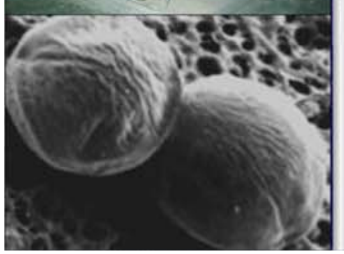
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Optimizing Conventional Water Treatment Plants

Presentation to the AWWOA Annual Seminar
Banff, Alberta, March 15th, 2006

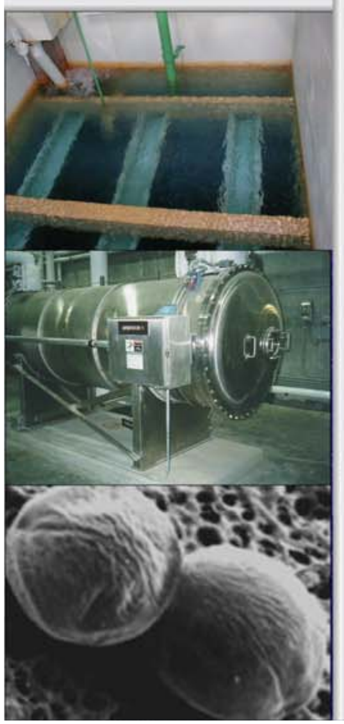
Simon Breese, Technical Practice Leader, Drinking Water
Earth Tech, Inc.

EarthTech
A Tyco International Ltd. Company

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

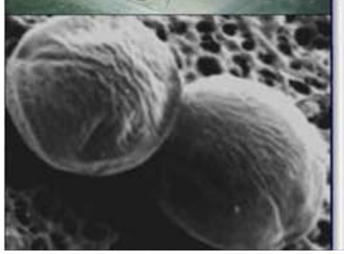


# Workshop Outline

- Approaches to Plant Optimization
- What defines “good” design/performance ?
- Common Causes of Sub-Par Performance
- Evaluation & Optimization of:
  - Coagulation & Flocculation
  - Clarification (Sedimentation or DAF)
  - Granular Media Filtration
- Discussion & Question Period

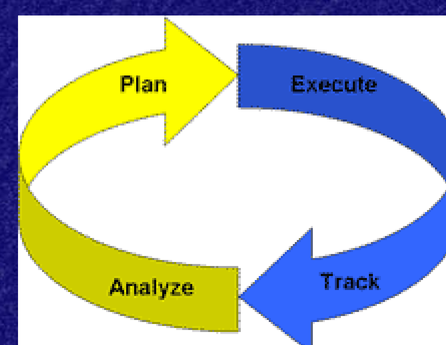
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# What is “Optimization” ?

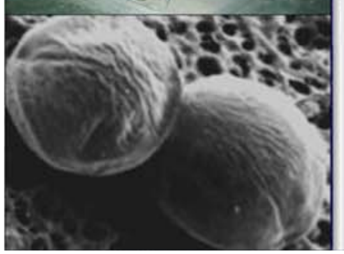
- “To attain the most efficient or effective use of” your water treatment plant
- Achievement of consistently high quality finished water on a continuous basis
- Important not to focus too much on individual processes
- Focus on OVERALL plant performance



EarthTech
A Tyco International Ltd. Company

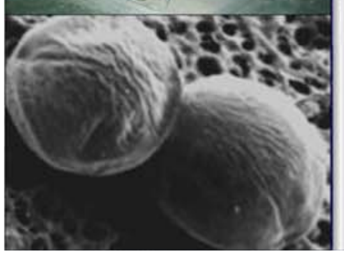
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Approaches to Plant Optimization

- Mostly common sense…not a "black art"
- Be organized, get the facts first !!
- Systematic gathering of information about plant performance:
  - Data trending & analysis
  - Check plant design criteria against "actual"
  - Track chemical dosing vs performance
  - Field measurements
  - **Visual Observations**



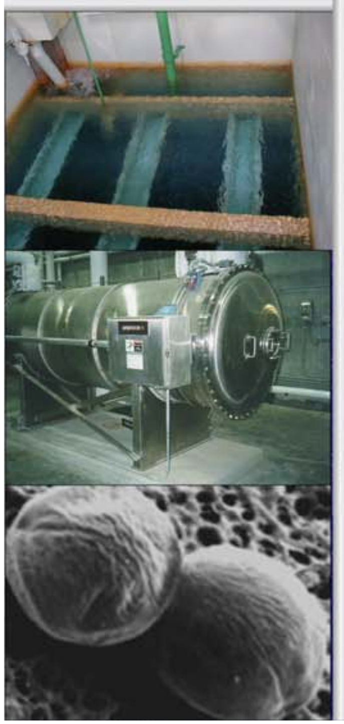
# Data Trending and Analysis

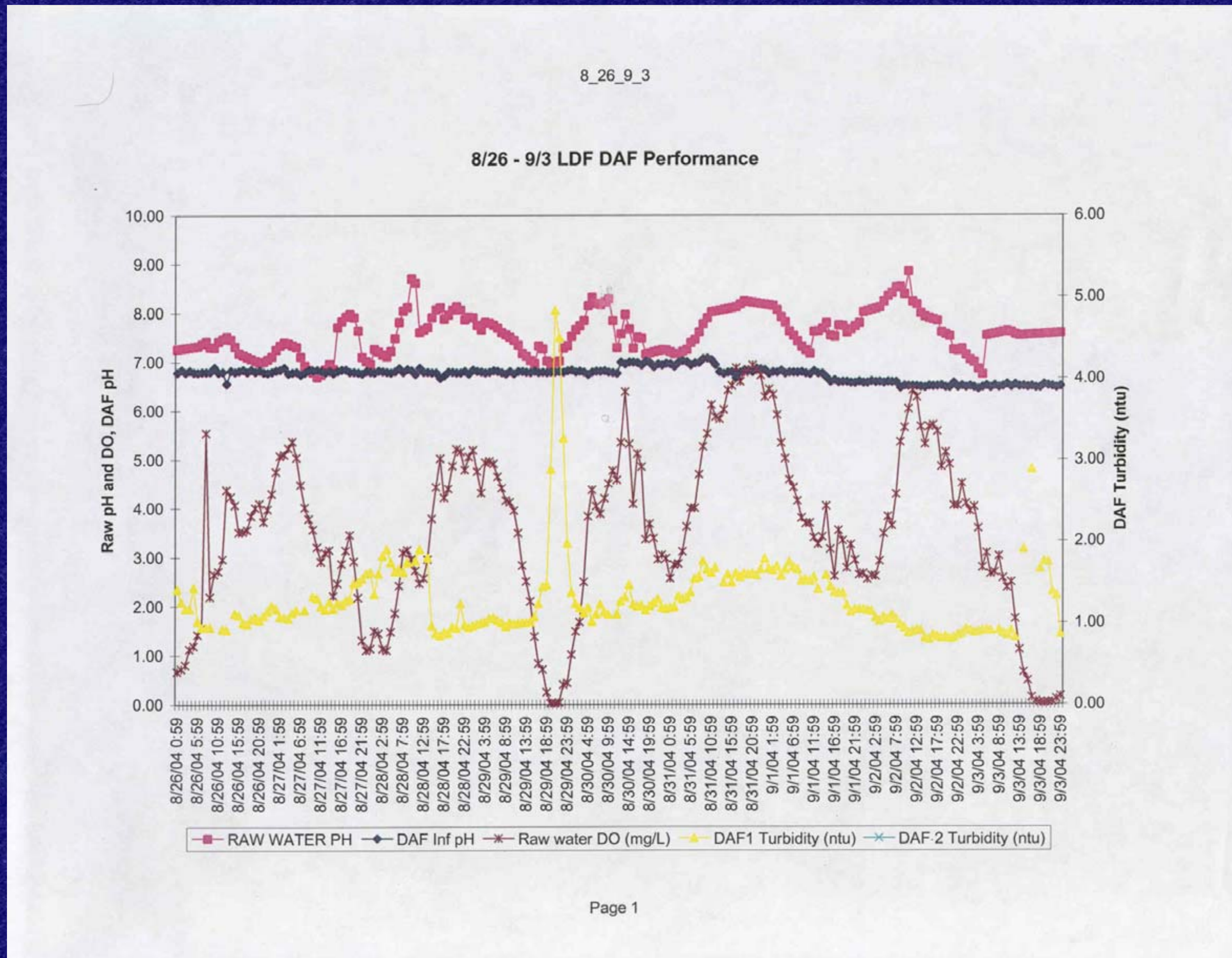
- The “GIGO” (Garbage In-Garbage Out) Principle Applies !!!
- Collect and collate plant data in a form which facilitates analysis….i.e. spreadsheet
- Correlate plant operating parameters against each other to look for valuable trends

# Analyzing trends can quickly solve problems

AWWOA Annual Seminar

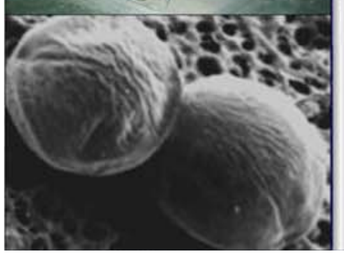
Banff, Alberta
March 15, 2006





AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

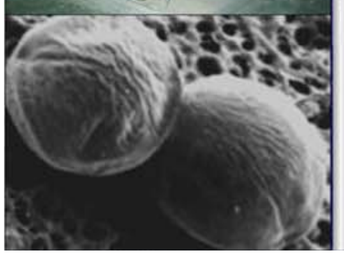


# Chemical Dosing Trends

- Understand how chemical dosing impacts plant performance
- Look for over- or under-dosing, track
  - Raw water turbidity vs Coagulant Dose
  - Raw and coagulated water pH and alkalinity vs coagulant dose
  - Clarified water turbidity vs coagulant dosage

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

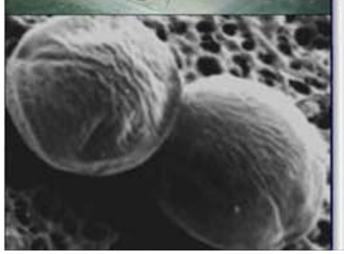


# Coagulation & Flash Mixing

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

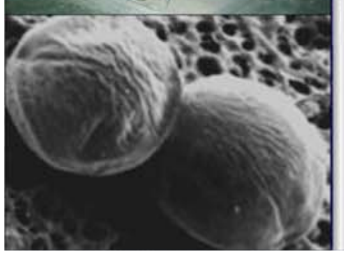


# Coagulation & Flash Mixing

- Getting the Chemistry Right
  - Coagulation Objectives
  - Selecting the Right Coagulant
  - Appropriate Coagulant Dosage
  - Matching Alkalinity with Coagulant Dosage
- Getting the Dosing & Mixing Right
  - Coagulation Mechanisms
  - Coagulant Mixing Methods
  - Coagulant Pumping

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



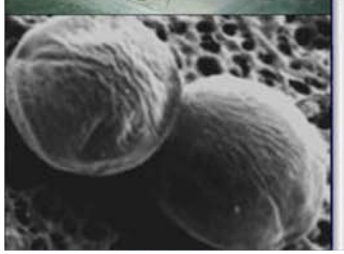
# What the heck is coagulation anyway ?

- The use of chemicals (coagulants) to destabilize colloidal material, and entrap them within a floc particle
- Once in particulate form, floc is easily removed

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



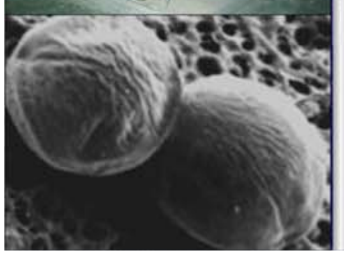
# Colloid Stability

- Colloids (<10um) are stable and remain in suspension by virtue of their electrostatic charge (predominantly negative)
- May take anywhere from 200$^{+}$ days up to 50$^{+}$ years to settle
- Without effective coagulation, solids removal would be impractical

EarthTech
A Tyco International Ltd. Company

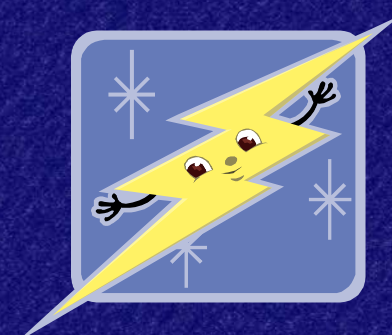
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Theory of Coagulation

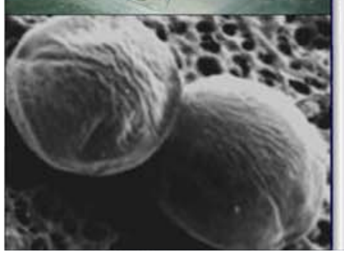
- Coagulation is achieved mainly through the reduction of the electrical double layer on the surface of a charged particle resulting in its destabilization or removal of charge
- Generally takes place in a matter of seconds after coagulant addition
- Once charge is removed, particles can stick together & **form a floc**



