White Mountain Apache Surface Water Conventional Treatment Plant Project: Technology Design Decision Pathway and Post-Construction Operational Review

Presenter: Michael A. Stover, PE
Environmental Protection Agency
Region 1 Indian Program Manager

Webinar Objectives

Participants will gain deeper understanding of:

- Safe Drinking Water Act and surface water treatment rules
- source surface water quality testing regimen
- microbiological contaminants and respective life cycles
- surface water treatment process alternatives and limitations
- decision-making path taking into consideration technical complexities and tribal capacity considerations

White Mountain Apache Reservation

Whiteriver, AZ

Why Surface Water Treatment?

- Tribe's groundwater sources declining 5% each year
  - caused by dewatering of aquifer due to over pumping and lack of significant natural recharge
- Variable arsenic levels in MF wells require selective blending – not viable
- Demand increasing as water distribution system expanded to serve outlying communities suffering from water source issues

Review of applicable Statutes, Regulations and Guidance

STATUTES
Congress and President
SDWA, CWA

↓

REGULATIONS
EPA and Public
LCR, SWTR, CCR

↓

POLICY, GUIDANCE and GUIDELINES
EPA
Op Cert, Capacity Development, DWSRF

Provisions of 1974 Safe Drinking Water Act (SDWA)

Gerald R. Ford
1974

- EPA to promulgate National Primary Drinking Water Regulations
- Established the public water system supervision (PWSS), underground injection control (UIC), and sole source aquifer (SSA) programs
- Provided for State implementation (primacy)

Provisions of 1974 SDWA (continued)

- Gave EPA authority to set drinking water standards
  - Recommended Maximum Contaminant Level (RMCL)
  - Maximum Contaminant Level (MCL)
  - Treatment technique (enforceable procedure or level of performance)

Status of Drinking Water Control Prior to 1986 Amendments

- Variable State regulations
- Monitoring organics not required for most systems
- Occasional outbreaks of giardiasis
- Rudimentary information management

1986 SDWA Amendments

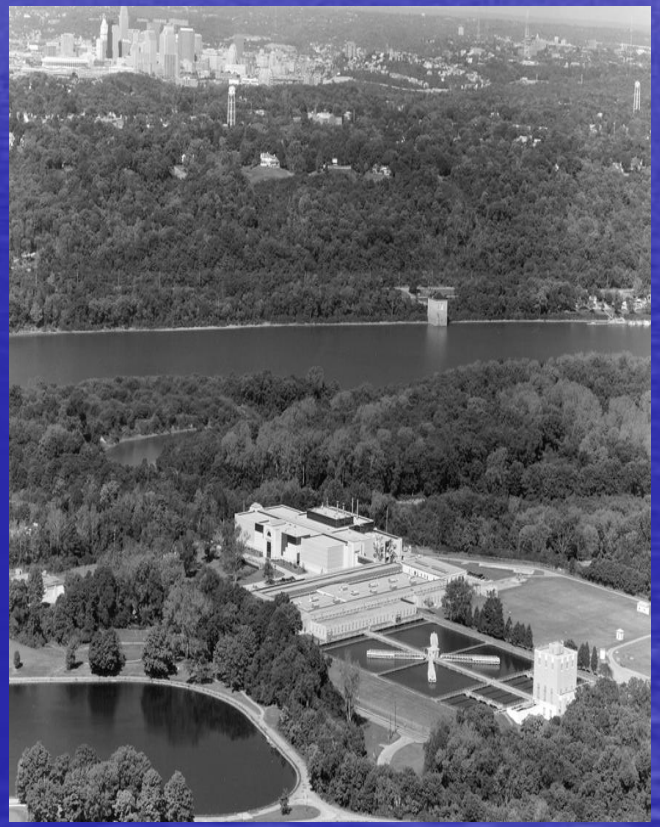
- Prescriptive
- Tight deadlines
- 83 contaminants in 3 years
- Additional 25 contaminants every 3 years
- Added ground water protection program
  - —Wellhead protection

SDWA Amendments

June 19, 1986

Effects of 1986 Amendments

- Creation of the NTNC category of water system
- Organic chemicals
  - Monitoring and detection
  - Risk communication
- Surface water treatment rule
  - Higher filtered water standards
  - Filtration avoidance
- CT calculations



SDWA Rules and Amendments (current)

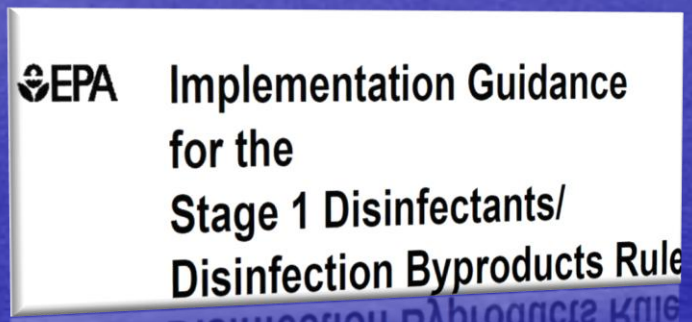
- MCL's for Primary and Secondary (1971, 1986)
- Total Coliform Rule (1989)
- Surface water Treatment Rule (1989)
- Interim Enhanced Surface Water (1998)
- Filter Backwash Recycling Rule (2001)
- Stage 1 and 2 D/DBR (1998, 2006)
- Long Term 1 and 2 Enhanced Surface Water Treatment Rules (2001, 2006)

Interim Enhanced Surface Water Treatment Rule:

- Requires 99 percent (2-log) physical removal of Cryptosporidium for system that filter.
- Requires less than .3 nephelometric turbidity units (NTU) in at least 95 percent of measurements taken each month. Places maximum level of NTU for a single measurement at 1 NTU.
- Requires combined filter effluent monitoring of NTU for conventional and direct filtration systems every 4 hours.
- Requires continuous (every 15 minutes) turbidity monitoring of filter effluent for conventional and direct filtration systems.
- Requires systems to conduct disinfections profiling and benchmarking. Requires sanitary surveys every 3 years.

Stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR)

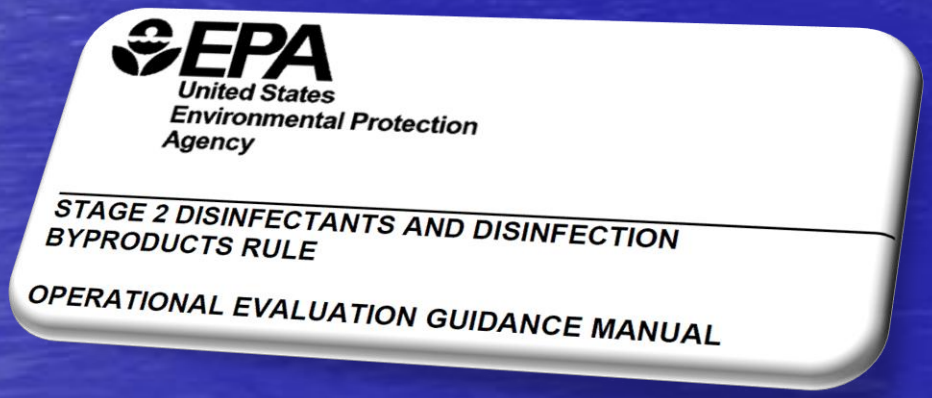
- Disinfectants
  - Chlorine
  - Chloramines
  - Chlorine Dioxide



- Disinfectant By-Products
  - Total Trihalomethanes (TTHMs)
  - Haloacetic Acids (HAA5)

Stage 2 Disinfectants and Disinfection Byproducts Rule

tightens monitoring requirements specifically relating to TTHMs and HAA5 – targeting likely locations in the distribution of high water age (dead ends, etc)



Disinfection Byproduct Rule

Sets percentage of Total Organic Carbon (TOC) removal as function of pH, TOC level in source water, and source water alkalinity

TABLE 2-1

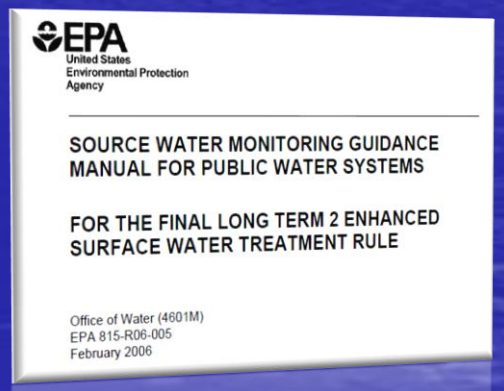
Required Removal of TOC by Enhanced Coagulation For Plants Using Conventional Treatment: Step 1 Removal Percentages[a, b]

SOURCE WATER TOC (mg/L)	SOURCE WATER ALKALINITY (mg/L as $CaCO_3$)		
	0 to 60	>60 to 120	>120[c]
>2.0 - 4.0	35.0%	25.0%	15.0%
>4.0 - 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Notes:

Long Term 2 Enhanced Surface Water Treatment Rule (LT2)

- 2-year Monitoring for Cryptosporidium
- Determine average results (RAA) after 2 years
- Microbial Tool Box (Bin Classification)
  - For Bin 1, oocyts < .075/Liter
- Treatment type evaluation and barriers to cysts


