (cont.)

- Case Studies - Workshop
  - Groundwater, iron removal, 10 MGD, TOC = 2 mg/L
  - Surface water, direct filtration plant, 50 MGD TOC = 2.1 mg/L
  - Surface water, conventional treatment plant, 50 MGD, TOC = 10 mg/L
- Summary



Stage 1 DBPR Case Study #4

Groundwater w/ Iron & Manganese Removal: 2 MGD



60

Stage 1 DBPR Case Study #4

Groundwater w/ Iron & Manganese Removal: 2 MGD

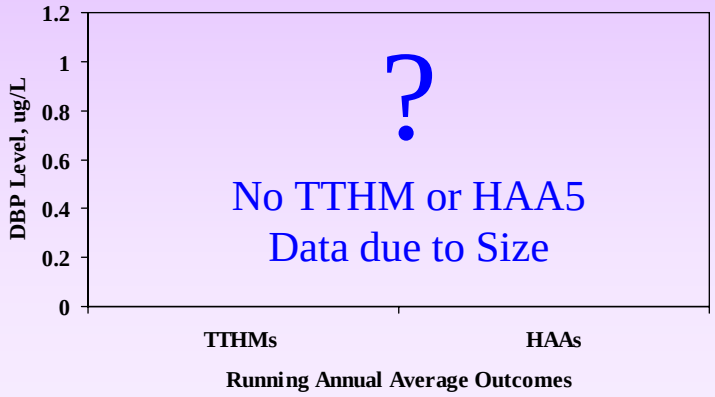
Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L) *	2	2	2
Bromide (μg/L)	?	?	?
pH	6.7	6.2	7.5
Turbidity (NTU)	0.10	0.12	0.08
Temperature (^{o}C)	13	9	16
Alkalinity (mg/L)	85	68	102
Iron (mg/L)	0.6	0.4	2.0
Manganese (mg/L)	0.1	0.05	0.3
UV-254 (ohms/cm)	?	?	?
Arsenic (μg/L)	< 50	< 50	< 50
* One TOC Sample Collected as Part of Groundwater Survey			

61

Stage 1 DBPR Case Study #4

Groundwater w/ Iron & Manganese Removal: 2 MGD



62

Case Study #4: Observations

Groundwater w/ Iron & Manganese Removal: 2 MGD

- Good Bacterial Quality for a Disinfected Groundwater
- Essential to Collect DBP Data
- Unknown DBP Precursor Water Quality
  - Bromide, UV254, SUVA, TOC

63

Case Study #4: Observations

Groundwater w/ Iron & Manganese Removal: 2 MGD

- Low Level Arsenic Measures Unavailable
- Radon Sampling has not been Performed
- Iron and Manganese are Elevated:
  - Co-occurs with arsenic, but existing treatment may already be effective for arsenic control
  - Oxidation & removal strategy for iron/manganese must be incorporated with overall compliance strategy

64

Case Study #4: Compliance Strategy Observations

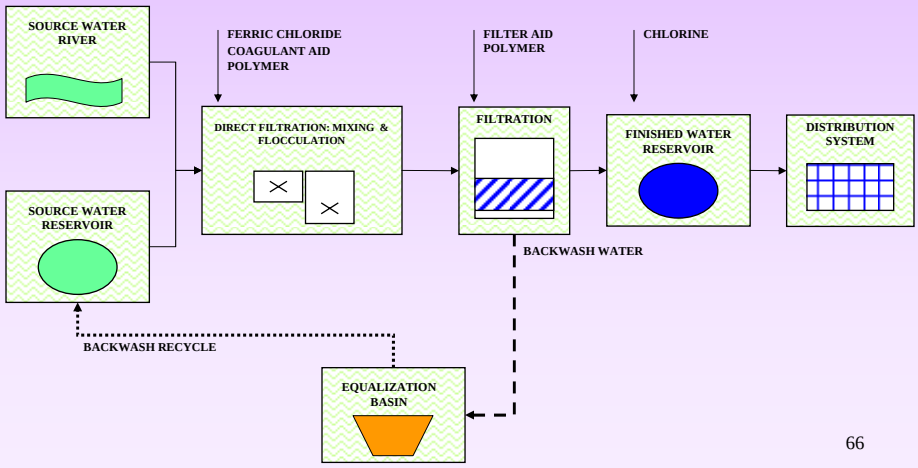
Groundwater w/ Iron & Manganese Removal: 2 MGD