AWWOA Annual Seminar

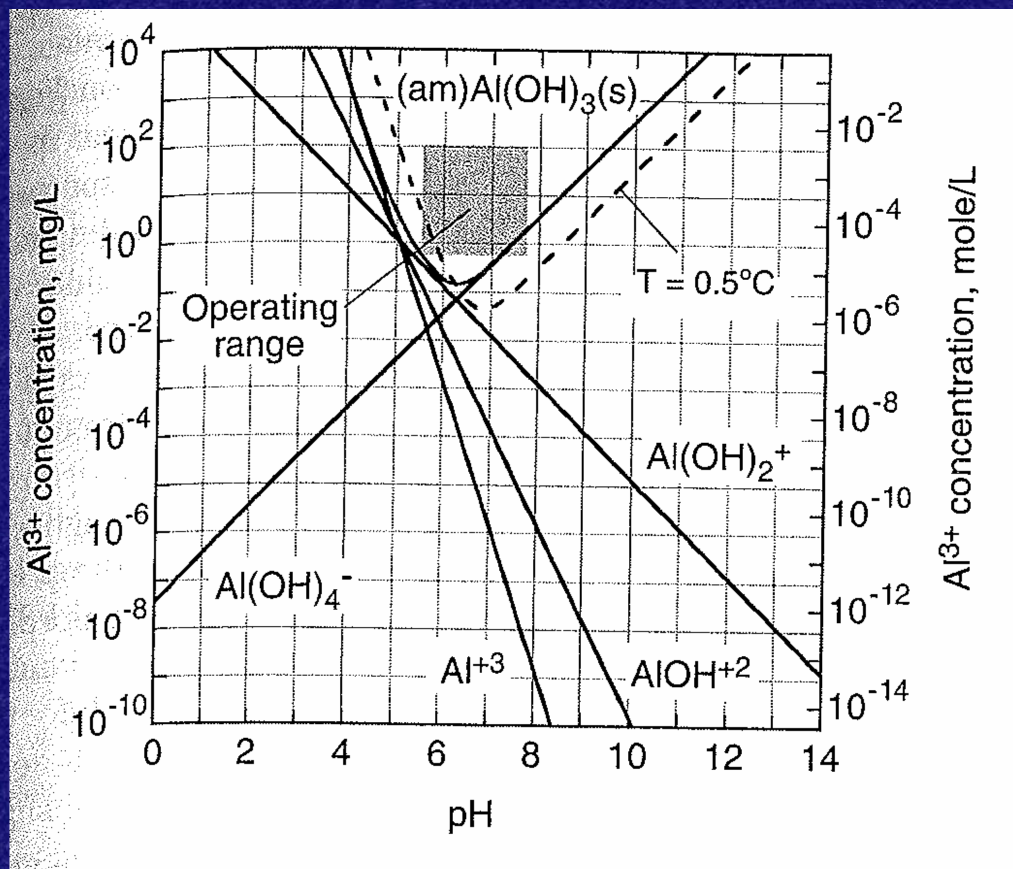
Banff, Alberta
March 15, 2006





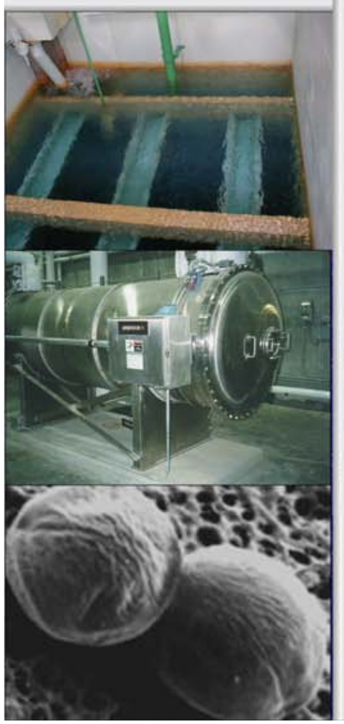
# Alum Coagulation

- Fairly tight “optimal” pH range 5.5 – 7.5



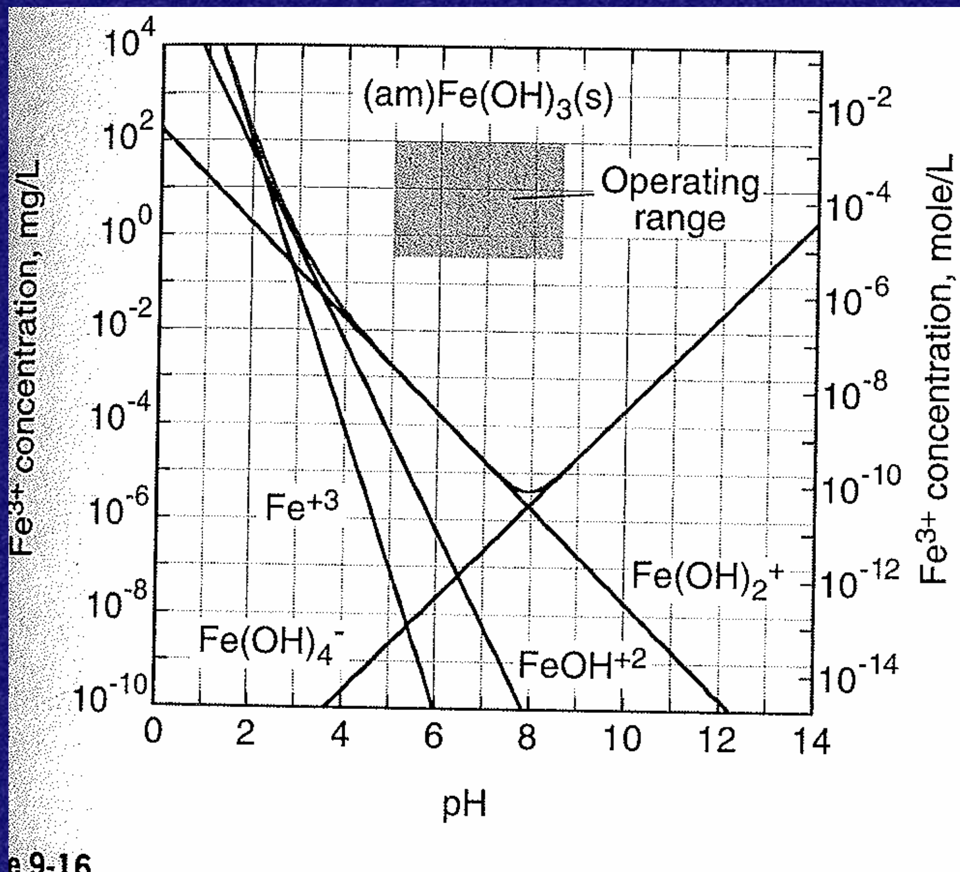
AWWOA Annual Seminar

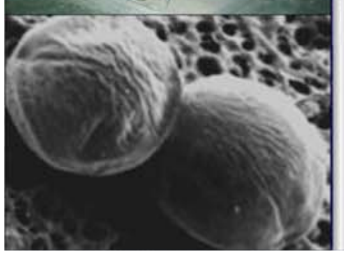
Banff, Alberta
March 15, 2006



# Ferric Coagulation

- Broader Effective pH range 5 – 8.5





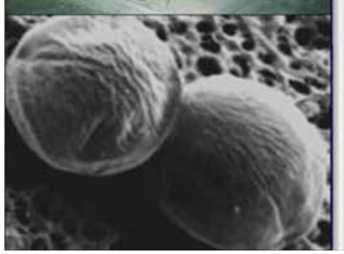
# Selecting & Evaluating Coagulants

- Jar test, jar test, jar test !!!
  - Different coagulants against each other
  - Coagulant and Flocculant Aid polymers
  - Chemical addition in varying order (coagulant, coagulant aid, alkalinity enhancing)
- **2 factors** most often overlooked:
  - Alumina ($Al_2O_3$) Content
  - Degree of Basicity

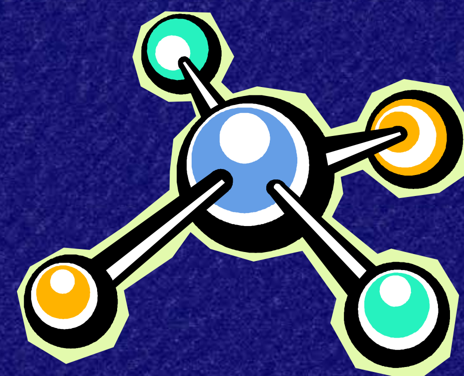
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

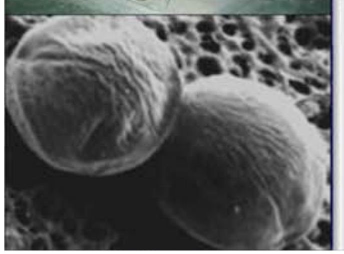
Banff, Alberta
March 15, 2006



# Understanding Alumina Content



Coagulant Chemistry



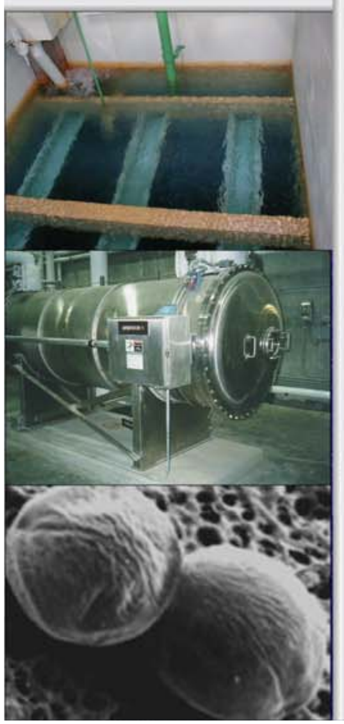
# Not all coagulants are created equal

| Coagulant | Percent as Alumina |
|---|---|
| Alum | 8.20% as Alumina |
| IsoPAC 70 | 11% as Alumina |
| Polyaminium Chloride (PACl) | 18% as Alumina |
| Aluminium Chlorhydrate (ACH) | 23.50% as Alumina |

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Standardization Based on Alumina

Therefore 10 PPM of Alum ( at 8.2% $Al_2O_3$) can result in comparative coagulants “dose standardized” by active Alumina composition being fed at:

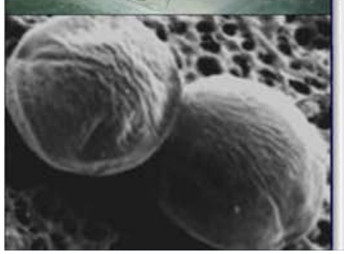
- Isopac 70 (11% $Al_2O_3$) = 7.45 PPM (25% less)
- PACl (18 % Al2O3) = 4.56 PPM (55% less)
- ACH (23.5 % Al2O3) = 3.49 PPM (65% less)

$Al_20_3$ content can be found on MSDS sheet

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

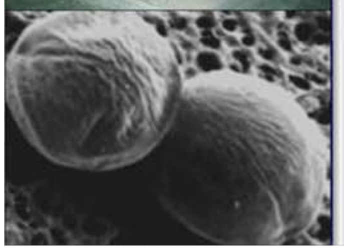
Banff, Alberta
March 15, 2006



# Understanding Coagulant Basicity

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Coagulation Chemistry

$$Al_2(SO_4)_3 \bullet 18\ H_2O + 3\ Ca(HCO_3)_2 \rightarrow$$

(Alum) (Water) (Calcium Bicarbonate)

$$2\ Al(OH)_{3\ (s)} + 3\ CaSO_4 + 6\ CO_2 + 18\ H_2O$$

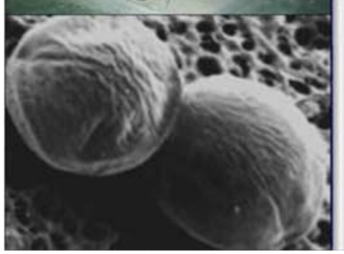
(Aluminum Hydroxide) (Sulphate Component)

Important: Every 1 mg/l of Alum added to water requires 0.45 mg/l of **Alkalinity** (as $CaCO_3$)

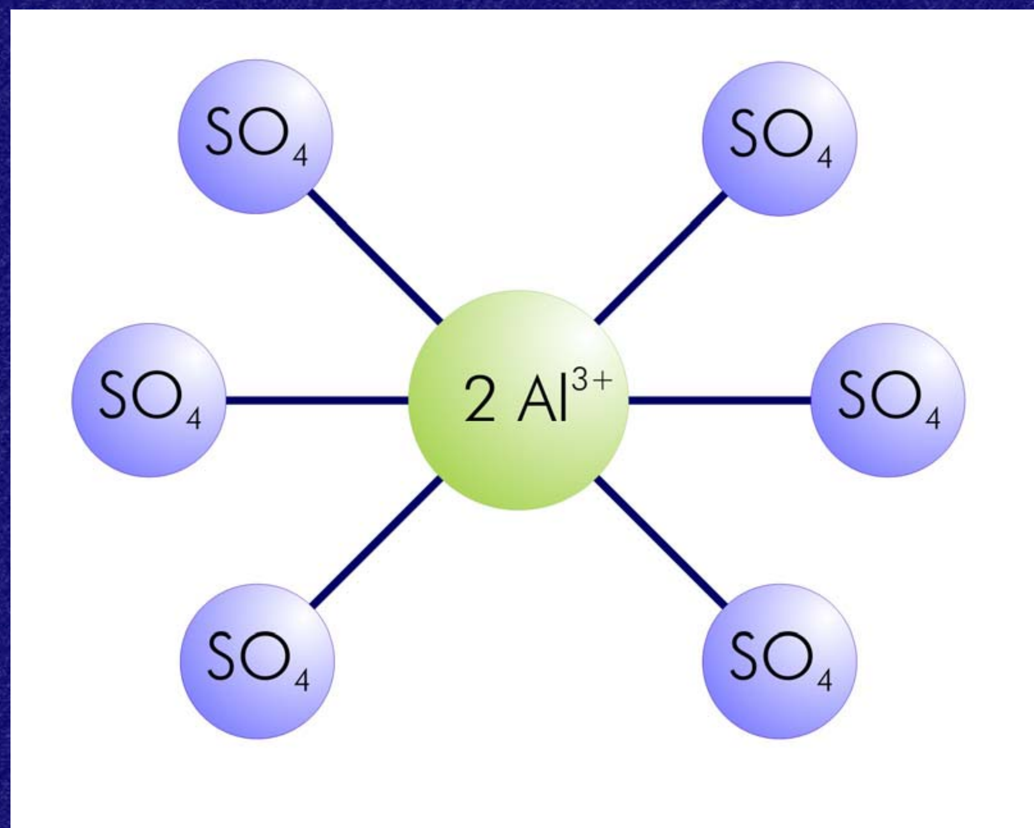
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Coagulation Reactions - Alum