EPA
United States
Environmental Protection
Agency

SOURCE WATER MONITORING GUIDANCE MANUAL FOR PUBLIC WATER SYSTEMS

FOR THE FINAL LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE

Office of Water (4601M)
EPA 815-R06-005
February 2006

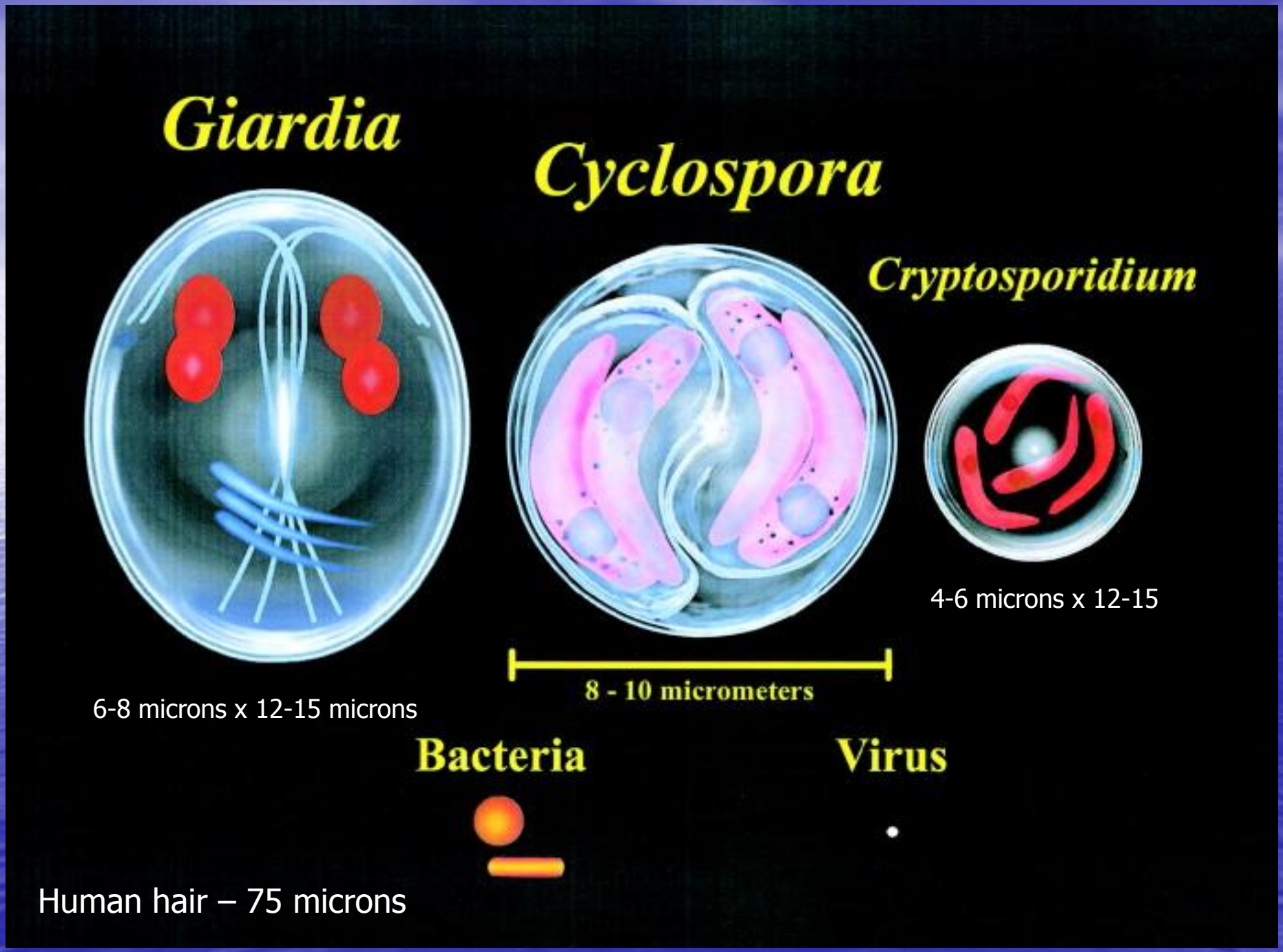
Filtered System Bin Classification and Treatment

Bin Number	*Cryptosporidium* Concentration (in oocysts/L)	Additional Treatment Beyond Current Requirements
1	*Crypto* < 0.075	No additional treatment
2	0.075 ≤ *Crypto* < 1.0	1.0 log (90%)
3	1.0 ≤ *Crypto* < 3.0	2.0 log (99%)
4	3.0 ≤ *Crypto*	2.5 log (99.7%)

"Microbial Toolbox"

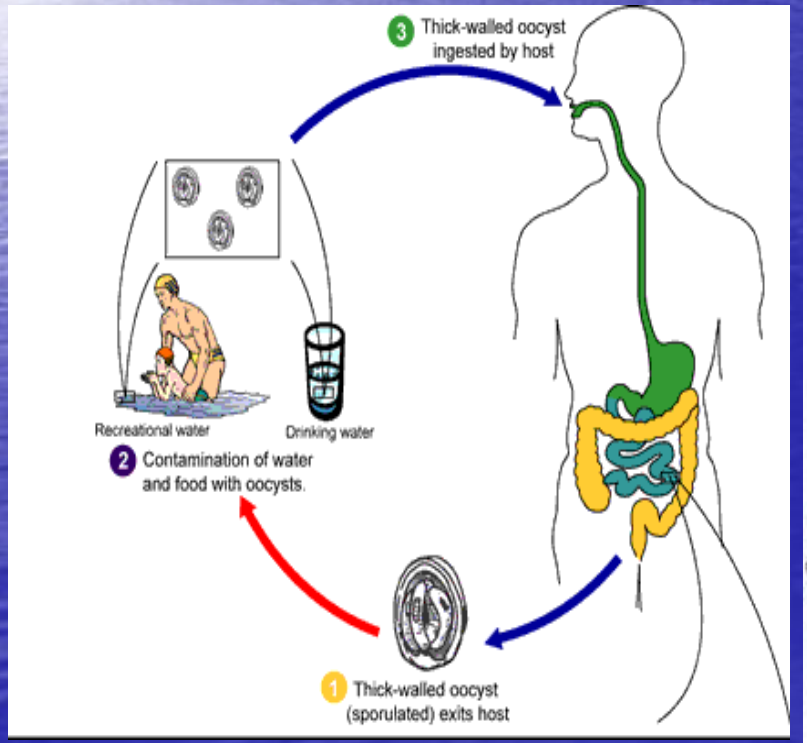
EPA Rules Steering Treatment Design

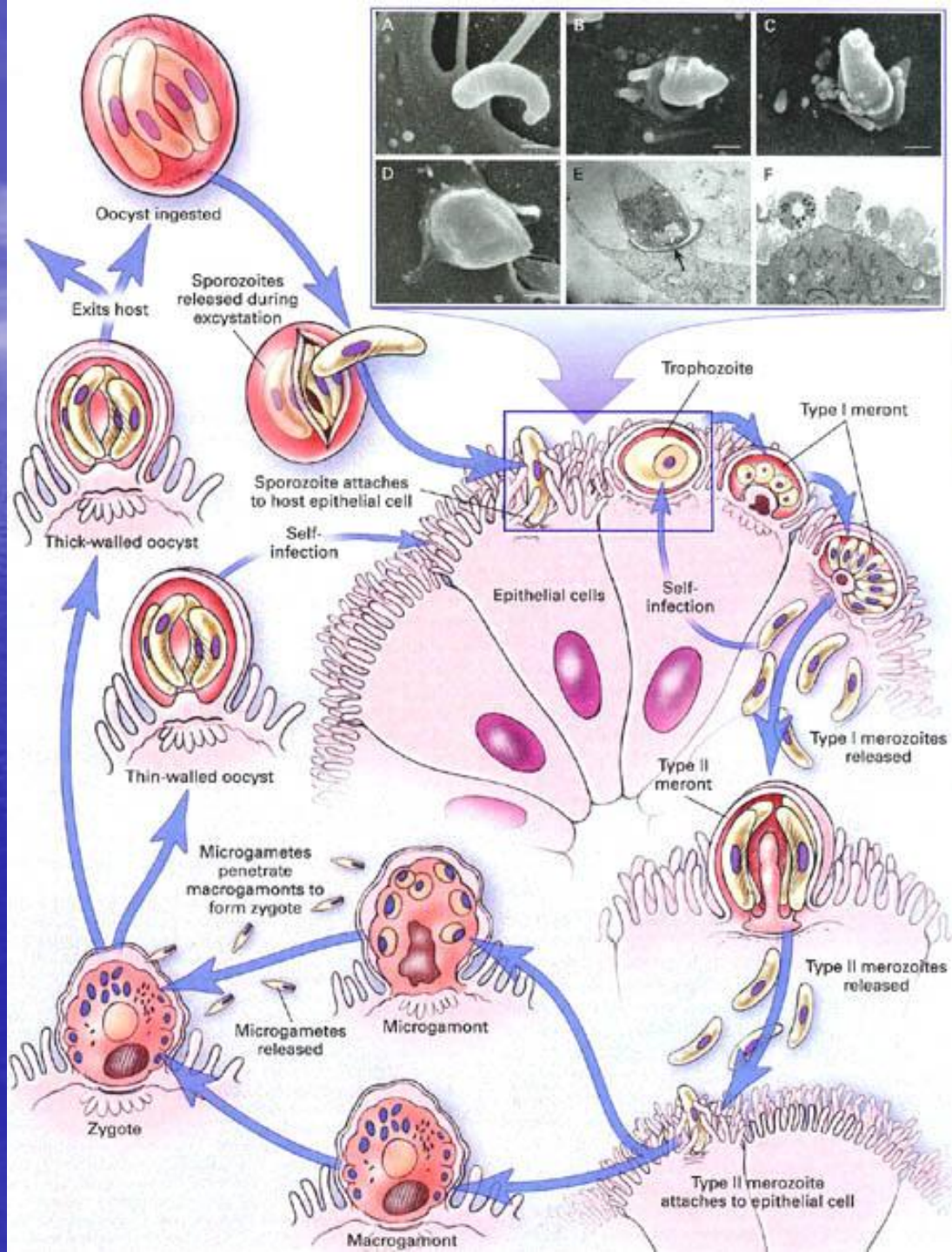
- LT2 Rules:
  - Cryptosporidium Results (RAA of oocysts/L)
  - Treatment process credit for removal of Crypto and Giardia
- Disinfection Byproduct Rule
  - Function of TOC, Alkalinity and pH


Giardia
Cyclospora
Cryptosporidium
4-6 microns x 12-15
8 - 10 micrometers
6-8 microns x 12-15 microns
Bacteria
Virus
Human hair – 75 microns

Life Cycle

- Cryptosporidiosis
  - Gastrointestinal illness
  - Generally self-limiting
  - Auto-infective cycle
  - Disease without treatment





Cryptosporidium - up close and personal

Cryptosporidiosis

- Characterized by severe watery diarrhea
- Pulmonary and tracheal infections
- Direct human surveys indicate a prevalence of about 2% of the population in North America.
- Serological surveys indicate that 80% of the population has had Cryptosporidiosis