- Manage ClO_2 dosage to stay within chlorite MCL
- Manage chlorine contact time prior to ammonia to control DBPs
- Critical to collect HAA5 data
- Sedimentation basins could be constructed to manage arsenic removal

65

Stage 1 DBPR Case Study #5

Surface Water Direct Filtration: 50 MGD



66

Stage 1 DBPR Case Study #5

Surface Water Direct Filtration: 50 MGD

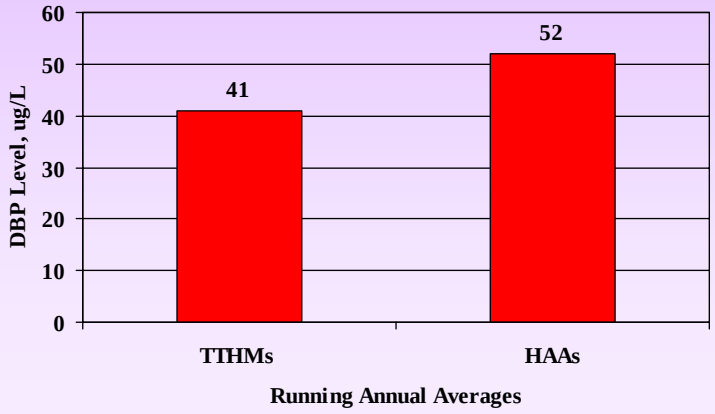
Blended Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L)	2.1	0.7	4.2
Bromide (µg/L)	0.22	0.15	0.35
pH	7.1	6.3	9.2
Turbidity (NTU)	6	1	27
Temperature (^{o}C)	9	4.1	17
Alkalinity (mg/L)	42	8	65
UV-254 (/cm)	0.045	0.028	0.136
SUVA (L/mg-m)	2.7	1.8	4.6
Total Coliform (colonies/100mL)	23	ND	105
Cryptosporidium (oocyst/100L)	ND	ND	ND
Giardia (cysts/100 L)	ND	ND	44
Viruses (plaque/100L)	ND	ND	ND

67

Stage 1 DBPR Case Study #5

Surface Water (Reservoir) Direct Filtration: 50 MGD



68

Case Study #5: Observations

- Elevated Bromide Levels
- Relatively Low TOC and Alkalinity
- Enhanced Coagulation is NOT Required, but SUVA Indicates TOC Removal Possible
- Plant Already Meets Stage 1 DBPR MCLs
- Plant Would NOT Meet Stage 2 LRAA MCLs
- Currently Blend Source Waters ~ 50:50

69

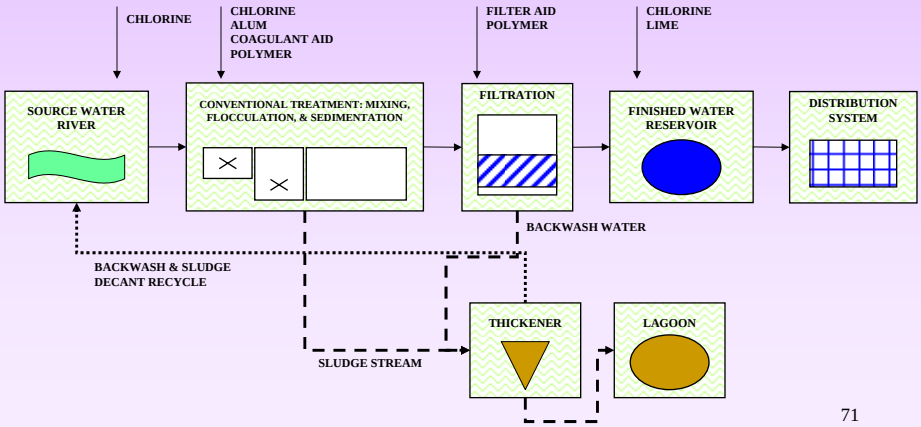
Case Study #5: Observations

- Reservoir Source has Higher TOC and Seasonal Algae
  - Leads to T&O problems
- Increased Reliance on Reservoir Supply in Future due to Increase Demand
- Future Water Quality may Cause Higher TTHMs and HAA5 in Distribution System