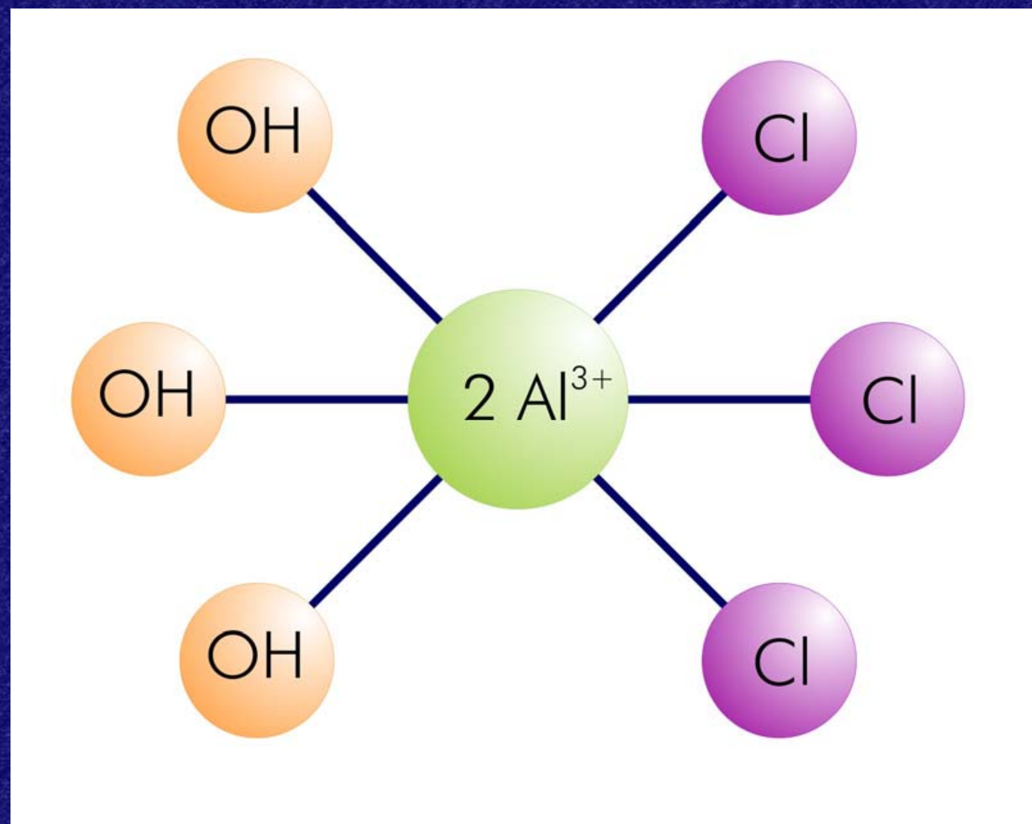

$$Al_2(SO_4)_3 \bullet 18\ H_2O + \mathbf{3\ Ca(HCO_3)_2} \rightarrow 2\ Al(OH)_3\ (s) + 3\ CaSO_4 + 6\ CO_2 + 18\ H_2O$$

EarthTech
A Tyco International Ltd. Company

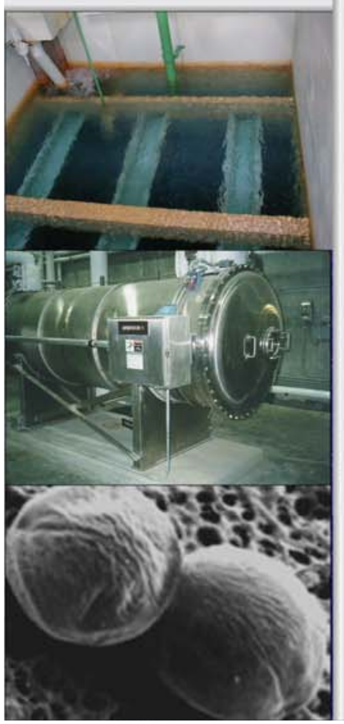
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

# Polyhydroxy Aluminum Chloride

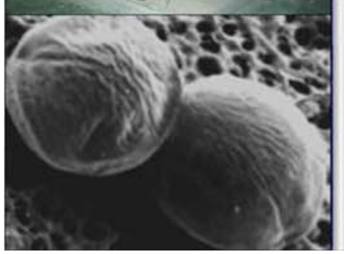



Therefore can be considered 50% **pre-hydrolysed** (3/6 sites)

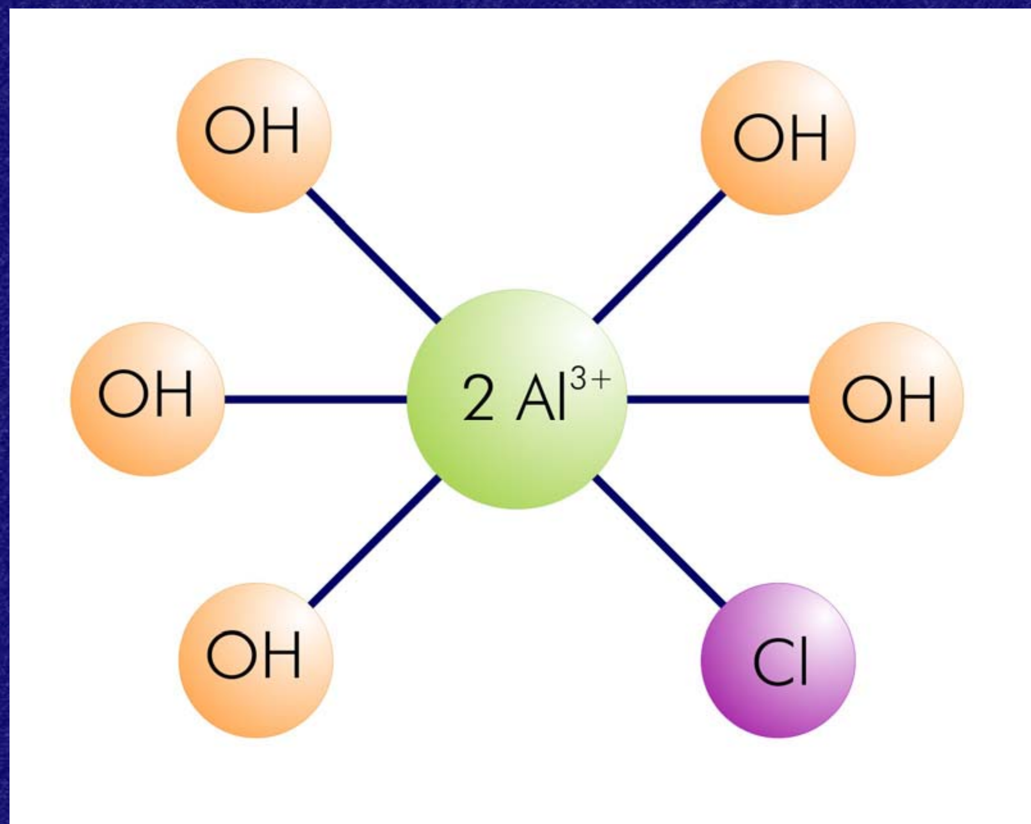


AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Aluminum Chlorohydrate (ACH)

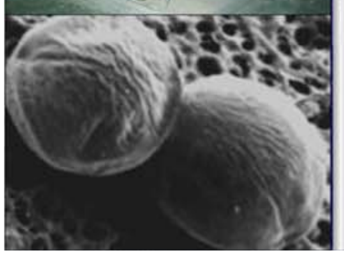



Therefore considered 80% **pre-hydrolysed** (5/6 = 0.83333)

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Degree of "Basicity"

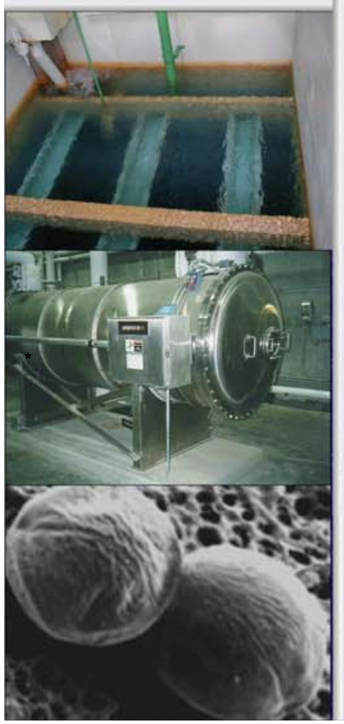
(Or Pre-Hydrolization)

| Coagulant | Extent of Pre-Hydrolization |
|---|---|
| Alum | 0% |
| PACl (ISOPAC) | 45% |
| ISOPAC 70 | 70% |
| ACH | 80% |

- Alum consumes more alkalinity than other aluminium based coagulants
- Higher consumption of alkalinity means greater impact on pH
- Optimal coagulation may not occur without sufficient "residual" alkalinity, at least 10 mg/L as $CaCO_3$

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

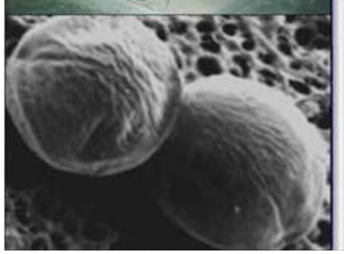


# Alkalinity Limitations

| Product | Alkalinity Available mg/L | $Al_20_3$ Strength | Basicity | MAX DOSE (Based on Basicity) | Alum Eqv (Based on $Al_20_3$) |
|---|---|---|---|---|---|
| **Alum** | **10** | **8.2** | **0%** | **20** | **20** |
| Isopac 70 | 10 | 11 | 70% | 67 | 89 |
| PACl | 10 | 18 | 45% | 36 | 80 |
| ACH | 10 | 23.5 | 83% | 118 | 337 |

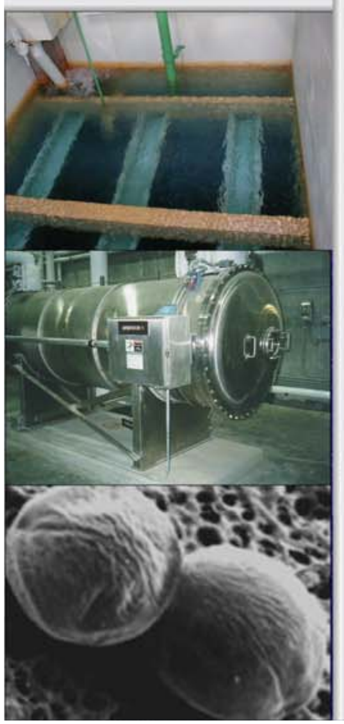
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



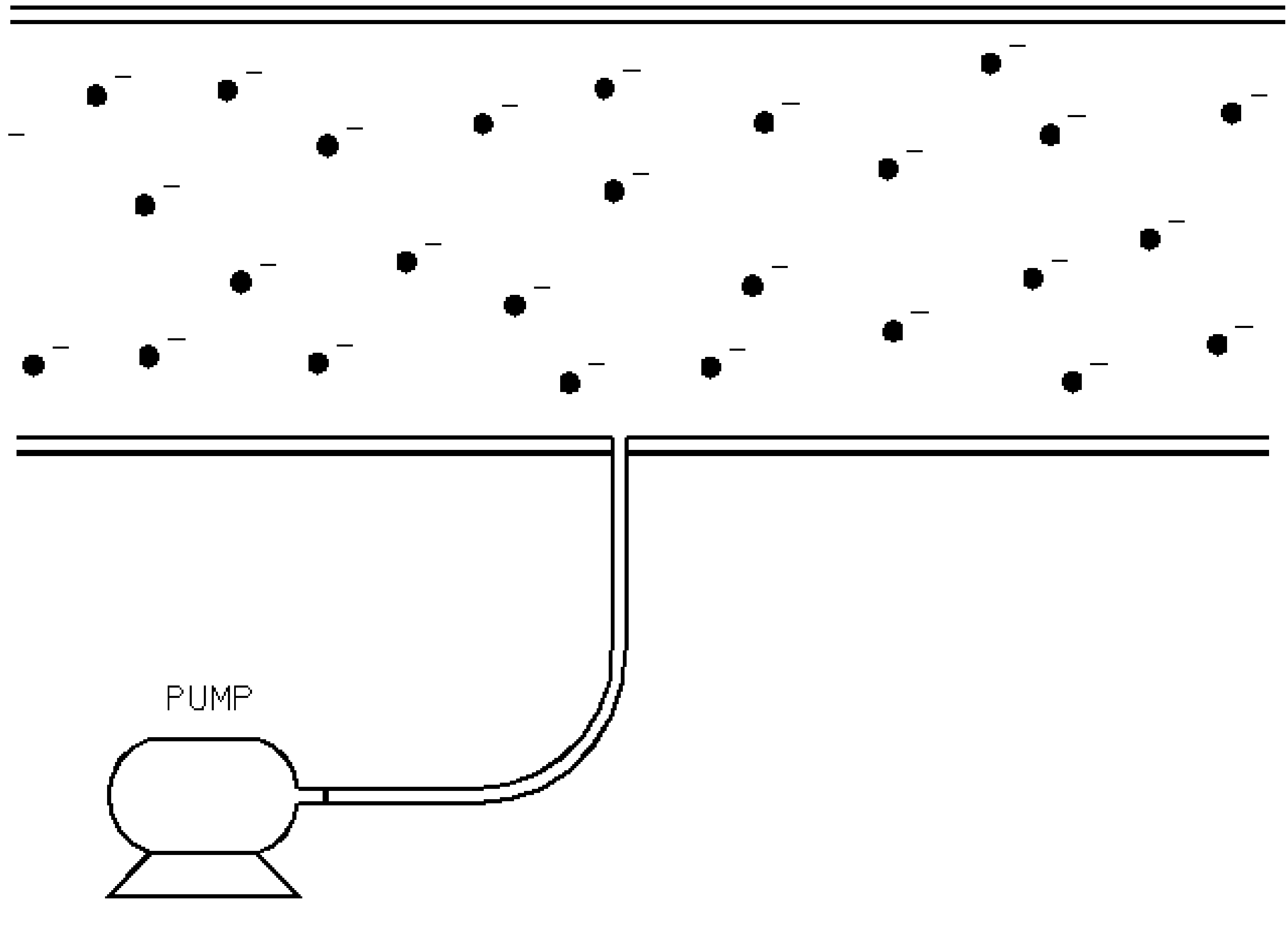
# Operational & Design factors affecting coagulation