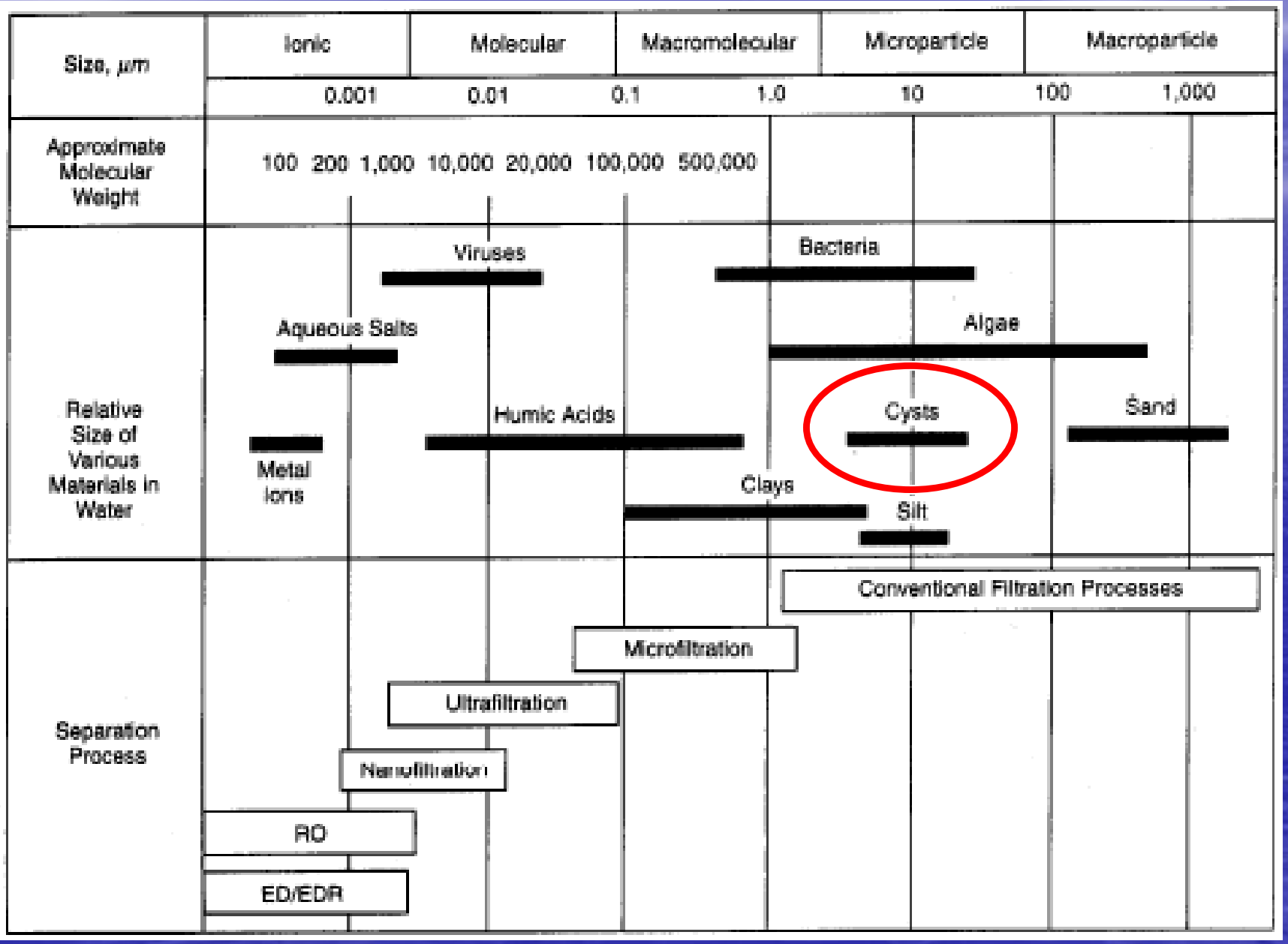
Giardiasis

- Most commonly diagnosed intestinal parasite in North America
- CDC estimates that as many as 2,500,000 cases occur annually in the US or almost one for every 100 persons
- Infestation rates of 60 percent of the children in day care centers across the country have been noted

Raw Water Quality Testing Program

- 48 months of Cryptosporidium and Giardia Testing: **0.074 oocysts/L Crypto**
- 24 months of standard testing of turbidity, alkalinity, TOC, pH, etc.
- Quarterly testing of TTHM and HAA9, TOX for 24 months
- Baseline testing for Metals, Inorganics, Radiological Compounds, VOCs, SOCs

Treatment Boundary Limits



Treatment Type Selection

- Treatment Types Evaluated:
  - Conventional (flocculation, sedimentation and filtration)
  - Direct Filtration
  - Microfiltration
  - Upflow Clarifier
- LT2: 3 log removal of Cryptosporidium required
  - Conventional, Slow Sand and Diatomaceous Earth filtration plants can achieve 3 log removal of Cryptosporidium (99.9%)
  - "direct filtration" = coagulation and filtration processes, but NO sedimentation process… can achieve only 2.5 log removal of Cryptosporidium per LT2
- 4 years of river testing: RAA of 0.074 oocysts/L allowed system to fall in **Bin 1** requirements if conventional treatment or "alternative filtration" such as microfiltration employed

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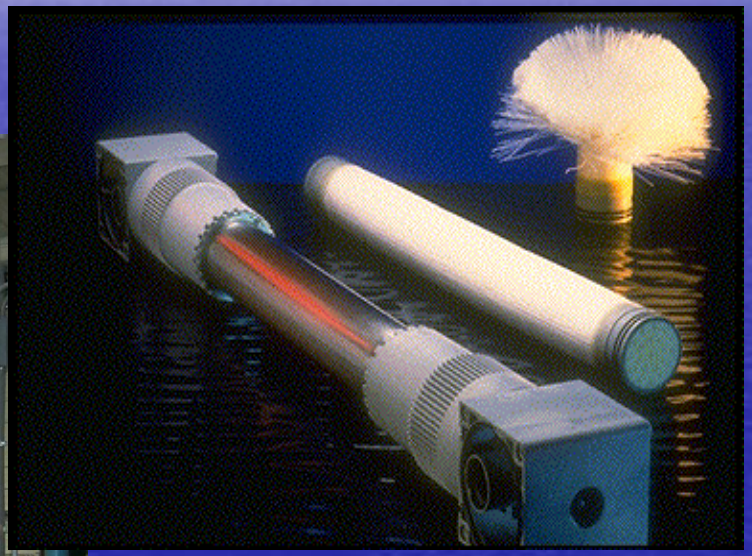
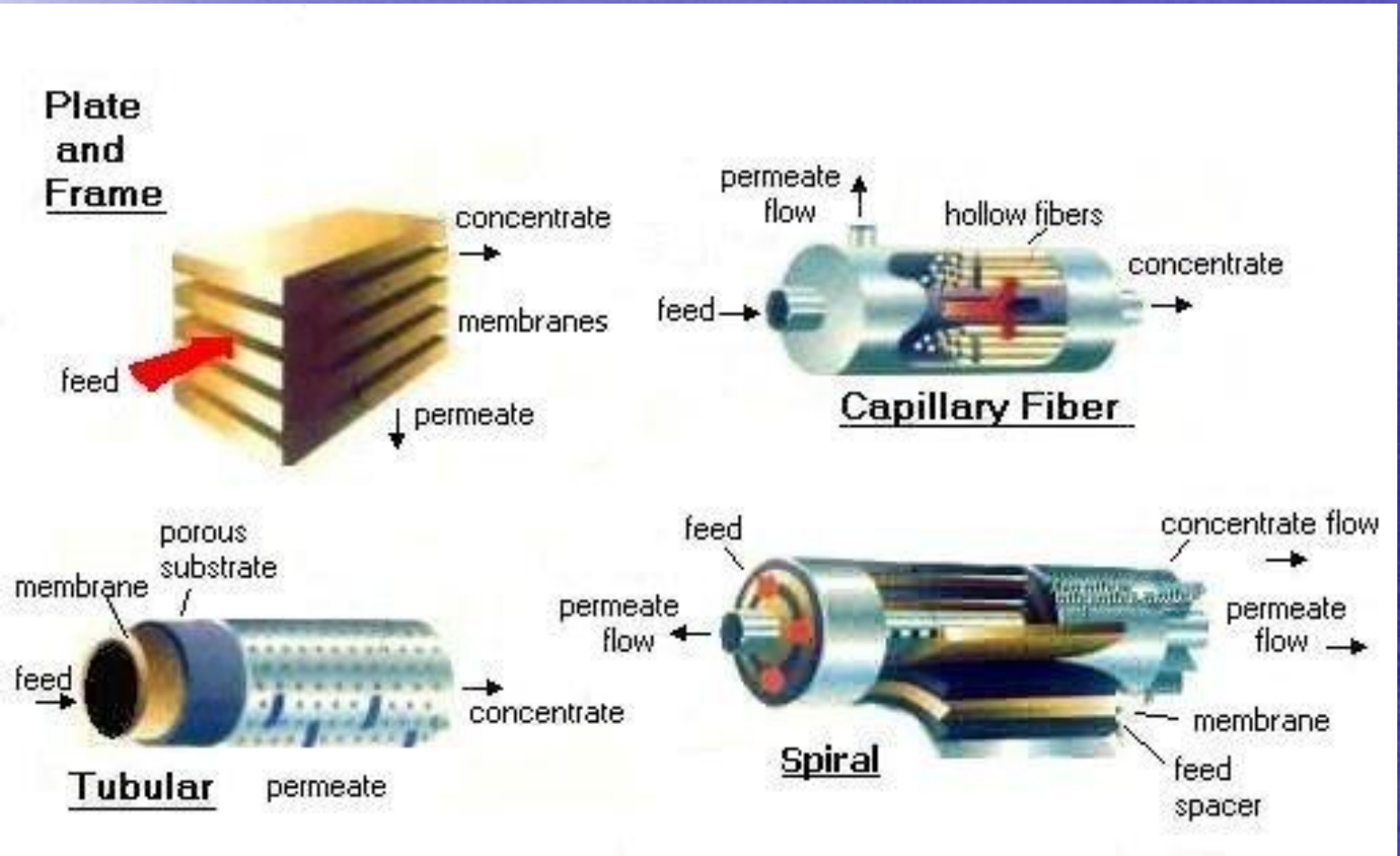
Consideration of Microfiltration Membrane Treatment



Microfiltration Membrane Treatment: How It Works



Advantages of Microfiltration Membrane Treatment

- Effective in removing Cryptosporidium, Giardia, some viruses and bacteria, and other particulate matter
- Continuous process resulting in automatic and uninterrupted operation
- Low energy utilization involving neither phase nor temperature changes
- Modular design – no significant size limitations
- Minimal moving parts with low maintenance requirements
- Discrete membrane barrier to ensure physical separation

Disadvantages of Microfiltration Membrane Treatment

- Pre-Treatment of source water is likely, especially with waters of higher turbidity
  - Condition the feed water to allow membrane treatment to be effective, by removing suspended solids and biological matter through coagulation/sedimentation
  - Modify the feed water to prevent membrane plugging, fouling and scaling (scale inhibitor, acid addition)
- Post-treatment may be necessary depending on the chemical characteristics of the source water and pre-treatment process