70

Stage 1 DBPR Case Study #6

Surface Water (River) Conventional Treatment: 50 MGD



71

Stage 1 DBPR Case Study #6

Surface Water (River) Conventional Treatment: 50 MGD

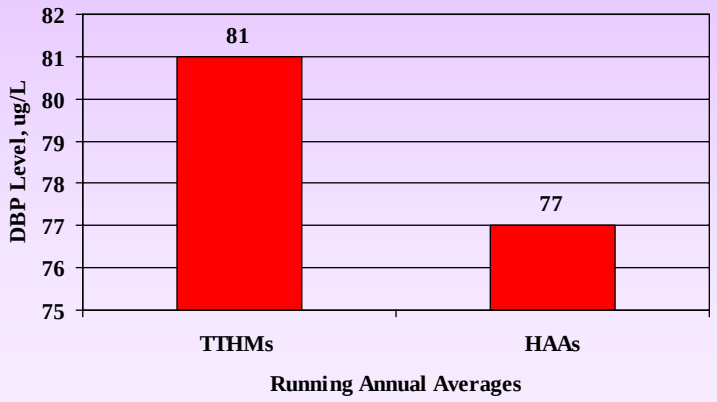
Influent Water Quality

Parameter	Average	Minimum	Maximum
TOC (mg/L)	10	3.6	22
Bromide (μg/L)	0.1	0.05	0.25
pH	6.8	6.2	7.5
Turbidity (NTU)	68	23	>1000
Temperature (^{o}C)	12	4.1	26
Alkalinity (mg/L)	23	12	55
UV-254 (/cm)	0.095	0.032	0.256
SUVA (L/mg-m)	7.5	4.1	16.0
Total Coliform (colonies/100mL)	1,250	800	37,000
Cryptosporidium (oocyst/100L)	25	ND	420
Giardia (cysts/100 L)	42	ND	680
Viruses (plaque/100L)	?	?	?

72

Stage 1 DBPR Case Study #6

Surface Water (River) Conventional Treatment: 50 MGD



73

Case Study #6: Observations

Surface Water (River) Conventional Treatment: 50 MGD

- High TOC Source Water
- Periodically Elevated Bromide
- Enhanced Coagulation is Required
- High SUVA Indicates TOC Removal by Coagulation is Promising
- Exceeds the TTHM MCL Marginally, but Significantly Above the HAA5 MCL

74

Case Study #6: Observations

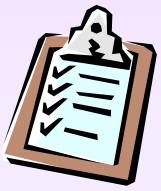
Surface Water (River) Conventional Treatment: 50 MGD

- Treatment Challenges from Source Water Quality:
  - Poor microbiological quality (High coliform bacteria, *Giardia*, and *Cryptosporidium*)
  - Low alkalinity can limit coagulation performance
  - High turbidity events can overload processes
  - Seasonal trend has cold temperature, low alkalinity, and high turbidity coinciding

75

Outline (cont.)

- Case Studies - Workshop
  - Groundwater, iron removal, 10 MGD, TOC = 2 mg/L
  - Surface water, direct filtration plant, 50 MGD TOC = 2.1 mg/L
  - Surface water, conventional treatment plant, 50 MGD, TOC = 10 mg/L
- Summary



Summary

- Your "Tool Kit" Contains Many Options
- There are Multiple "Right" Solutions
- Changing One Parameter Can Impact Many Others
  - Look for interactions in water quality and treatment objectives
- Compliance May Be Costly

77

Summary (cont.)

- Operational Issues Associated with Your Solution(s) Must be Carefully Assessed
  - Bench or pilot test as practicable
  - Learn from others' experiences
- Understand the Implications of the Changes you Make for Meeting Other Regulations
- CONSIDER FUTURE REGULATORY CHANGES

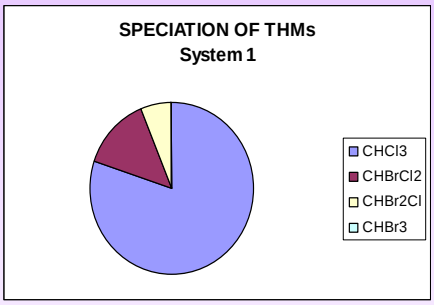
78

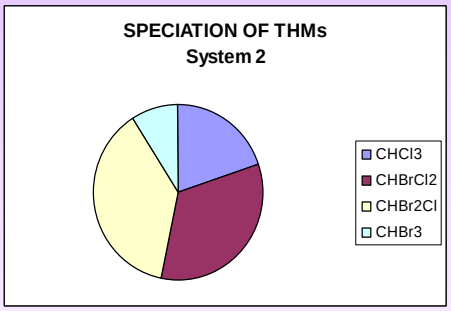
Things to Consider

- Test for all Nine Bromine and Chlorine-Containing HAA Species
- Track Levels of Brominated THMs and HAAs

79

Things to Consider





80