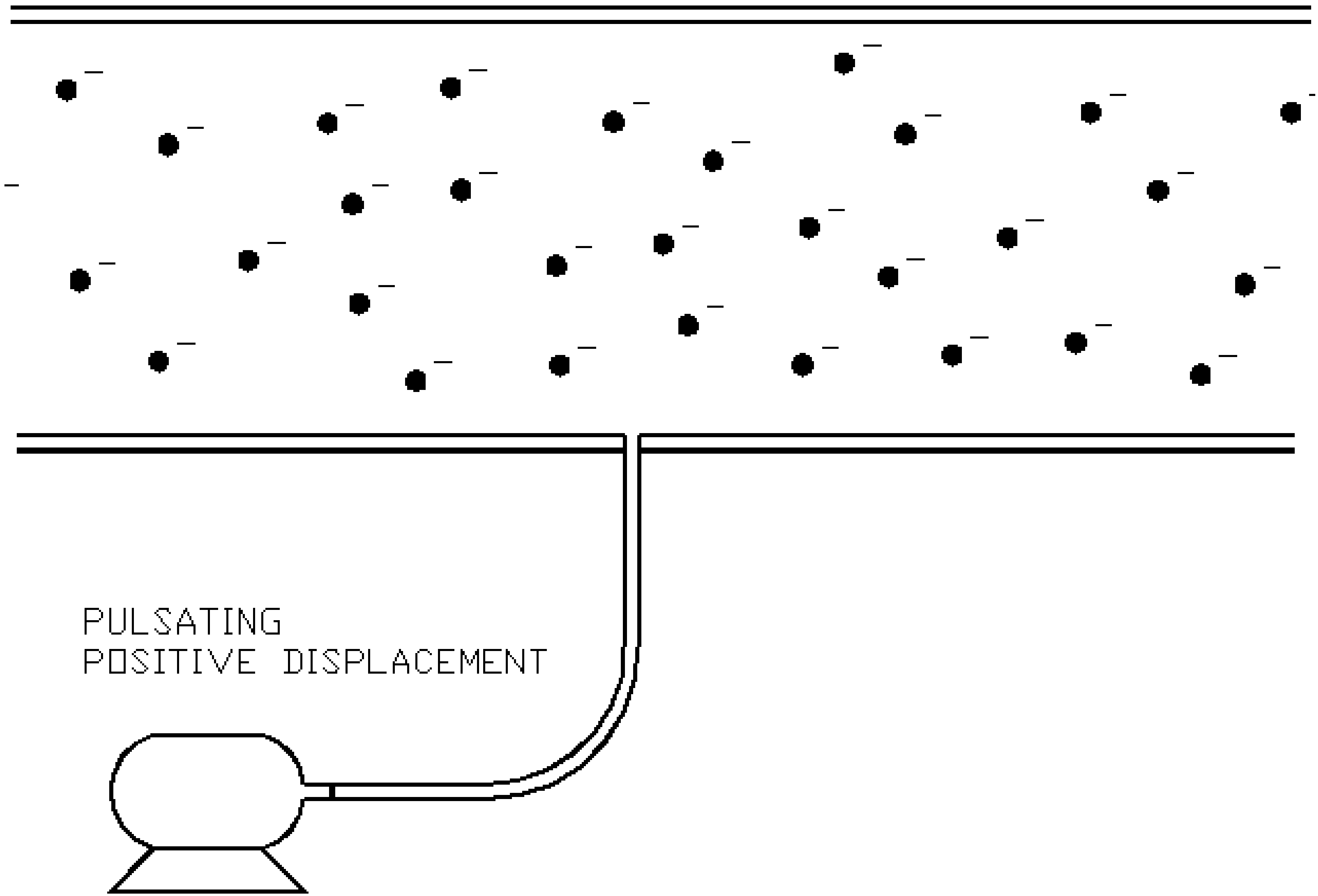
- Uniformity of Coagulant Flow
  - Ideally dose in a steady stream
  - Many utilities moving to gear pumps, to avoid pulsation inherent with metering pumps
- Vigour of coagulant mixing
  - Coagulation reactions take a fraction of a second – Instantaneous mixing is critical
  - Static mixers can lose effectiveness at lower flows
- pH and Alkalinity
  - Consider the need to add alkalinity if coagulant demands are higher. Soda ash generally the most effective additive
  - Generally try to ensure 10 – 20 mg/L as $CaCO_3$ residual alkalinity after coagulation

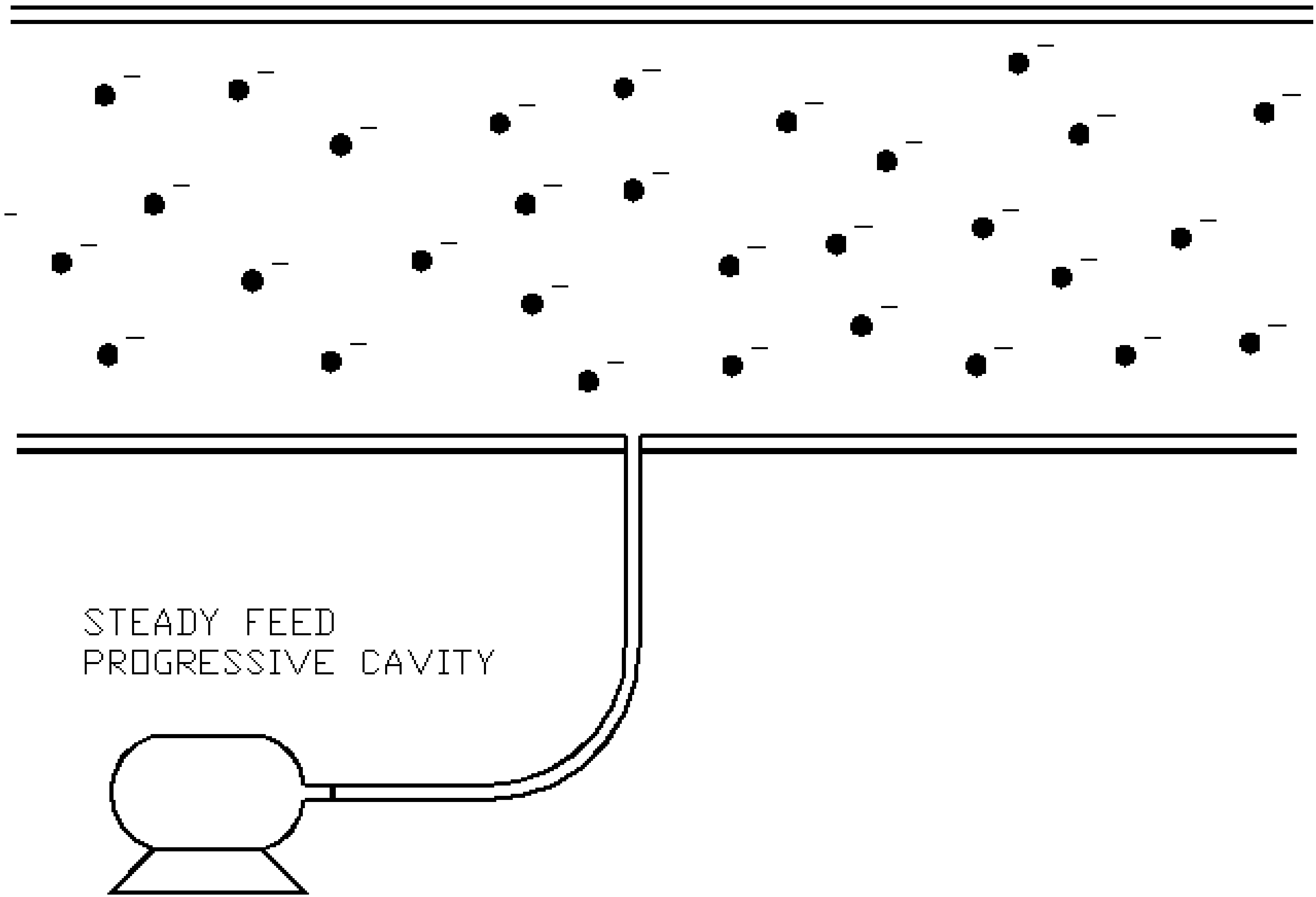


# Common problems with coagulation

- Under or over-dosing – Use Jar Testing !!
- Mixing of insufficient energy – Undesirable coagulation reactions occur
- Fouling or clogging of injectors or diffusers – Usually caused either by pre-dilution of coagulant, or poor mixing at the point of injection
  - Causes high, very localized coagulant concentrations
  - Significant precipitation around the injector
- Trying to mix too many chemicals at once, causing side reactions


PUMP


PULSATING
POSITIVE DISPLACEMENT

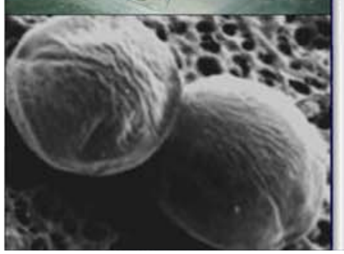

STEADY FEED
PROGRESSIVE CAVITY

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



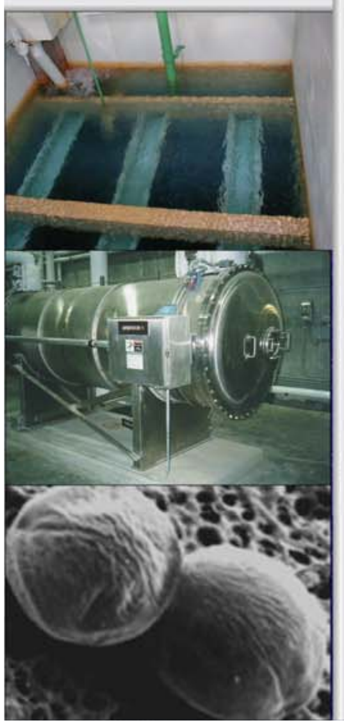


# Coagulant Mixing

- Rapid Mixing is Critical – True “Flash” Mixing is desired
- Speed of coagulation reactions are very quick – From a fraction of a second to 7 seconds
- Excessive mixing time is wasted
- NEVER pre-dilute coagulant to improve mixing turbulence

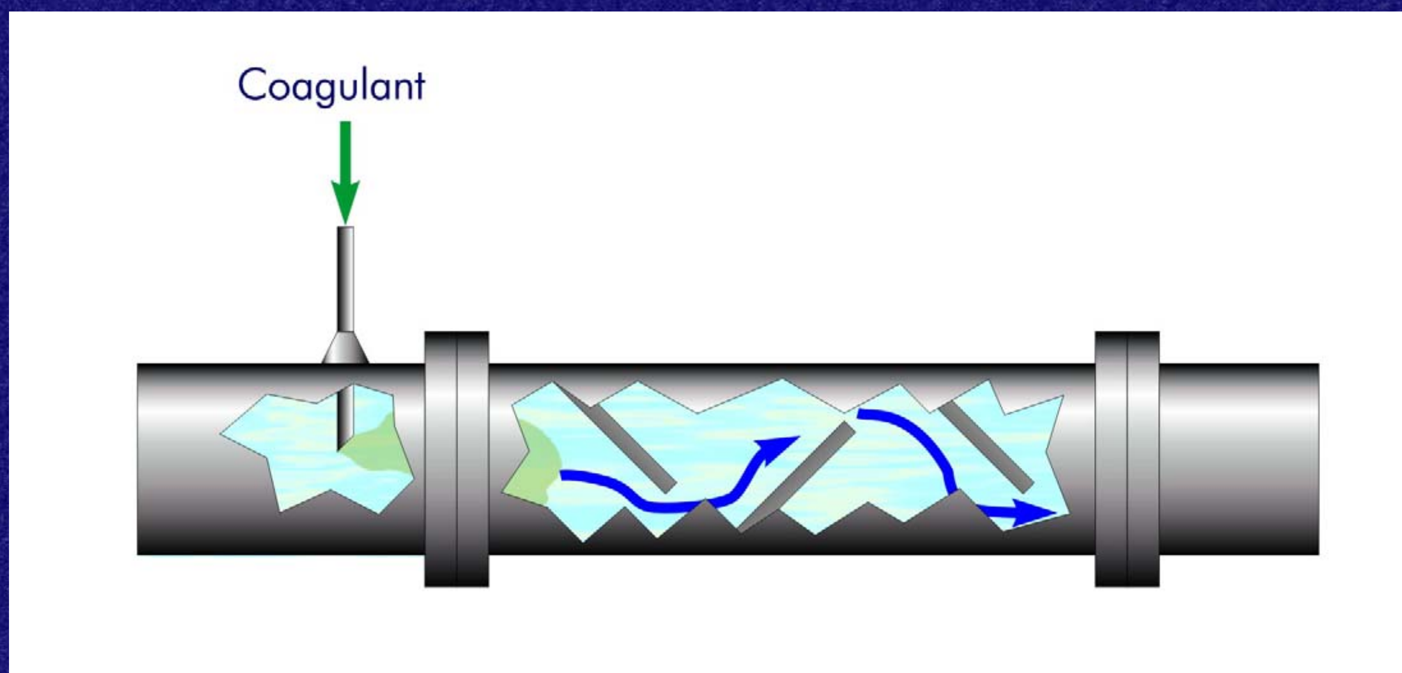
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

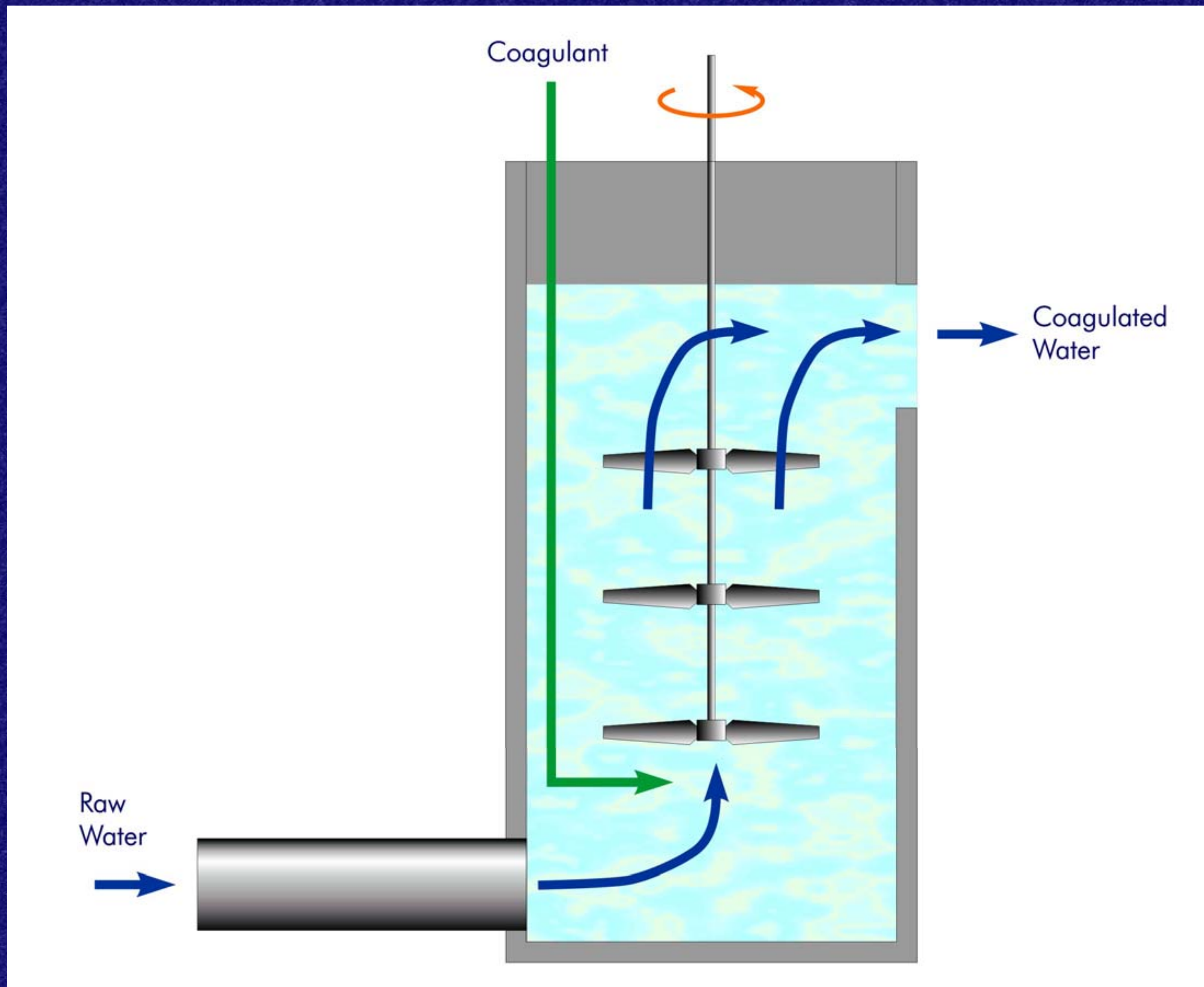


# Static Mixing

- Very common in small plants
- Mixing energy is linked to flow
- Low flow = Low Mixing Energy = Poor Flash Mixing