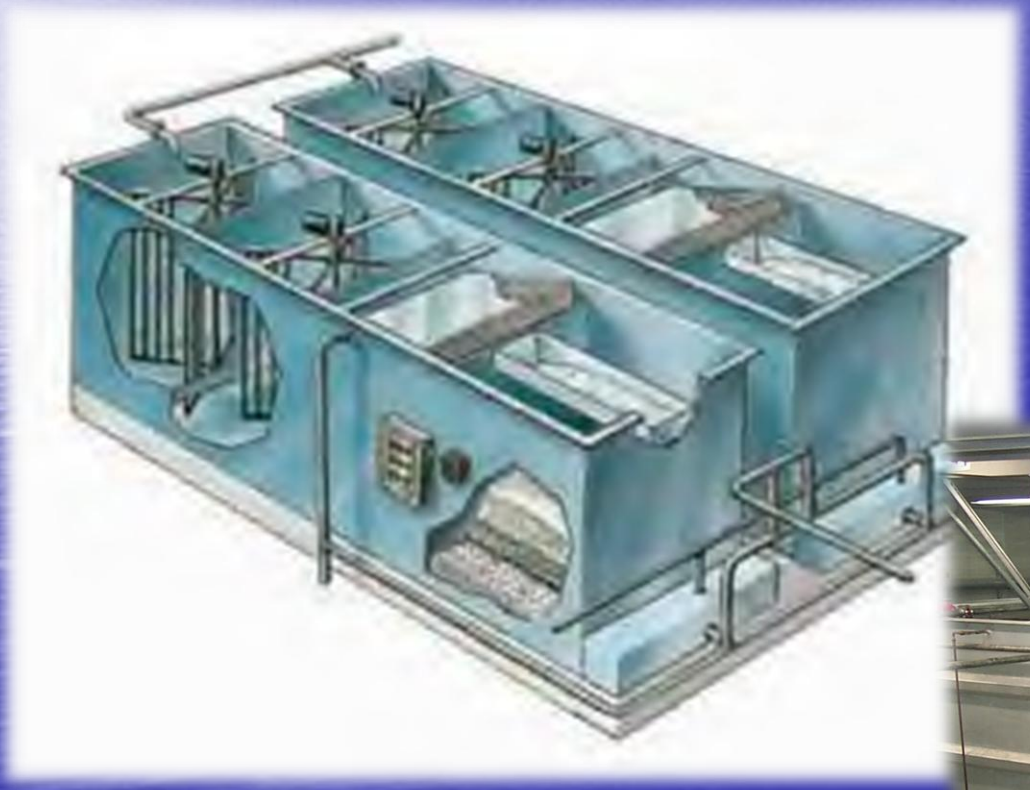
Fouling: Reversible and Irreversible

- **Reversible fouling: Membranes can be cleaned physically, biologically or chemically.**
  - **Physical cleaning includes sponges, water jets or backflushing using a permeate**
  - **Biological cleaning uses biocides to remove all viable microorganisms**
  - **Chemical cleaning involves the use of acids and bases to remove foulants and impurities**

- **Irreversible Fouling:**
  - **Irreversible fouling is the strong attachment of particles which cannot be removed by physical cleaning**
  - **Formation of a strong matrix of fouling layer with the solute during a continuous filtration process will result in reversible fouling being transformed into an irreversible fouling layer**

- **Key Consideration: When microfiltration fails through irreversible fouling, the failure is unforgiving and completely catastrophic across the system**

Consideration of Conventional Water Treatment



- Coagulation
- Flocculation
- Sedimentation
- Filtration

Mechanisms of coagulation

1) Adsorption and Charge neutralization
   - reduce the magnitude of the repulsive force by adding a substance of opposite charge to neutralize the surface charge
   - high turbidity waters –relatively low dosage of alum/ferric
2) Precipitation and Enmeshment (sweep floc)
   - Various salts (alum, ferric chloride, magnesium hydroxide) added to a suspension in high enough concentrations to form precipitates into which colloidal particles become enmeshed as the precipitates settle
   - low turbidity water –relatively high alum or ferric dose
3) Adsorption and Interparticle Bridging
   - organic molecules (polymers) with a large molecular size with multiple electrical charges along the polymer
   - adsorb to multiple particles in suspension, thereby forming a bridge between the particles causing a larger collection of particles to form

Inorganic Coagulants

- Aluminum
  - aluminum sulfate (alum) $Al_2(SO_4)_3\ 14.3H_2O$
  - sodium aluminate $NaAlO_2$

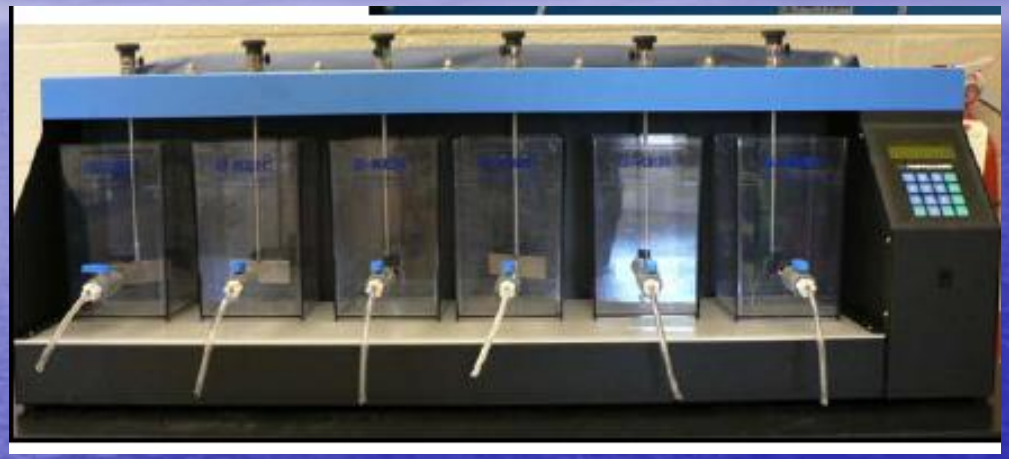
- Iron
  - ferric chloride $FeCl_3$
  - ferrous sulfate $FeSO_4\ 7H_2O$
  - ferric sulfate $Fe_2(SO_4)_3$

- Pre-hydrolysed metal salts
  - polyaluminum chloride (PACl)
  - aluminum chlorohydrate (ACH)
  - pH/Dosage critical (consume alkalinity)

Polymers

- dry or liquid
- non-ionic (no charge)
- cationic (positive charge - use for negatively charged particles)
- anionic (negative charge - use for positively charged particles)
- wide range of sizes (molecular weights)

Jar Test to adjust to water quality changes



Typical 6-paddle jar tester (Hach)

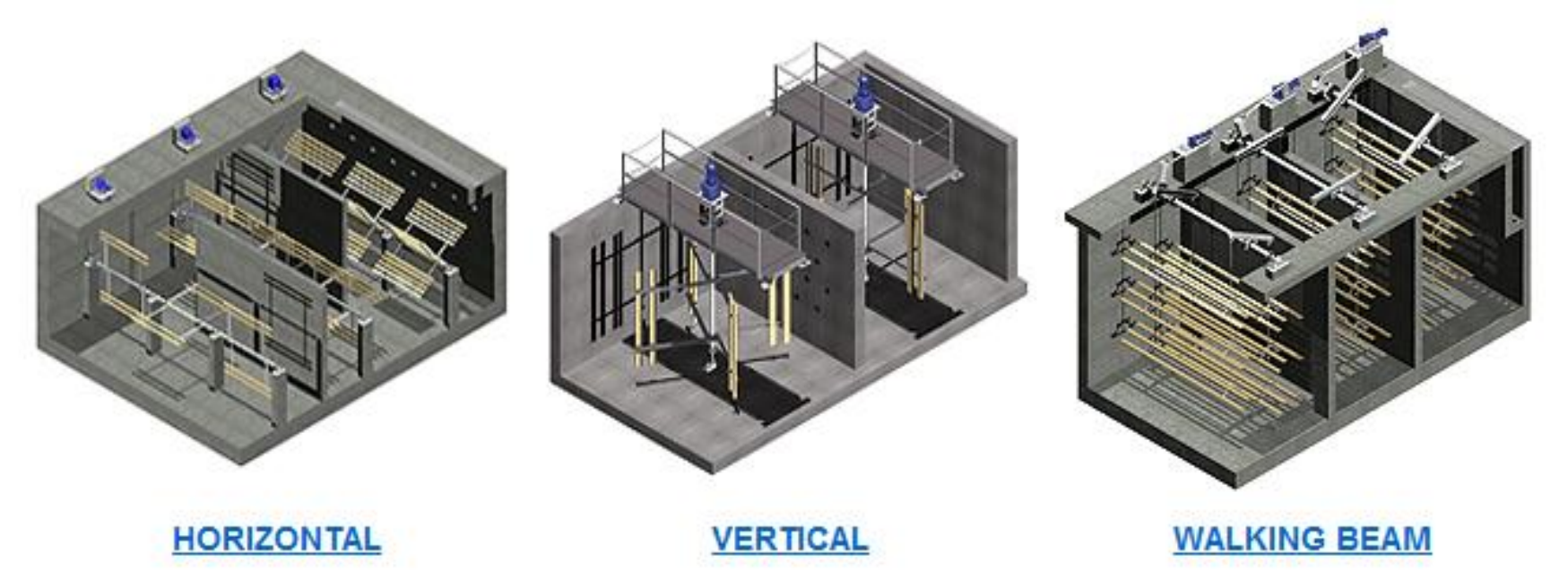
- optimize dosage of select chemical
- range of dosages tested
- rapid mix, flocculation and settling simulated
- conditions similar to treatment facility
- settled supernatant is sampled and analyzed for parameter of interest
- dosage exhibiting minimum turbidity is selected

Flocculation Process

flocculation is slow mixing process to encourage collision of particles and the gel to form a larger mass that will be settled or filtered from solutions.

Flocculation Process (continued)

Three typical types of flocculation apparatus:



Flocculation Process (continued)

- Mean Velocity Gradient: G=15-75/sec
- Detention time of 20-40 minutes
- Plug flow
- Water depth of 10 – 15 ft
- Stages: commonly 1, 2, or 3 stages
- Temperature can have effect on floc formation
- Changes viscosity of water - slower transport

Sedimentation Process

- *Tube Settlers*
  - inclined tubes (60 degrees to horizontal)
  - 0.4-0.8 gpm/ft^2 of tube surface area
  - 1,500-4,500 gpd/ft^2 loading rate
  - 10 ft depth below the tubes to allow sludge settling
  - 2-3 ft depth above tubes to the effluent

- *Plate Settlers*
  - 0.3-0.7 gpm/ft^2 of plate area
  - basin loadings of 3000-8000 gpd/ft^2