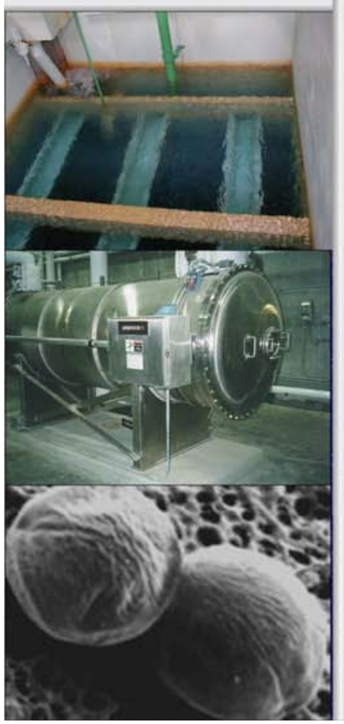


# Mechanical Flash Mixing

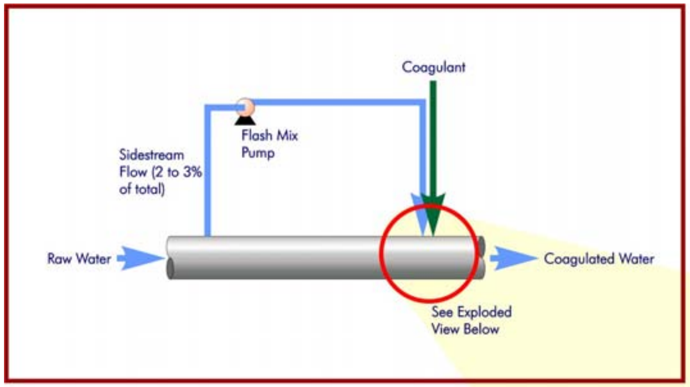


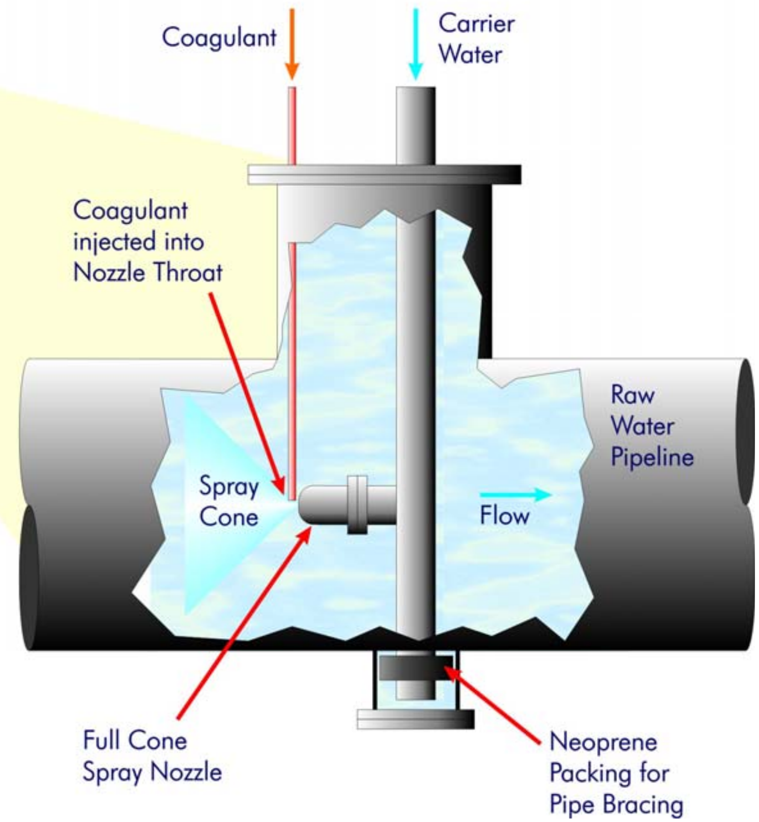

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# "Jet" Flash Mixing

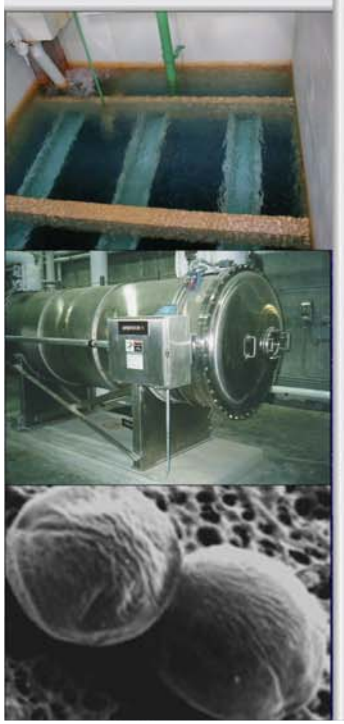



- ★ Most energy efficient
- ★ Flash mix achieved within 1 pipe diameter

AWWOA Annual Seminar

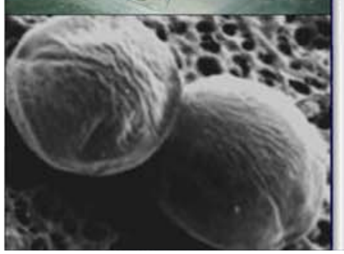
Banff, Alberta
March 15, 2006



EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

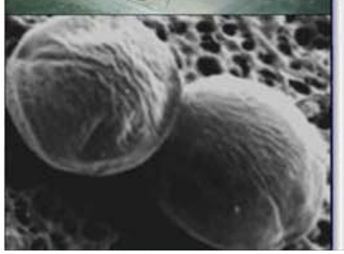


# Flocculation Good Practice

- Tapered flocculation (G = 20 – 70 s-1) for sedimentation – 20 – 30 min total
- Perforated intra-cell baffle walls to minimize short circuiting
- Higher energy (G = 100 $s^{-1}$) non-tapered flocculation for DAF – 15 min total
- Maximum blade tip speed 2 – 3 m/s for vertical turbine flocculators to avoid floc damage
- Include variable speed drives to adjust flocculation energy for optimal performance

AWWOA Annual Seminar

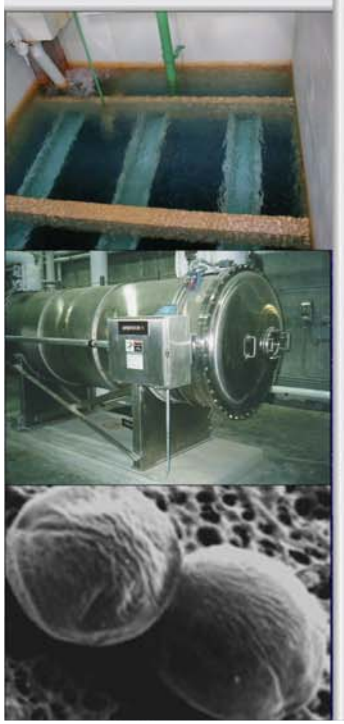
Banff, Alberta
March 15, 2006



# Clarification

# What constitutes "good" clarifier performance ?

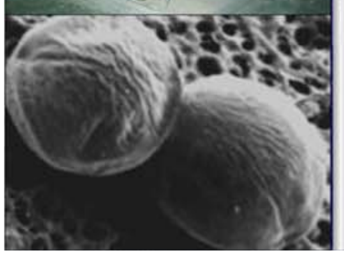
- Consistently less than 2 NTU is excellent
- Stable when faced with rapidly changing water quality conditions
- Produces a sludge of consistent quality:
  - Sedimentation: 0.5 – 1 %TS
  - DAF (Hydraulically desludged): 0.5 – 1 %TS
  - DAF (Mechanically scraped): 2 – 3 %TS
  - ActiFlo: Generally 0.1 – 0.3 %TS
- Poor performance can be difficult to rectify – Often design related



EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



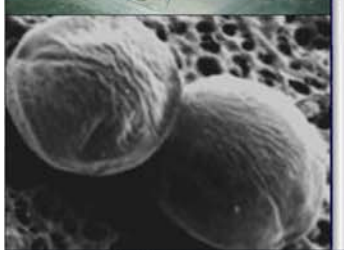
# Common Causes for Poor Clarifier Performance

- Density currents due to temperature variation within basins
- Excessive operating loading rates
- Entrained air – Incidental flotation
- Poor hydraulics due to uneven inlet flow splitting or flocculation circulatory patterns
- Sudden changes in raw water conditions
- Chemical under- or over-dosing
- Inappropriate sludge removal rates
- Insufficient air loading (DAF) or sand concentrations (ActiFlo)

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

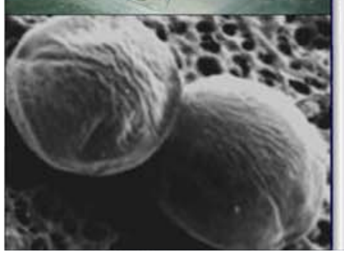


# Is your clarifier suited to your raw water quality ?

| **Clarification Process** | **High Algae Load** | **Highly Coloured Sources** | **Low Tubidity, Impounded Sources** | **Moderate Turbidity, Impounded Sources** | **Elevated Turbidity, River Sources** | **Lime Softening** |
|---|---|---|---|---|---|---|
| Conventional or High Rate Sedimentation | ☆☆ | ☆☆ | ☆☆ | ☆☆☆ | ☆☆☆☆ | ☆☆☆ |
| Sludge Blanket Clarification | ☆☆ | ☆☆ | ☆☆ | ☆☆☆ | ☆☆☆ | ☆☆☆☆☆ |
| DAF (Conventional Or High Rate) | ☆☆☆☆☆ | ☆☆☆☆☆ | ☆☆☆☆☆ | ☆☆☆ | No-Go | No-Go |
| ActiFlo | ☆☆☆ | ☆☆☆☆ | ☆☆☆☆ | ☆☆☆☆☆ | ☆☆☆☆☆ | No-Go |

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



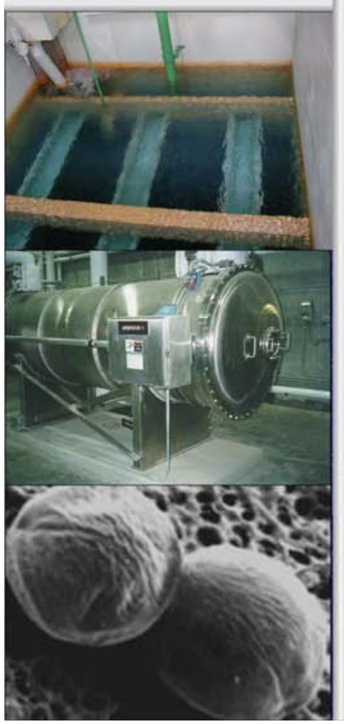
# Is your clarifier operating at or below design capacity ?

- Loading Rate – Flow per Unit Area, $m^3/m^2/hr$, or m/hr
- Typical Loading Rates
  - Traditional Sedimentation: Up to 4 m/hr
  - Conventional DAF: Up to 20 m/hr
  - High Rate DAF: 30 - 45 m/hr
  - ActiFlo: 40 - 60 m/hr
- Loading rate is an AVERAGE over the entire basin area
- Localized high velocities can cause major problems

EarthTech
A Tyco International Ltd. Company

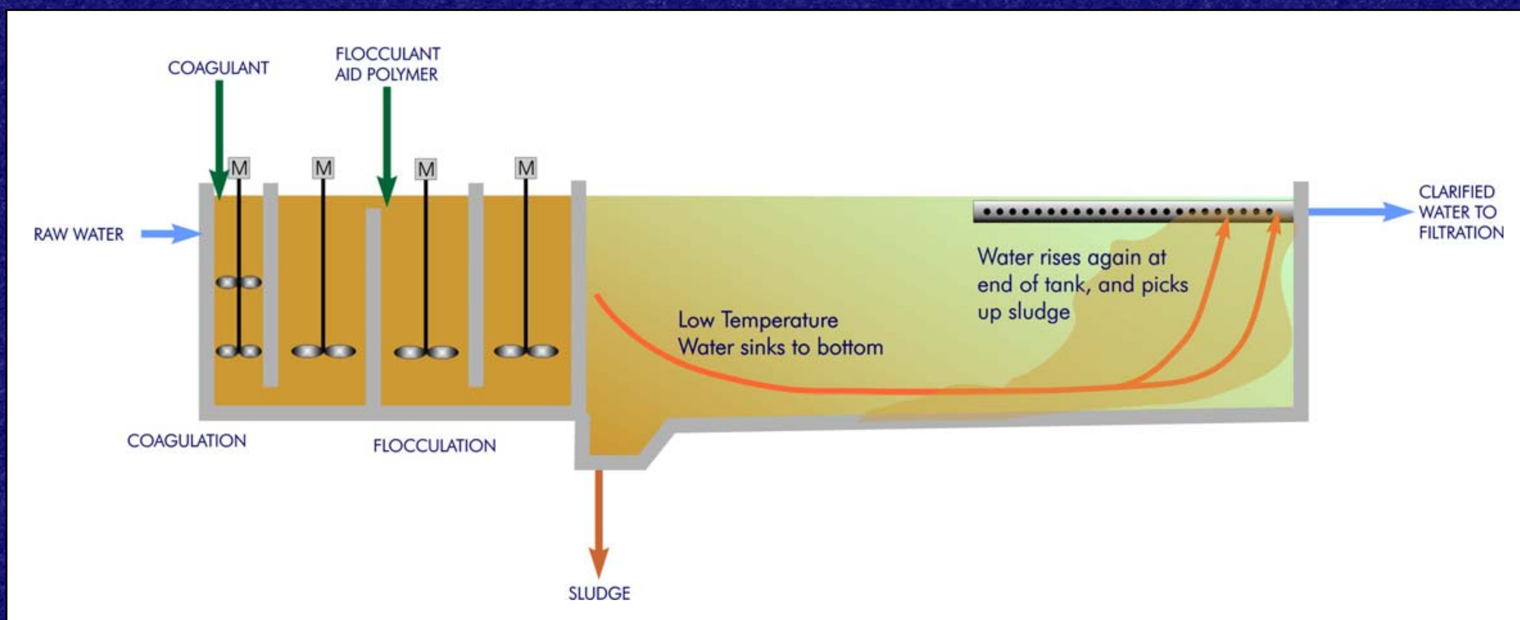
AWWOA Annual Seminar

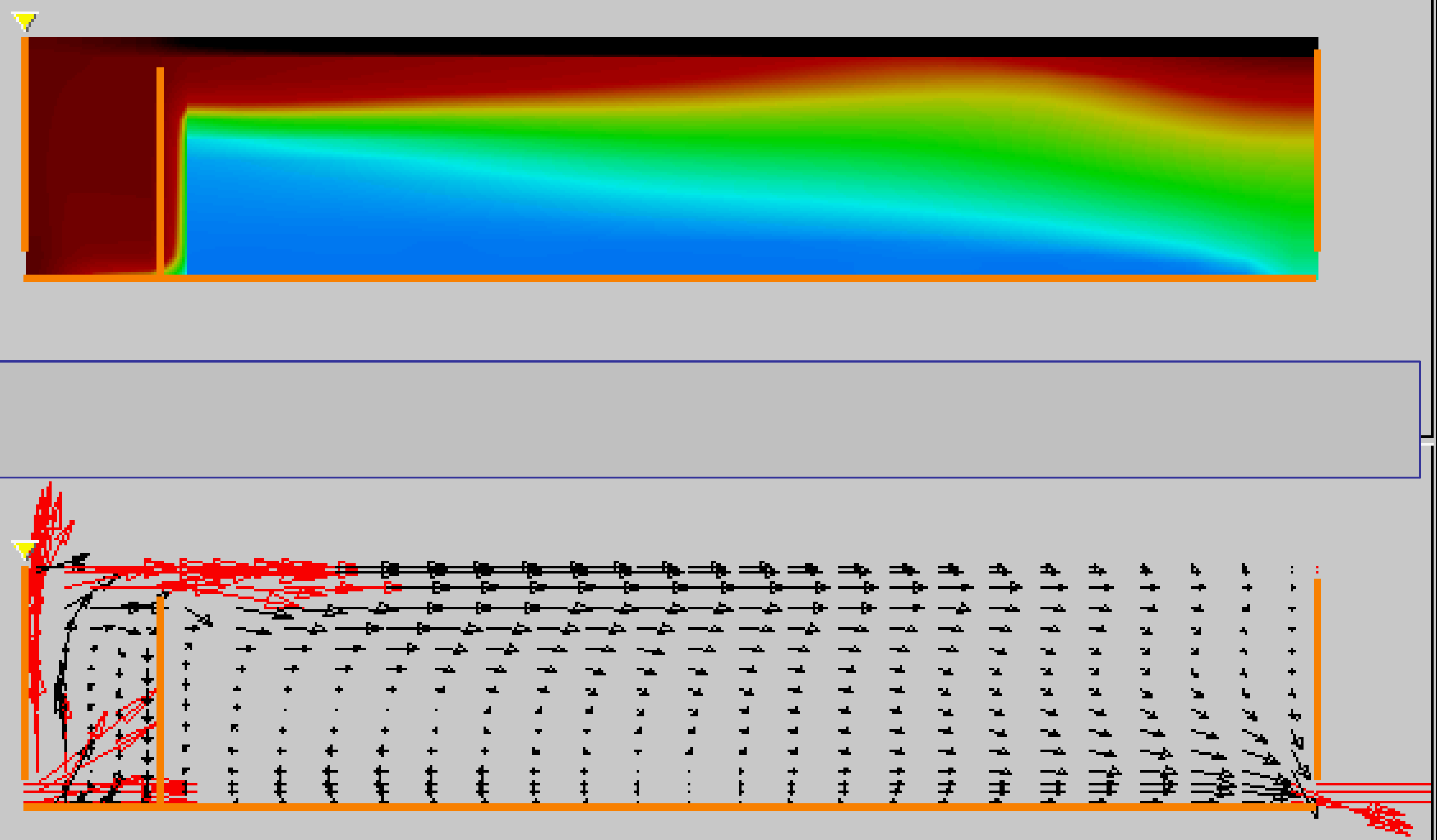
Banff, Alberta
March 15, 2006



# Density Currents

- Generally worst in large sedimentation basins due to surface warming
- Can cause significant floc carryover

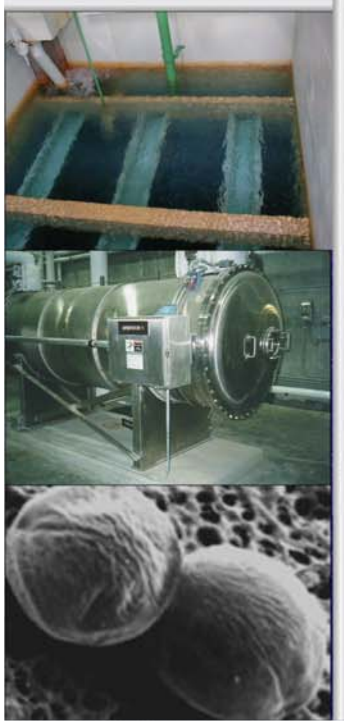




EarthTech
A Tyco International Ltd. Company

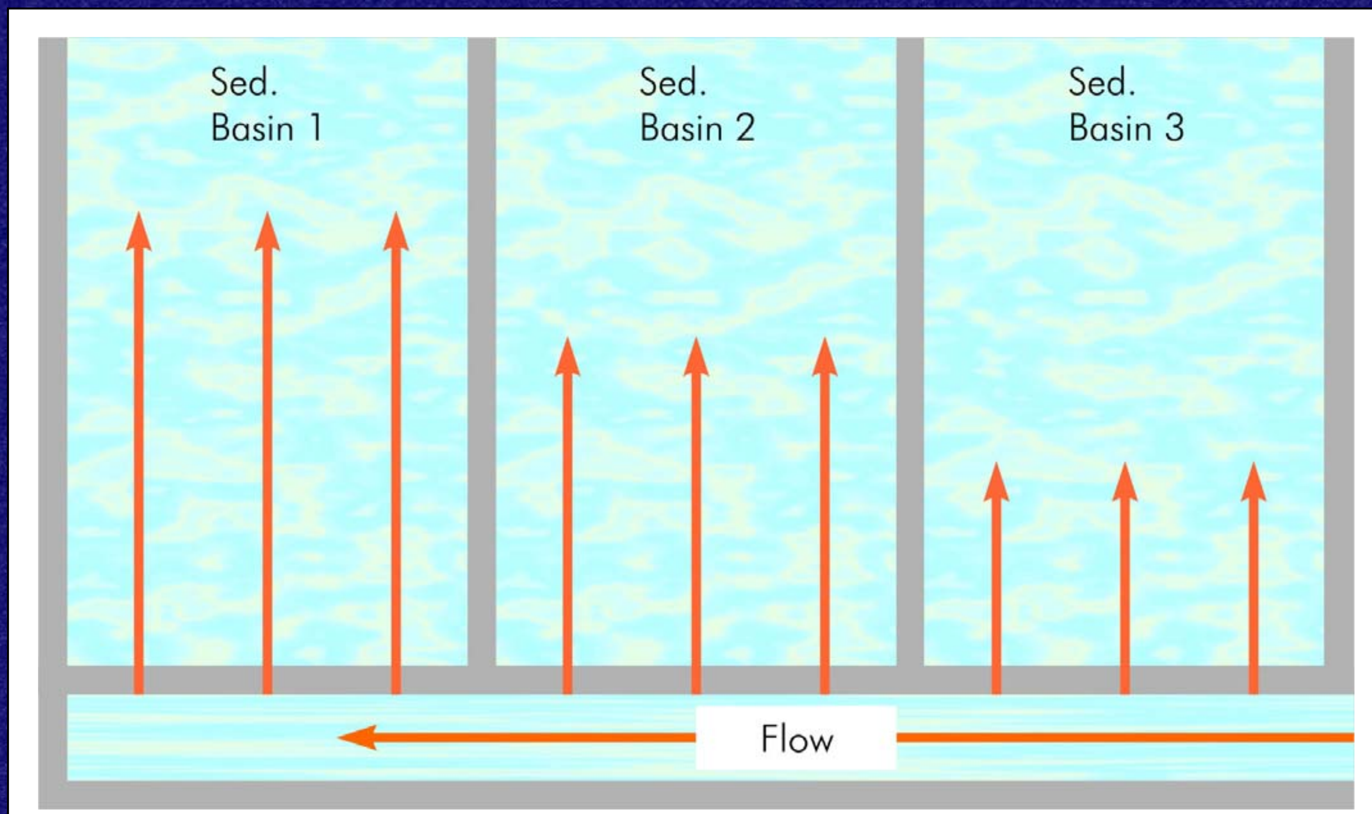
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Inlet Flow Distribution

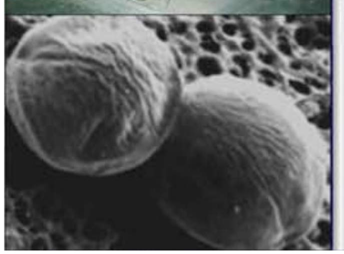
- Generally caused by poor inlet channel design
- Sometimes caused by uneven inlet weirs



EarthTech
A Tyco International Ltd. Company

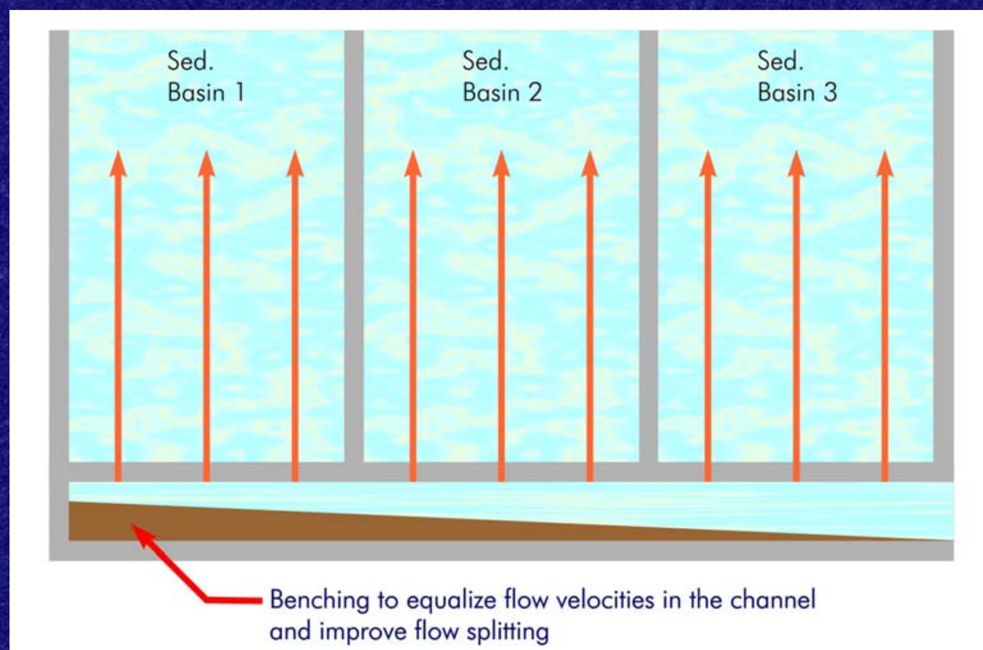
AWWOA Annual Seminar

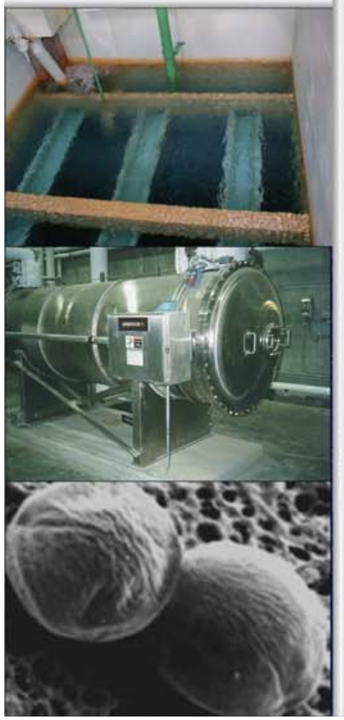
Banff, Alberta
March 15, 2006



# Rectifying Mal-Distribution

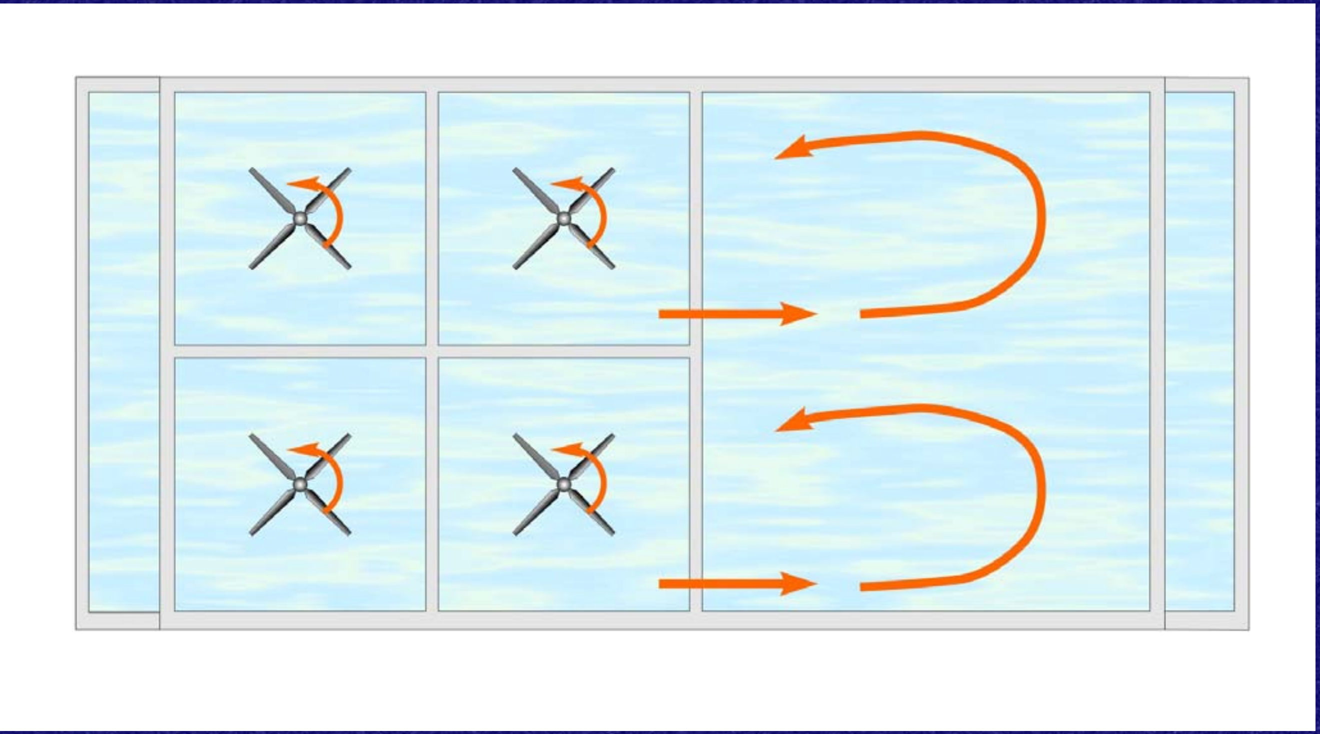
- Switch to flow meters and valves, but often there is insufficient head
- Modify the inlet channel to provide tapering and equalize velocities