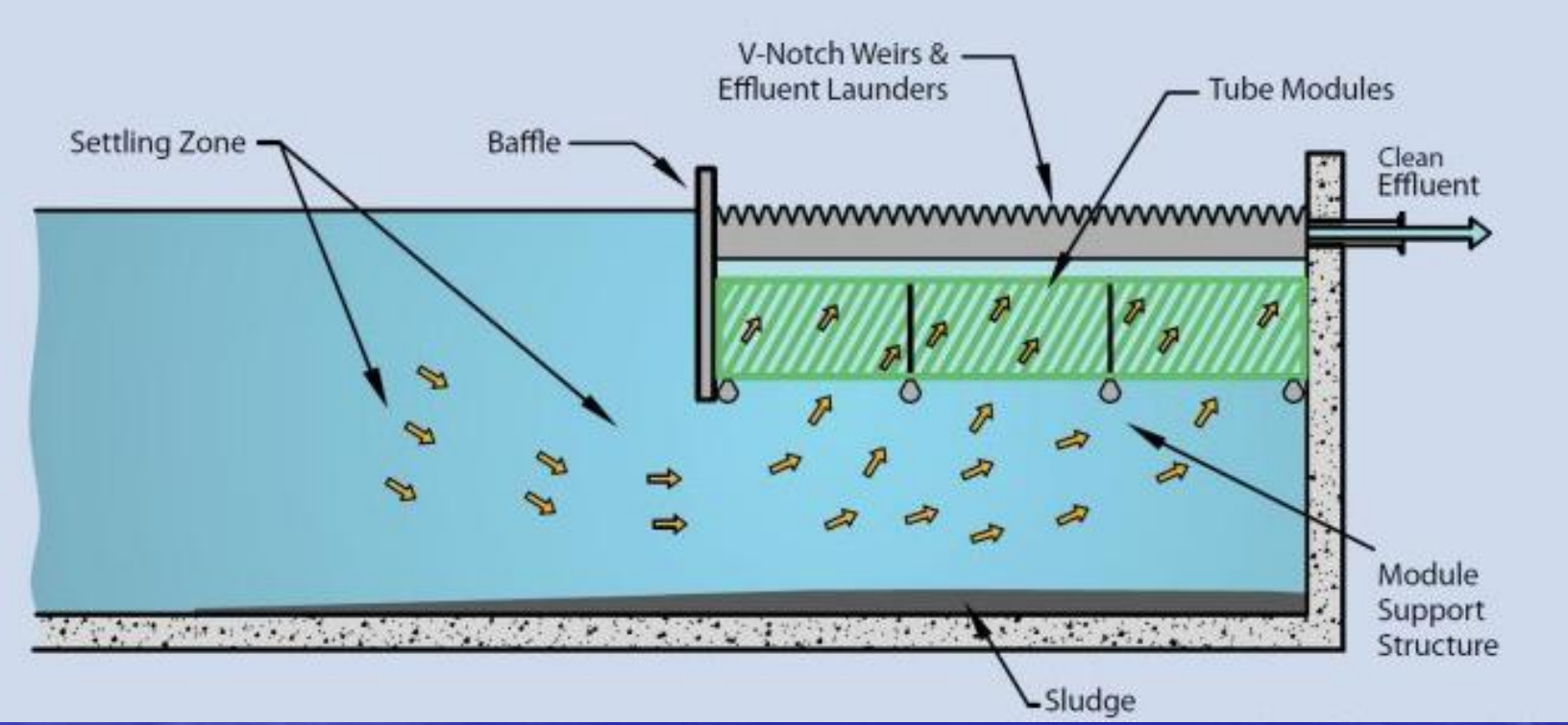
Sedimentation Process
(continued)

Tube settlers

Plate settlers

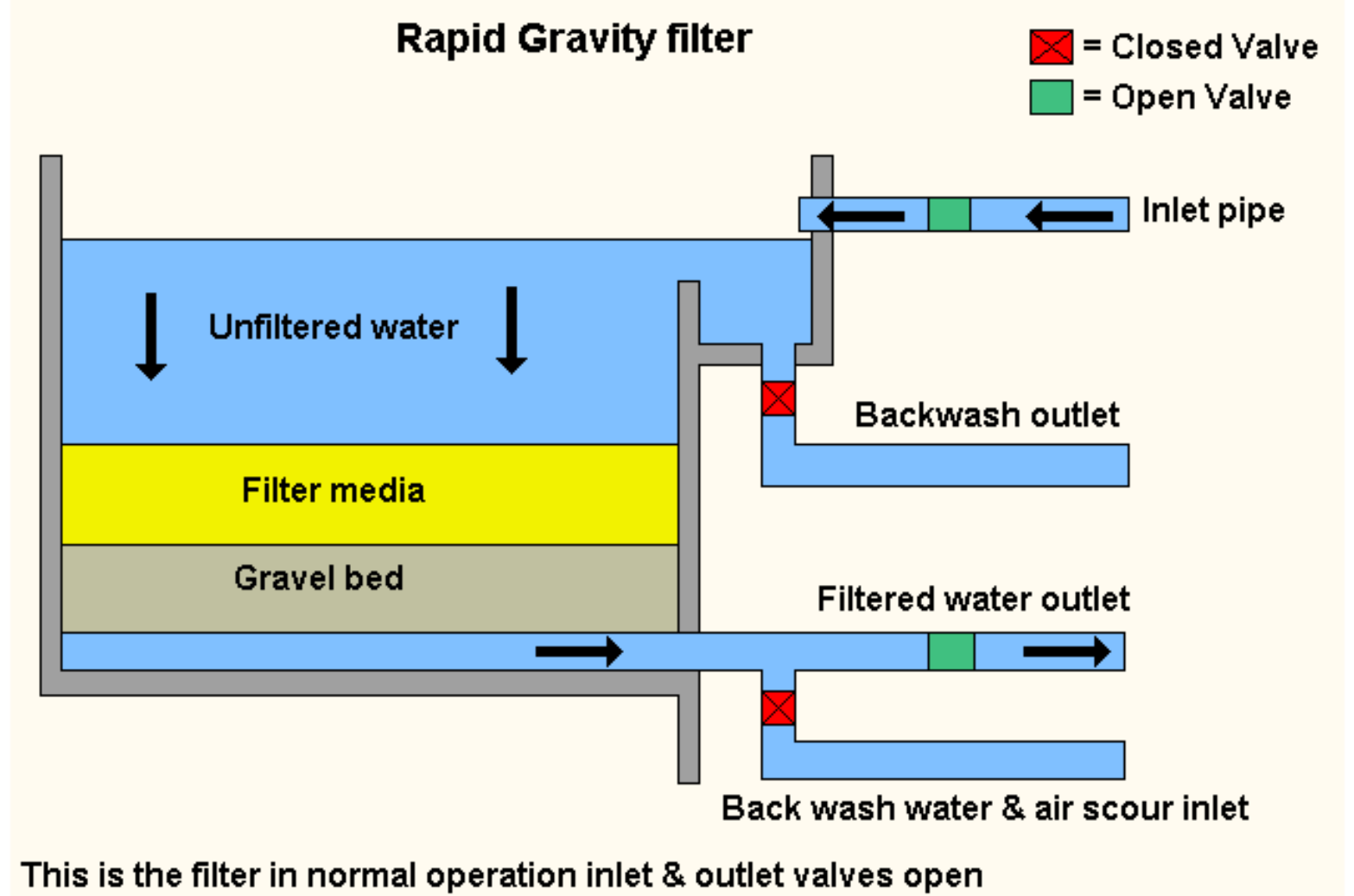
Sedimentation Process (continued)

Tube settler mechanism



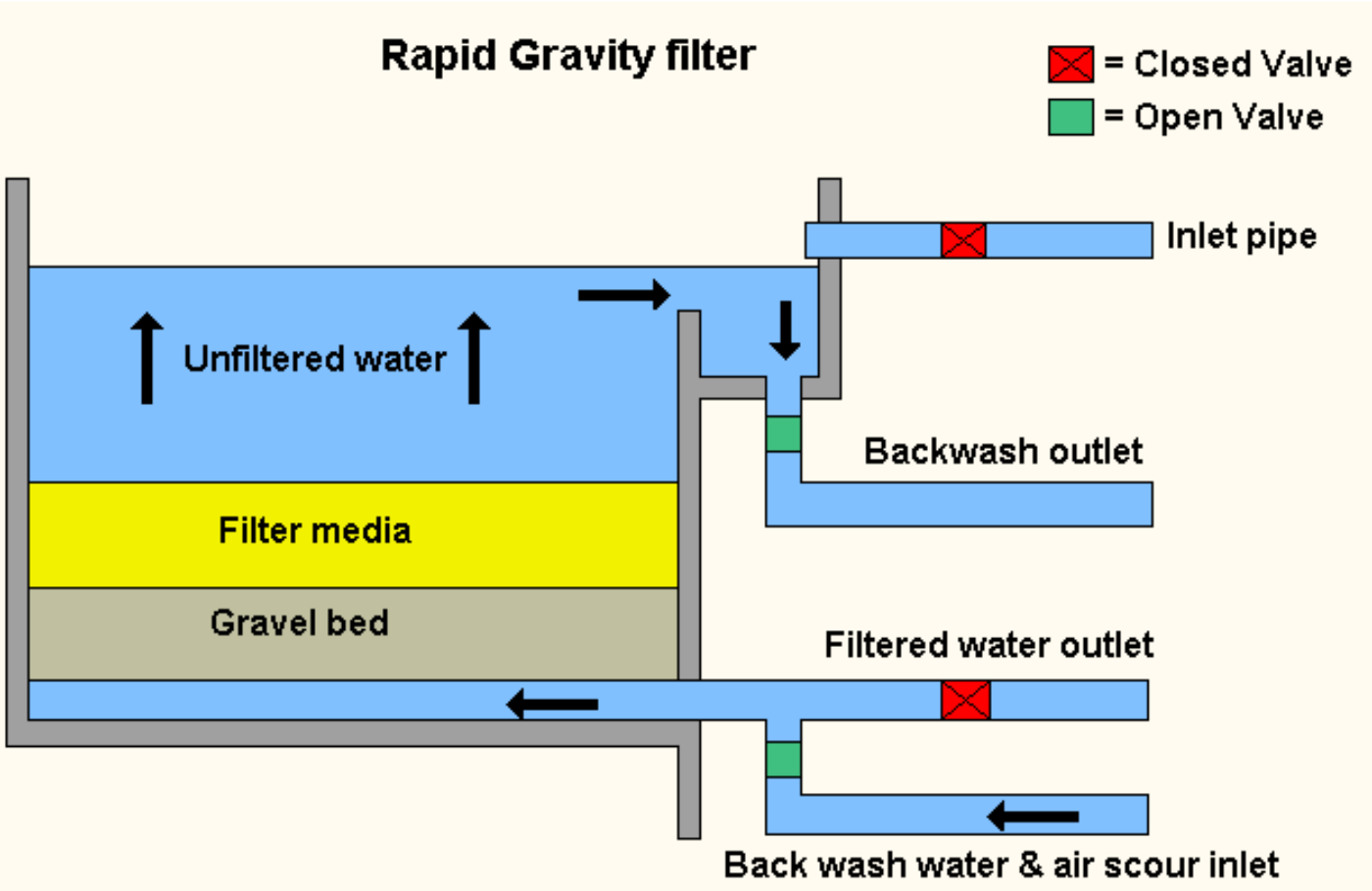
Multi-Media Gravity Filtration

Normal Filtration Process



Multi-Media Gravity Filtration

Backwash Process



This is the valve positions when a wash is taking place

Treatment Type Selection: O&M considerations

- With varying river turbidity, flocculation and sedimentation process would be common to both conventional treatment and microfiltration
- Jar tests are relatively simple to conduct
- Flexibility with treatment trains – one can be taken out of service
- Failure with conventional treatment is manageable with conventional treatment; failure of irreversible fouling of membrane is catastrophic and replacement cost is prohibitive
- Convention Treatment lends flexibility with treatment trains – one can be taken out of service
- Conventional treatment is a proven technology – 100+ years. Microfiltration is relatively newer (< 40 years) and
- Local knowledge and experience base with nearby conventional systems including Jicorilla Apache

Treatment Type Selection: Human Factors

- High turnover rate of operators; no guarantee of longevity; low skill level
- Operator diligence to system requirements may not be consistent
- No guarantee of capital replacement should membranes irreversibly fail
- Local circuit rider assistance can assist with lower tech systems, but not necessarily with more complex systems

Decision: Conventional Treatment

- Adaptable to varying turbidities and water quality
- Higher initial capital cost (larger building, less compact equipment) but more sustainable, flexible alternative
- Enhanced Coagulation to handle TOC if necessary
- LT2: conventional treatment with coagulation, flocculation and sedimentation process provides a second pathogen barrier = 3.0 log removal for Cryptosporidium