# Clarifier Inlet Mal-Distribution

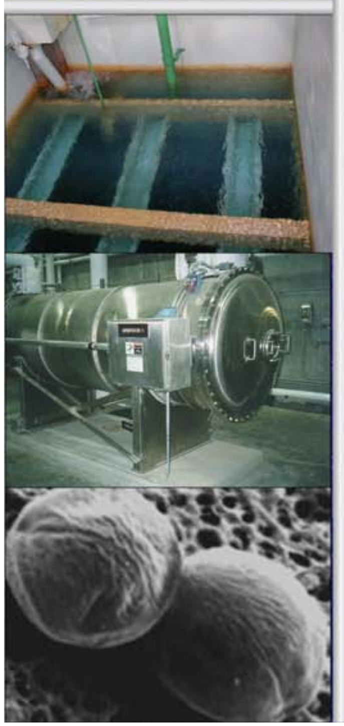
- Poorly designed flocculation basins can result in bulk circulation, resulting in high localized entry velocities



EarthTech
A Tyco International Ltd. Company

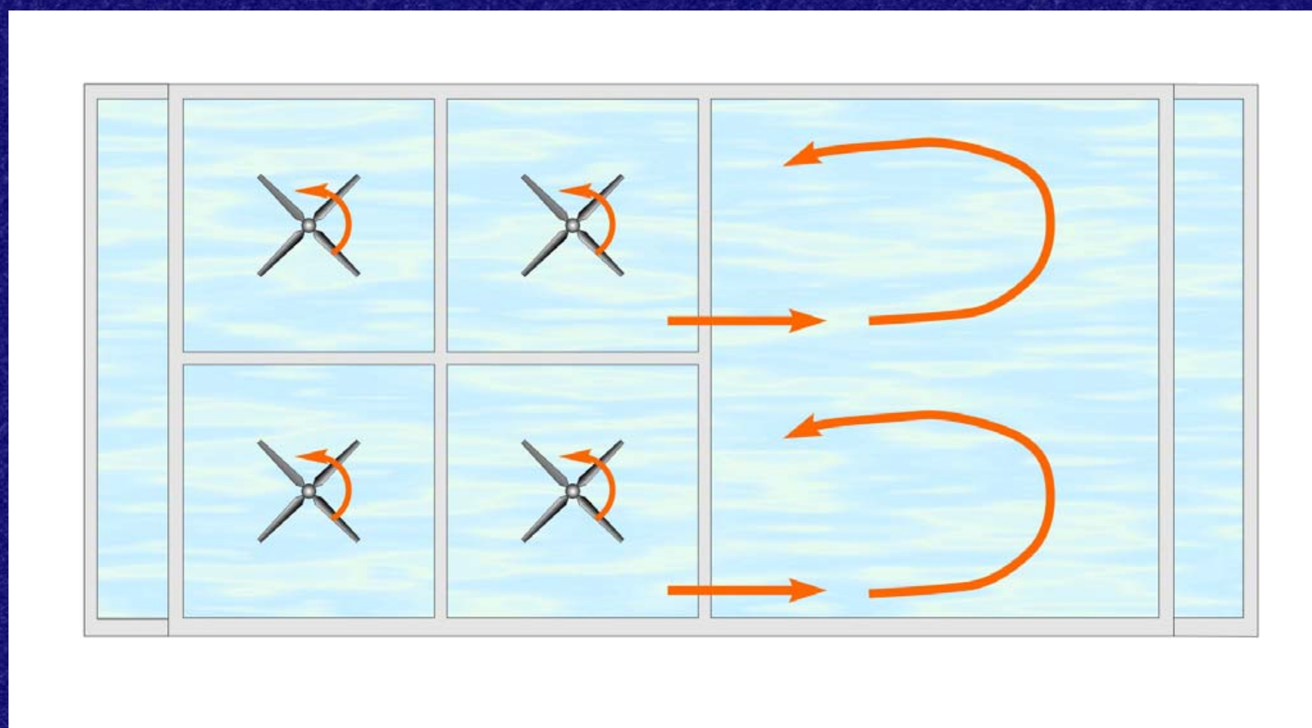
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



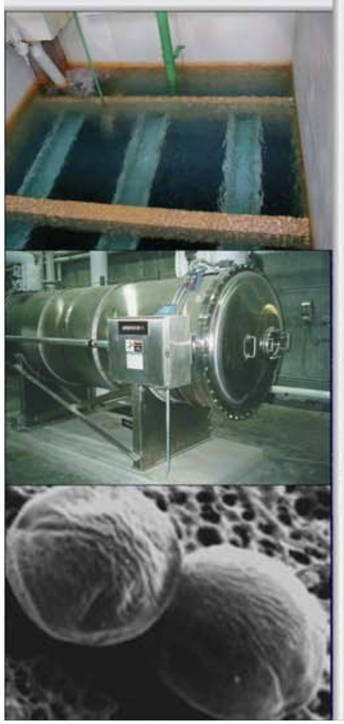
# Clarifier Inlet Mal-Distribution

- Better flow distribution usually requires head loss to be introduced
- Mitigation can be difficult, without causing floc damage



AWWOA Annual Seminar

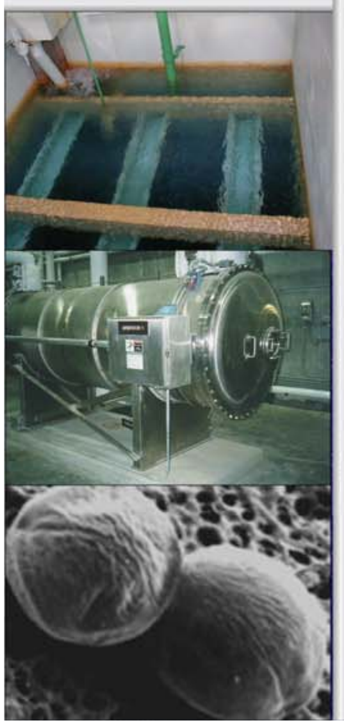
Banff, Alberta
March 15, 2006



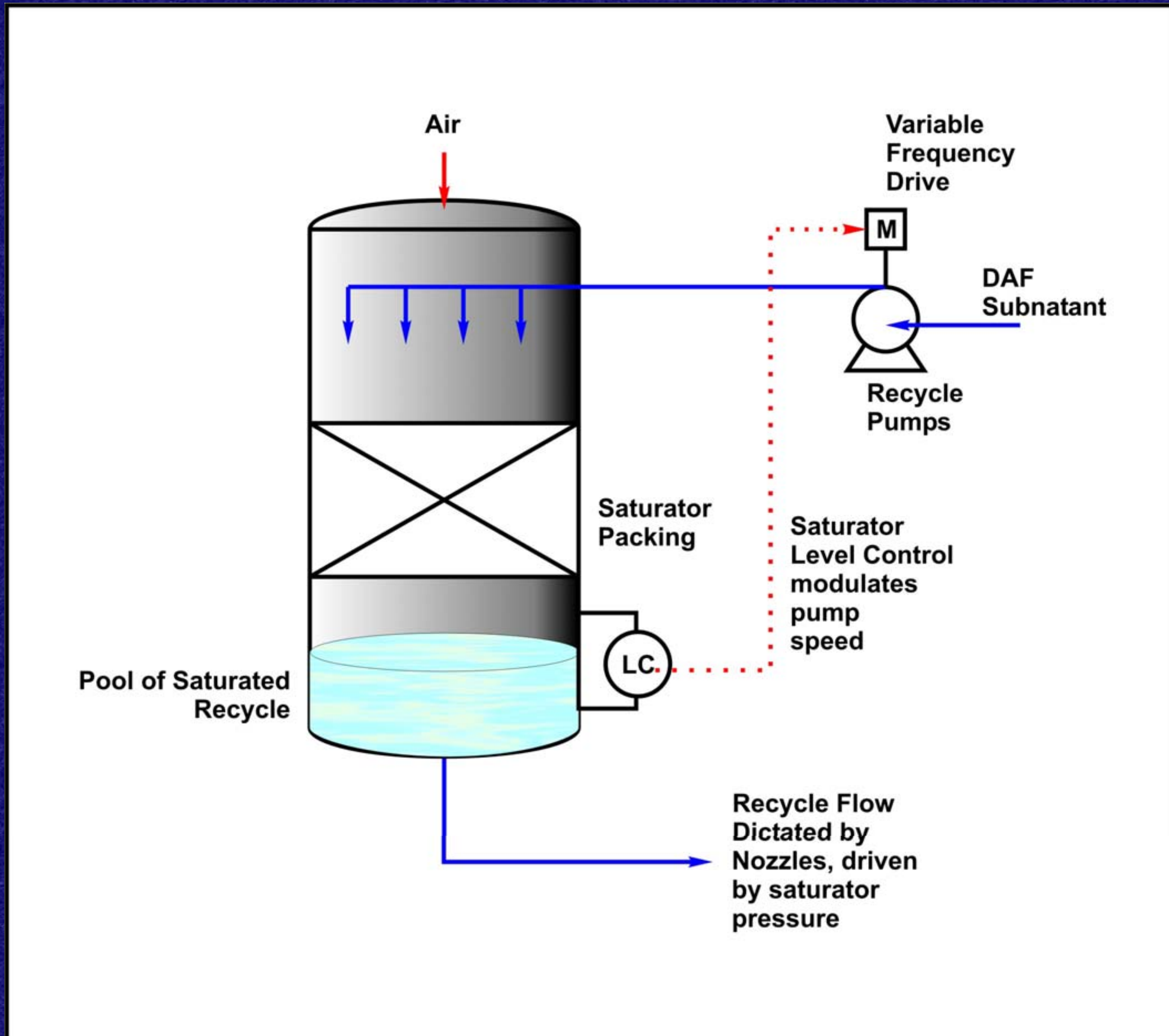
# DAF Clarifiers: How Much Air is Enough ?

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# DAF Saturator Control



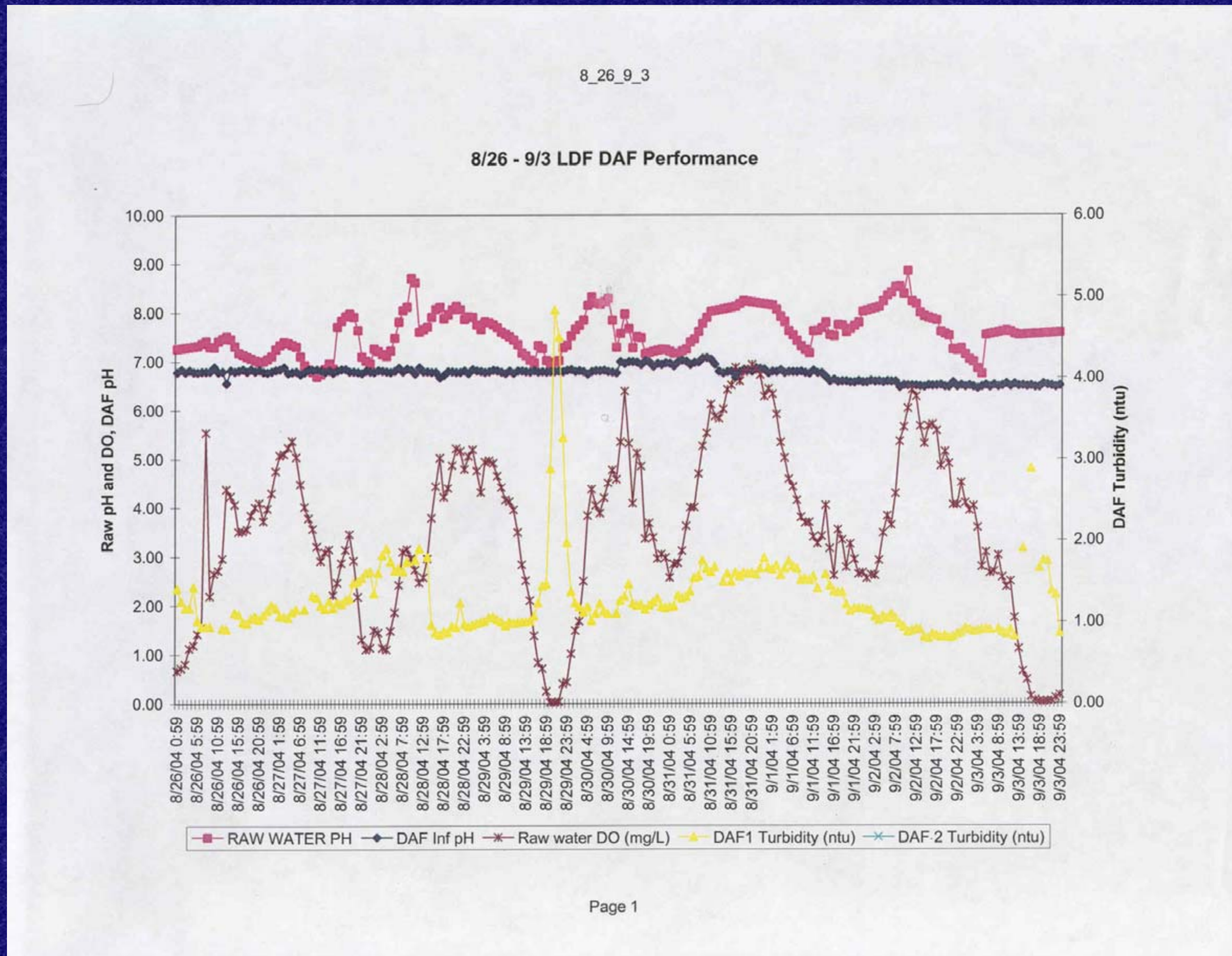
EarthTech
A Tyco International Ltd. Company