TOC Considerations

Results of Raw Water Quality Testing

- Average TOC: 2.6 mg/L
- Average ALK: 102 mg/L
- Average pH: 7.88

Disinfection Byproduct Rule

TABLE 2-1

Required Removal of TOC by Enhanced Coagulation For Plants Using Conventional Treatment: Step 1 Removal Percentages[a, b]

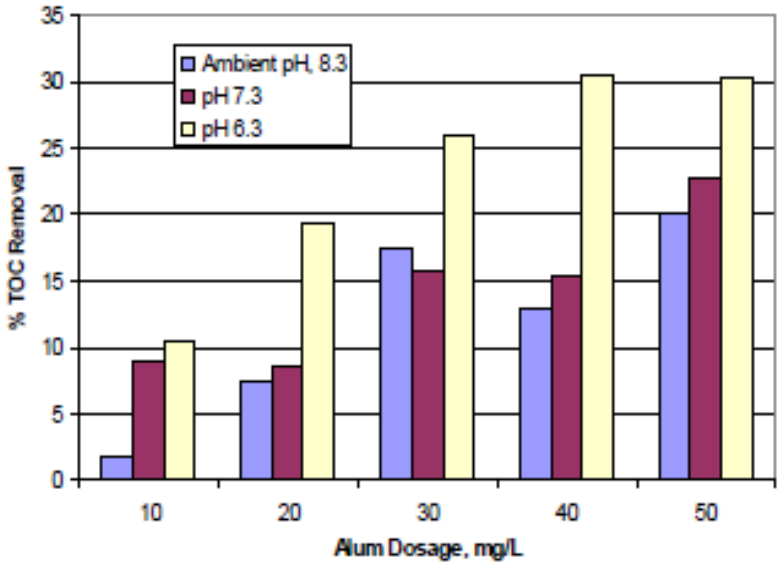
SOURCE WATER TOC (mg/L)	SOURCE WATER ALKALINITY (mg/L as $CaCO_3$)		
	0 to 60	>60 to 120	>120[c]
>2.0 - 4.0	35.0%	25.0%	15.0%
>4.0 - 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Notes:

Enhanced Coagulation can achieve 25% reduction in TOC

Organics (TOC Removal)

- Removed by adsorption, co-precipitation into the coagulant
- Frequently need higher dosages than those required for turbidity removal
- pH sensitive



Cryptosporidium Considerations

- With results of raw water testing: 0.074 oocysts/L, the system falls within Bin 1 of the LT2 microbial toolbox
- A 3 log removal (99.9%) will be achieved without need for additional barriers

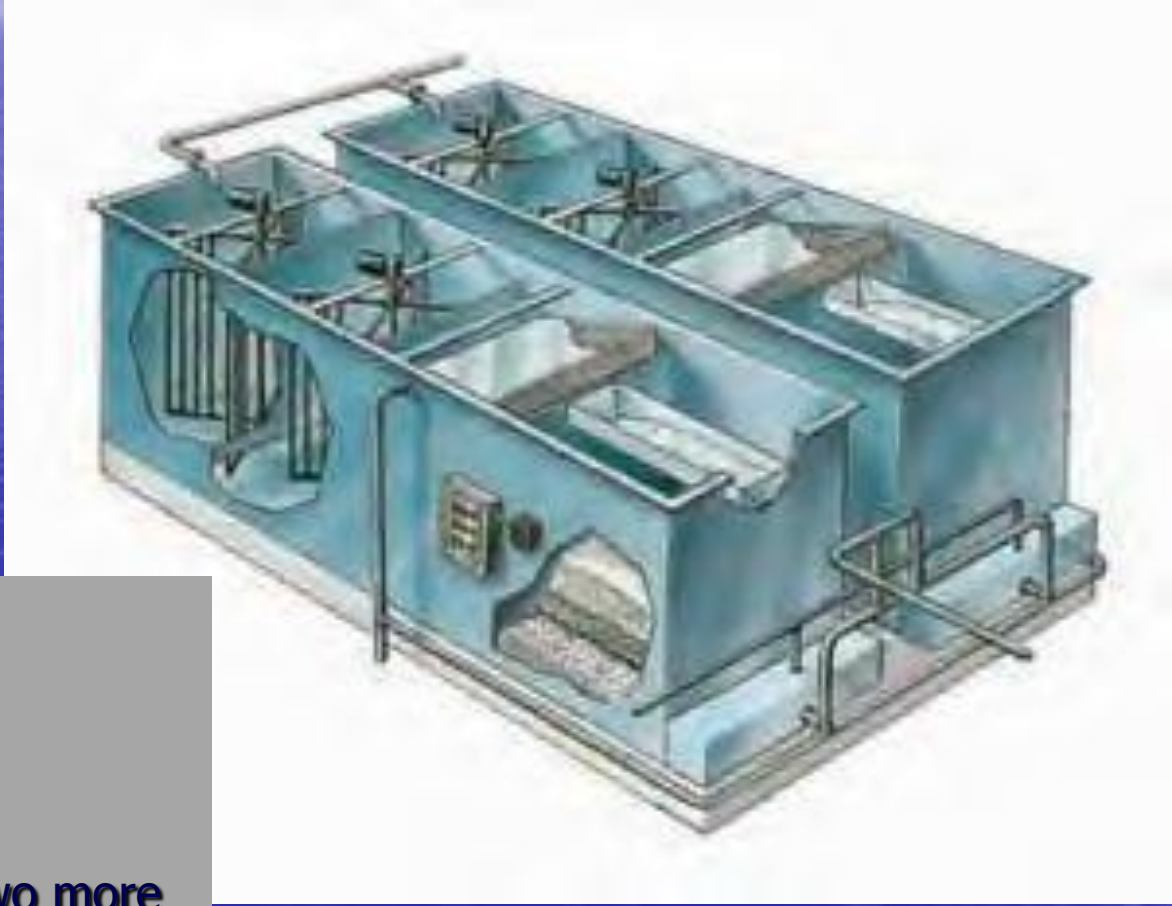
Filtered System Bin Classification and Treatment

Bin Number	*Cryptosporidium* Concentration (in oocysts/L)	Additional Treatment Beyond Current Requirements
1	*Crypto* < 0.075	No additional treatment
2	0.075 ≤ *Crypto* < 1.0	1.0 log (90%)
3	1.0 ≤ *Crypto* < 3.0	2.0 log (99%)
4	3.0 ≤ *Crypto*	2.5 log (99.7%)

What if Crypto monitoring results in future fall outside of Bin 1?

- Ultraviolet treatment can be installed
  - Effective for crypto control
  - Spacer designed into plant plumbing for easy installation, electrical conduit incorporated into design should UV be necessary

Conventional Treatment Components

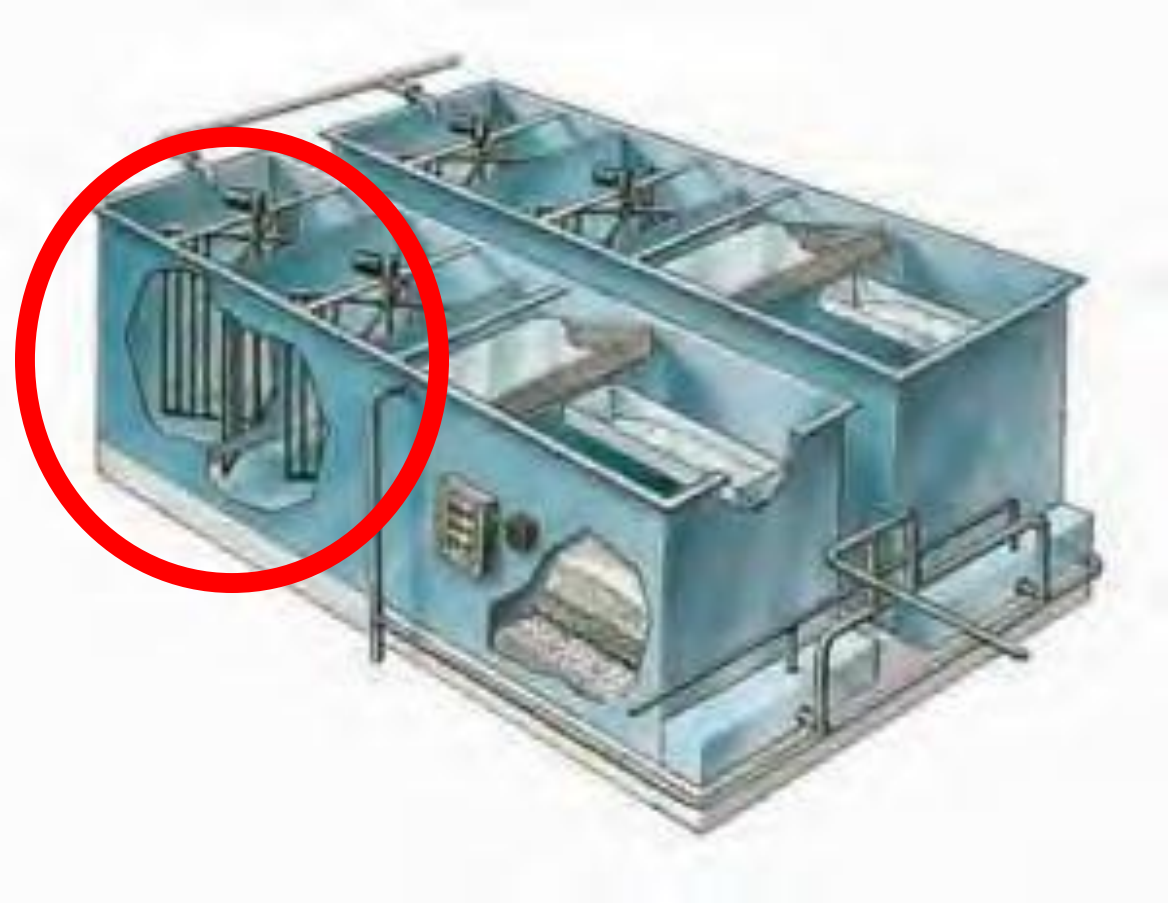


Treatment Trains
Manufacturer: Tonka
Capacity: 1MGD each
Two installed
Building has space for two more

Conventional Treatment Components (continued)

Flocculation Chamber
(slow-moving paddles)

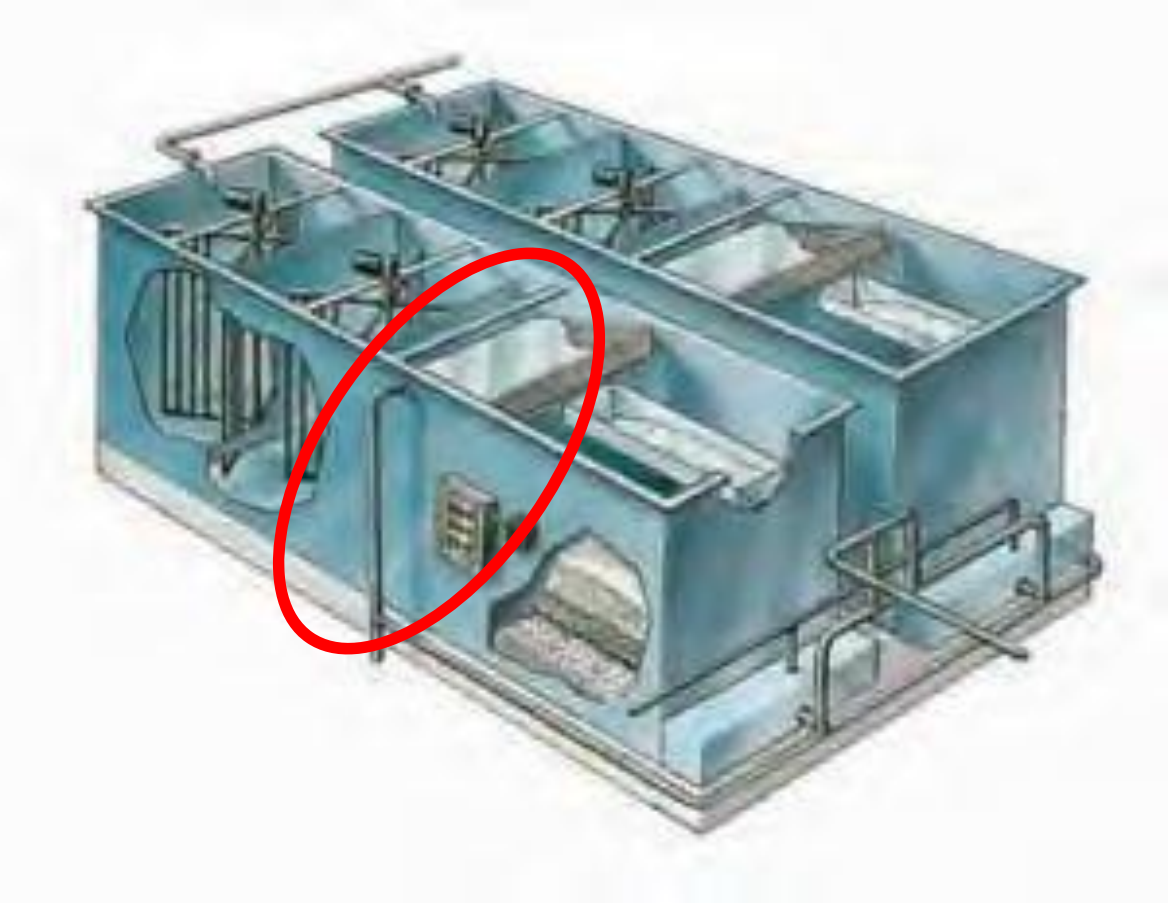
Chemicals
- Alum
- Anionic Polymer
- Ferric Chloride
- PACl/ACH



Conventional Treatment Components (continued)

Settling Chamber (tube settlers used)

Underdrain for sludge transport Automatic with manual override

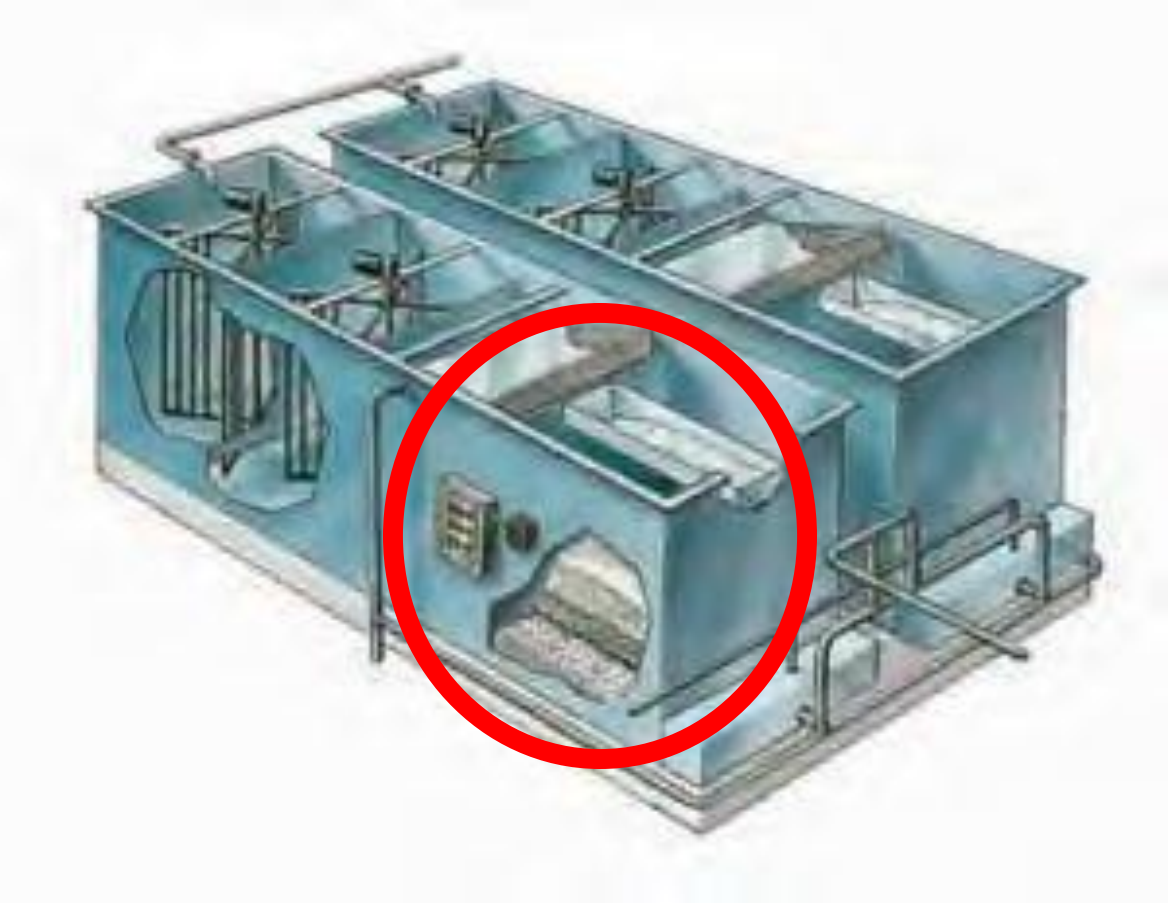


Conventional Treatment Components (continued)

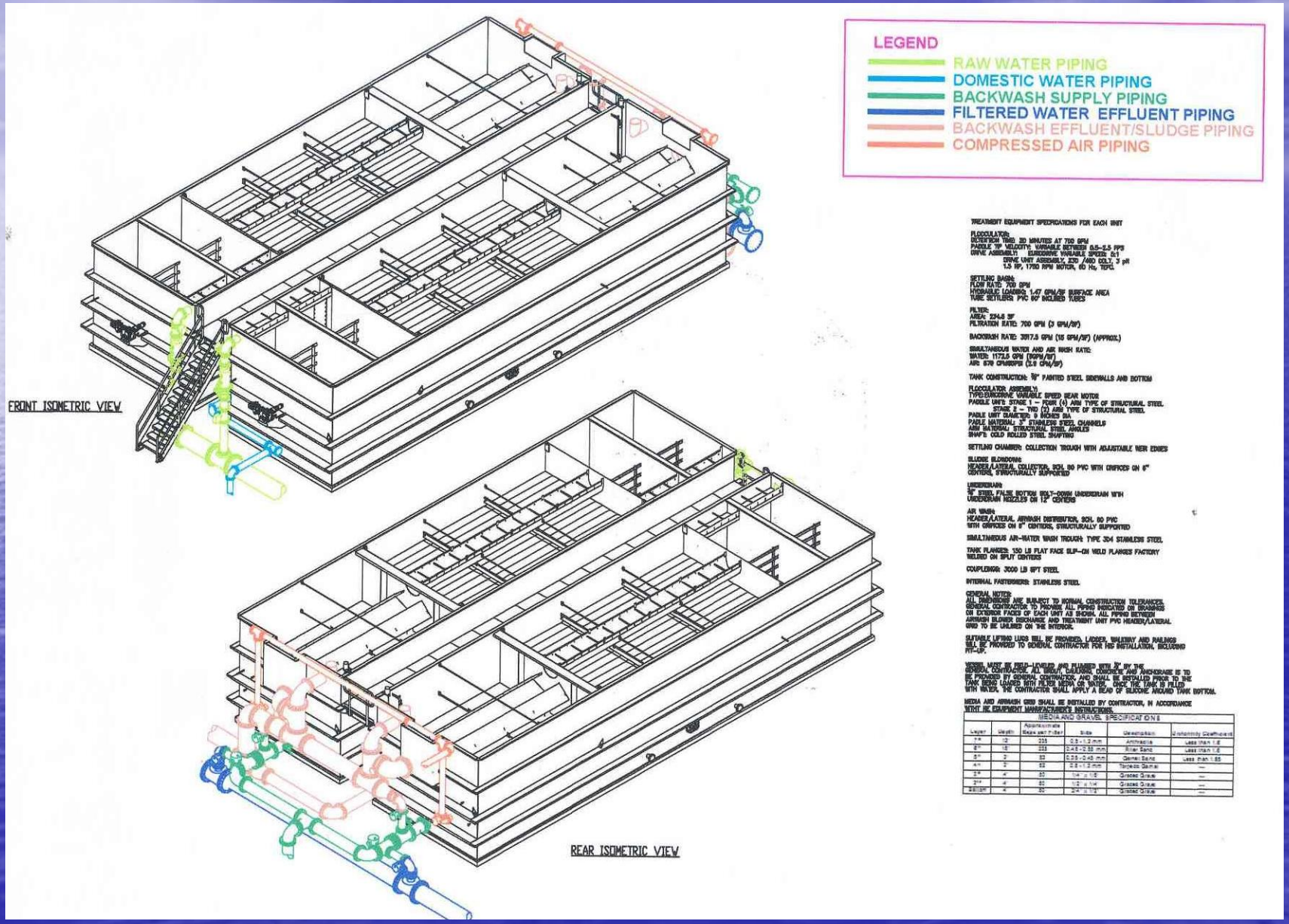
Gravity Filter
- Anthracite
- Garnet Sand
- Silica Sand
- Gravel

Simultaneous air and water wash

Unique trough design (<1 inch media loss per year guarantee)



Treatment Train Schematic



Tonka - UTS Unit

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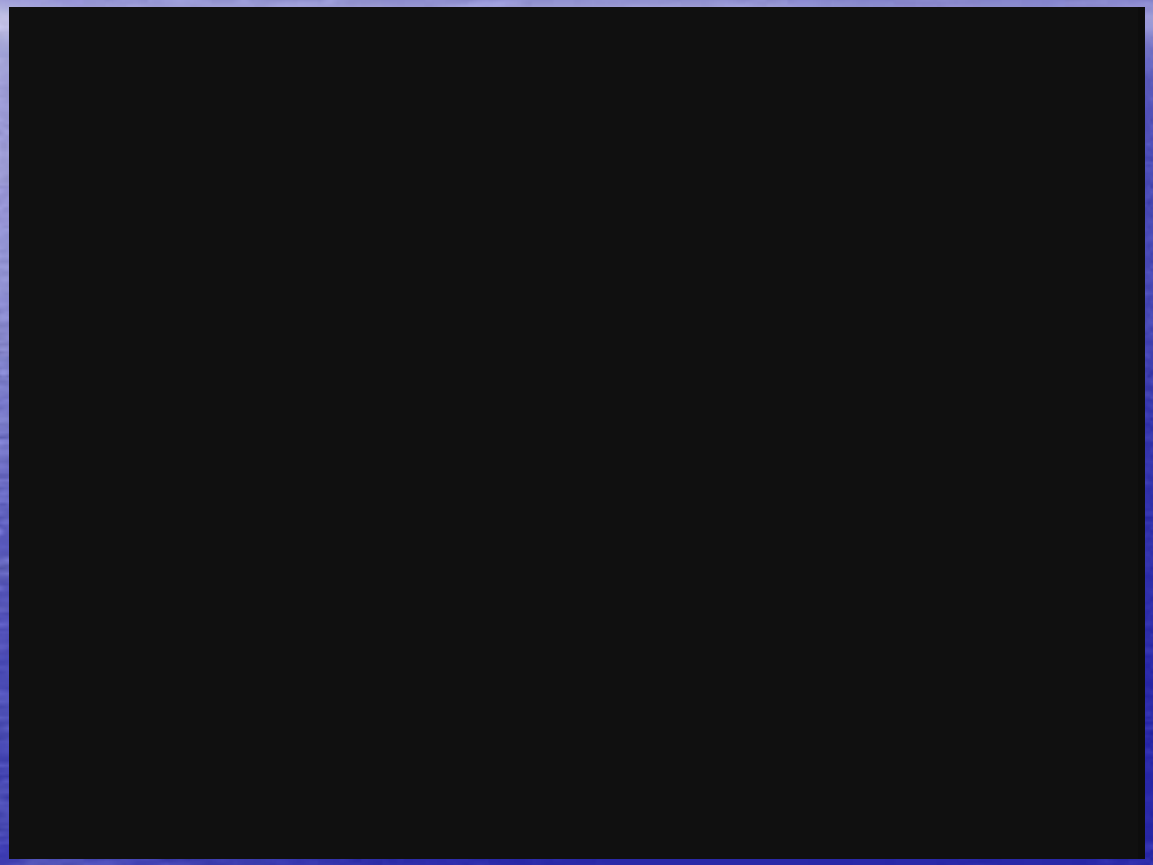
Tonka Gravity Filtration Unit

Backwash Process

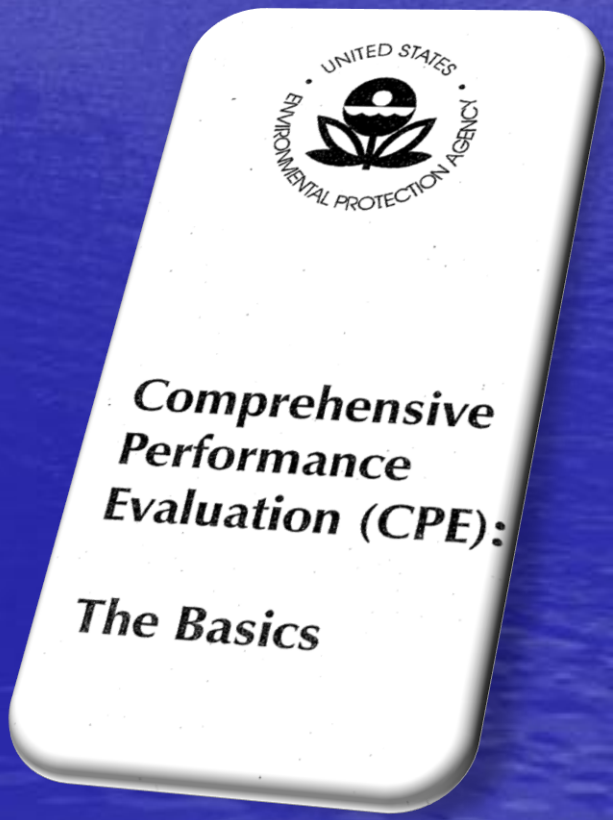


Diversion Construction

Treatment Building Construction

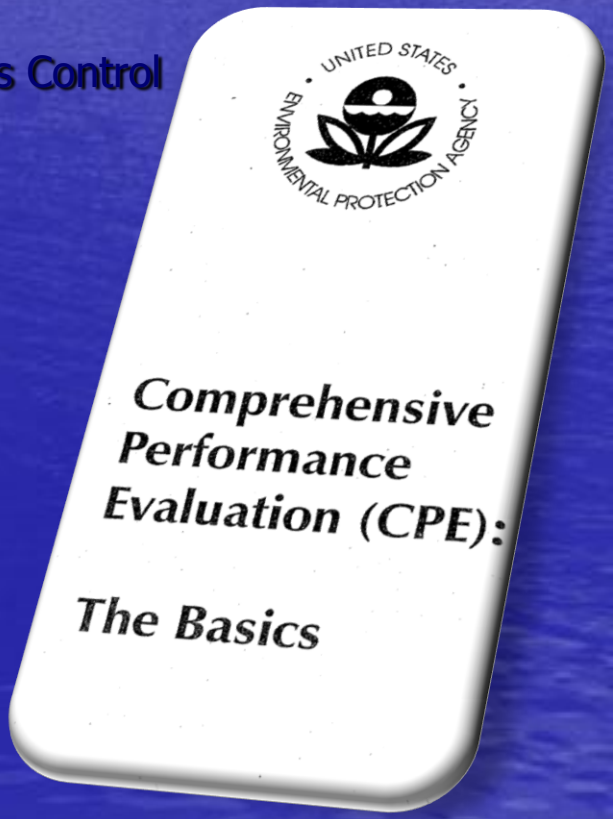
Post-Construction Operation and Maintenance Comprehensive Performance Evaluation

- Completed on treatment plant October 9-11, 2012
- Assessment of plant performance
- Evaluation of major unit processes
- Identification and prioritization of Performance-limiting factors
- Follow-up activities necessary
- Preparation of a CPE report



Comprehensive Performance Evaluation (Results)

- Nine (9) factors identified that have significant impact on plant performance including:
  - Operations: Training
  - Operations: Application of Concepts and Testing to Process Control
  - Operations: Process Control Testing
  - Administration: Financial, Staff, Compensation
  - Operation: Guidelines and Policies
  - Design: Instrumentation and Automation
  - Administration: Policies



Comprehensive Performance Evaluation (Results)

Ranking	Class (A, B or C)	Performance Limiting Factor
6	B	Administration: Compensation • Operation of a granular media, coagulation/flocculation/sedimentation/filtration/disinfection surface water treatment plant demands a level of expertise and skill that is unlikely to be obtained for "laborer" wages.
7	B	Operations: Guidelines and Procedures • Lack of written standard operating procedures specific to the WTP. 1. How to respond to changes in raw water quality. 2. Step-by-step procedures for chemical adjustments and verification of the accuracy of such adjustments.
8	C	Design: Instrumentation/Automation • A streaming current monitor (SCM) is not available to make chemical feed adjustments when the raw water quality changes and the WTP is not staffed.
8	C	Administration: Policies • Management has not adopted formally adopted the EPA's optimization goals. In spite of this, the management and operators continually produce water of significantly higher quality than required by federal regulations. One of the first steps, perhaps the first step, in achieving optimization is to adopt optimization as a goal.

PROJECTED IMPACT OF COMPREHENSIVE TECHNICAL ASSISTANCE

The last step of the CPE process is to assess the potential for improved performance through

Comprehensive Performance Evaluation (results, continued)

Effluent Turbidity Levels

<u>2011</u>
95% of CFE values: .23 NTUs
Maximum level CFE: .26 NTUs

<u>2012</u>
95% of CFE values: .23NTUs
Maximum level CFE: .27 NTUs

EPA United States Environmental Protection Agency

Interim Enhanced Surface Water Treatment Rule: A Quick Reference Guide

Overview of the Rule	
Title*	Interim Enhanced Surface Water Treatment Rule (IESWTR) 63 FR 69478 - 69521, December 16, 1998, Vol. 63, No. 241 Revisions to the Interim Enhanced Surface Water Treatment Rule (IESWTR), the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR), and Revisions to State Primacy Requirements to Implement the Safe Drinking Water Act (SDWA) Amendments 66 FR 3770, January 16, 2001, Vol 66, No. 29
Purpose	Improve public health control of microbial contaminants, particularly *Cryptosporidium*. Prevent significant increases in microbial risk that might otherwise occur when systems implement the Stage 1 Disinfectants and Disinfection Byproducts Rule.
General Description	Builds upon treatment technique approach and requirements of the 1989 Surface Water Treatment Rule. Relies on existing technologies currently in use at water treatment plants.
Utilities Covered	Sanitary survey requirements apply to all public water systems using surface water or ground water under the direct influence of surface water, regardless of size. All remaining requirements apply to public water systems that use surface water or ground water under the direct influence of surface water and serve 10,000 or more people.

*This document provides a summary of federal drinking water requirements; to ensure full compliance, please consult the federal regulations at 40 CFR 141 and any approved state requirements.

Major Provisions	
Regulated Contaminants	
Cryptosporidium	▶ Maximum contaminant level goal (MCLG) of zero. ▶ 99 percent (2-log) physical removal for systems that filter. ▶ Include in watershed control program for unfiltered systems.

Turbidity Performance Standards	Conventional and direct filtration combined filter effluent:
	▶ ≤ 0.3 nephelometric turbidity units (NTU) in at least 95 percent measurements taken each month.
	▶ Maximum level of 1 NTU.

Comprehensive Performance Evaluation (overall results/recommendations)

- Plant process is in full compliance with SDWA
- TOC: 25% removal achieved without need for enhanced coagulation
- Chemical recipe: needs adjustment for improved floc formation
- Sedimentation: detention time not optimal to minimize turbidity when supernatant reaches filter
- Filter Performance:
  - ✓ no mud balls
  - *x* Anthracite loss: lost 8 inches in less than 2 years

- Optimization goals:
  - ❑ increase Filter performance to achieve 0.1 NTUs in 95% of samples and maximum of .3 NTUs (cost effective?)
  - ❑ Adjustments to backwash sequence recommended to reduce media loss
  - ❑ Add SCD to make chemical adjustments in lieu of jar testing especially for when operator not present (appropriate?)

Team Players

IHS Phoenix Area/Eastern District Engineers

Project Engineer
Rick Rivers

Tribal Council with EPA and IHS Engineers

Thank You!

Questions?

CAPT Michael A. Stover, PE
Indian Program Manager
EPA New England – Region 1
Boston, MA
stover.michael@epa.gov
(617) 918-1123