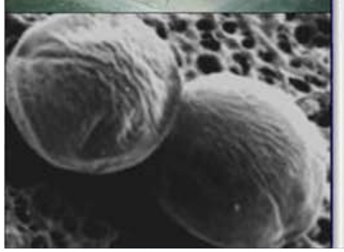
ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

# Not enough air is a bad thing !!



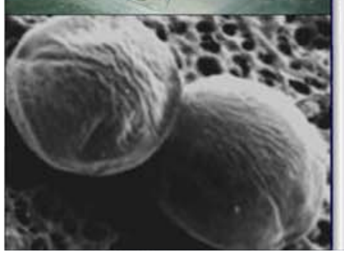



EarthTech
A Tyco International Ltd. Company

ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Entrained Air Problems

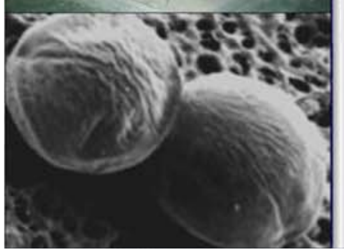
Clarifier performing well in early morning

Launders and Inclined Plates readily visible

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

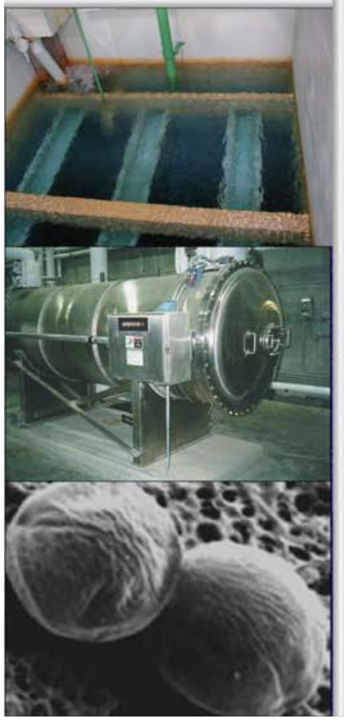


# …..starting to deteriorate !!!

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

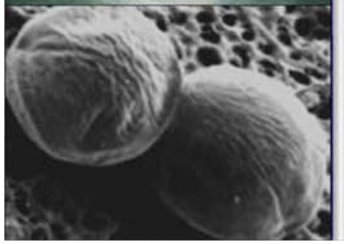


# …and getting worse !!!

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

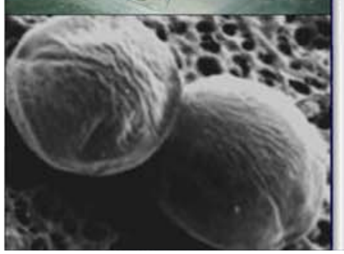


# This is a sedimentation basin ??

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

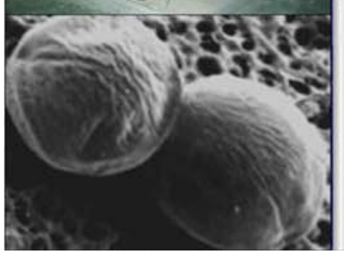
Banff, Alberta
March 15, 2006



# Extended downtime for cleaning !!!

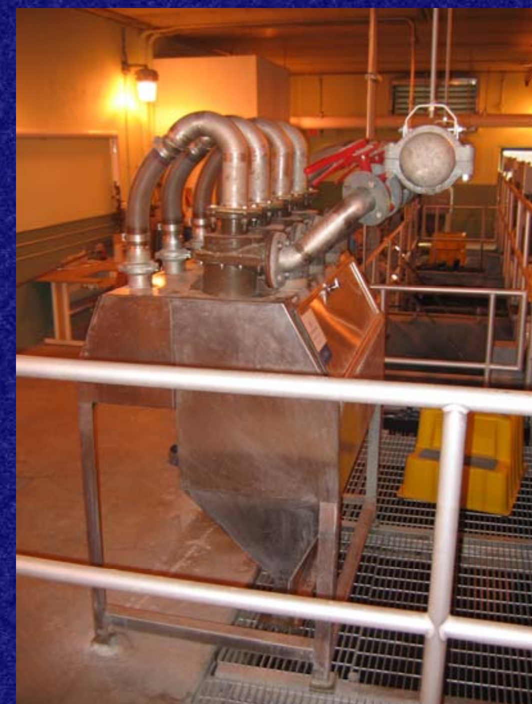
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



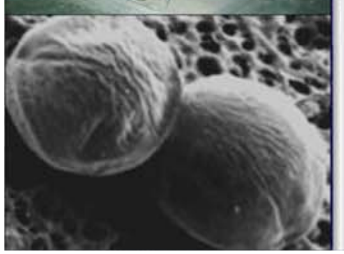
# ActiFlo Operational Issues

- Control of hydrocyclones to adjust waste flows
- Control of polymer dosing crucial:
  – Under-dosing = floc carryover
  – Over-dosing = polymer carryover
- Sand Concentration
  – Generally aim for 3 – 5 g sand/L
  – John Meunier trying to develop an on-line sand concentration analyzer ?



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

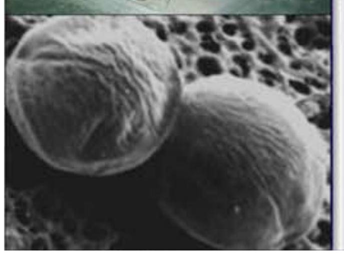


# Granular Media Filtration

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



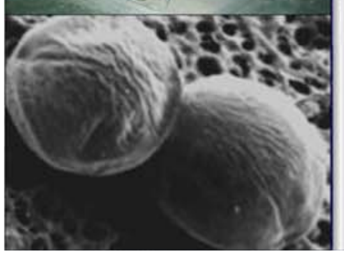
# What constitutes “good” filter performance ?

- Consistently less than 0.3 NTU
- Particle counts < 50 particles/mL
- > 2-log removal of *Giardia* and *Cryptosporidium* sized particles
- Long and predictable filter runs (24+ hours)
  – Same for each filter
- Minimal premature particle breakthrough
- Poor performance can be difficult to rectify, but many issues can be resolved with simple fixes

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



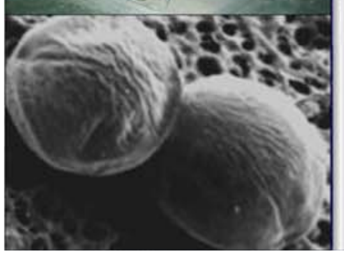
# What constitutes “good” filter design ?

- Most efficient media design has largest media at the top, and the finest at the bottom
- However, backwashing immediately re-classifies bed to place the finest grains at the surface
- Therefore use multi-media to mimic this effect, with coarse grains in the top layer to trap solids, and finer layer below for polishing

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006





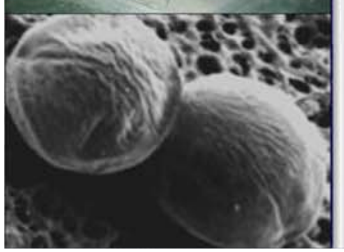
# What constitutes “good” filter design ?

- “Conventional” Filter Design
  - Typical Loading Rates 6 – 9 m/hr. Higher possible with pilot testing
  - Total Media Depth ≤ 1 m
  - Anthracite: ES 0.8 – 1.2 mm, UC 1.4 – 1.65
  - Sand: ES 0.45 – 0.55 mm, UC 1.4 – 1.65
- “Deep Bed” Filter Designs
  - Typical Loading Rates much higher, relying on chemical dosing to a greater extent
  - Total Media Depth 2 – 3 m
  - Anthracite: ES 0.8 – 1.2 mm, UC 1.4 – 1.65
  - Sand: ES 0.45 – 0.55 mm, UC 1.4 – 1.65

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006





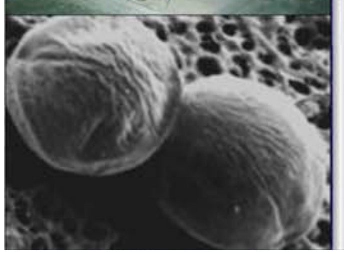
# Filter Auxiliary Cleaning

- Air Scour
  - Air flow: 0.9 – 1.5 $m^3/min/m^2$
  - Air scour provides a vigorous cleaning action, due to “collapse pulse” action
- Surface Wash
  - Generally falling out of favour, but common in older filters
  - Typical Flows:
    - Fixed nozzles: 5 $m^3/m^2/hr$
    - Rotating Arms: 1.2 $m^3/m^2/hr$

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006





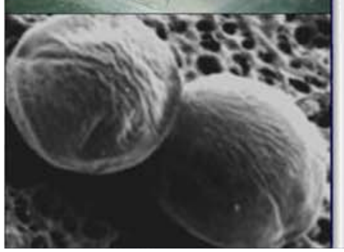
# Good Filter Design Practice

- If dual-media is used, media should be hydraulically compatible to reduce intermixing:

$$\frac{d_1}{d_2} = \left[ \frac{\left(\rho_2 - \rho_{water}\right)}{\left(\rho_1 - \rho_{water}\right)} \right]^{\left(\frac{2}{3}\right)}$$

$\rho_1, \rho_2, \rho_{water}$ = Density of Media 1, Media 2, and water

$d_1, d_2$ = Diameter of Media 1, Media 2



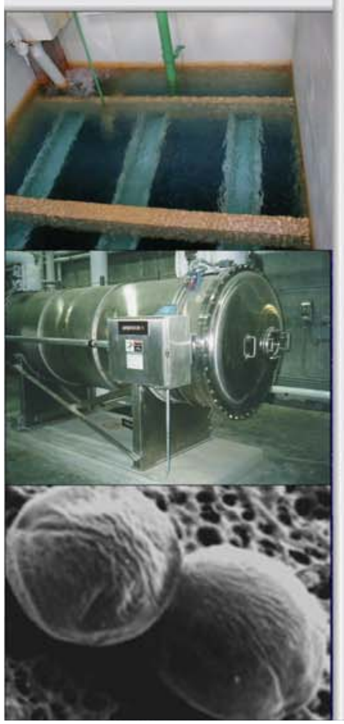
# Good Filter Design Practice

- The important thing to remember is that all media should be selected to share a common fluidization velocity
- This minimizes intermixing of media layers
- Severe intermixing causes short filter runs by reducing void volume in upper layer of filter
- Note: Media characteristics can change over time:
  - Encrustations
  - Deposition
  - Physical degradation of media grains (wear)

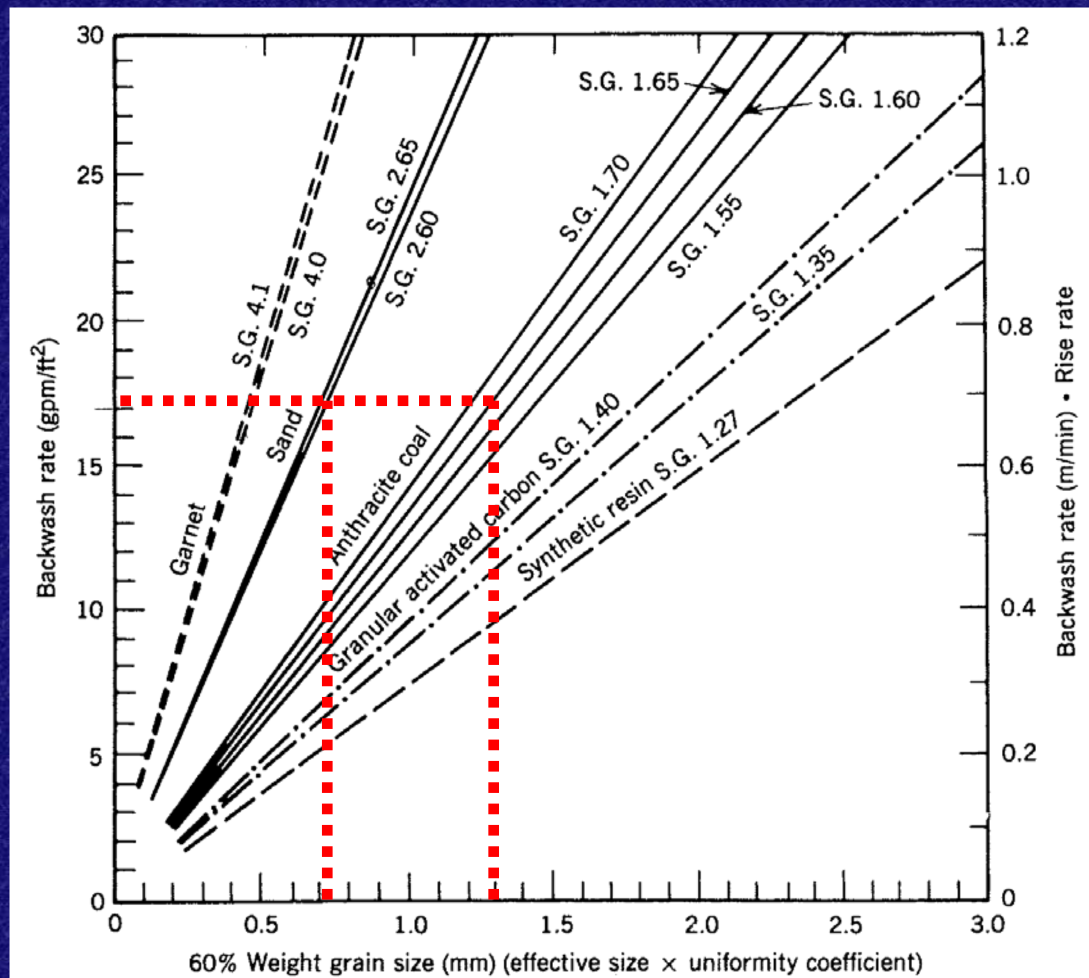
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



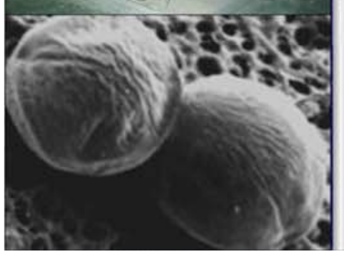
# Appropriate Backwashing Rates



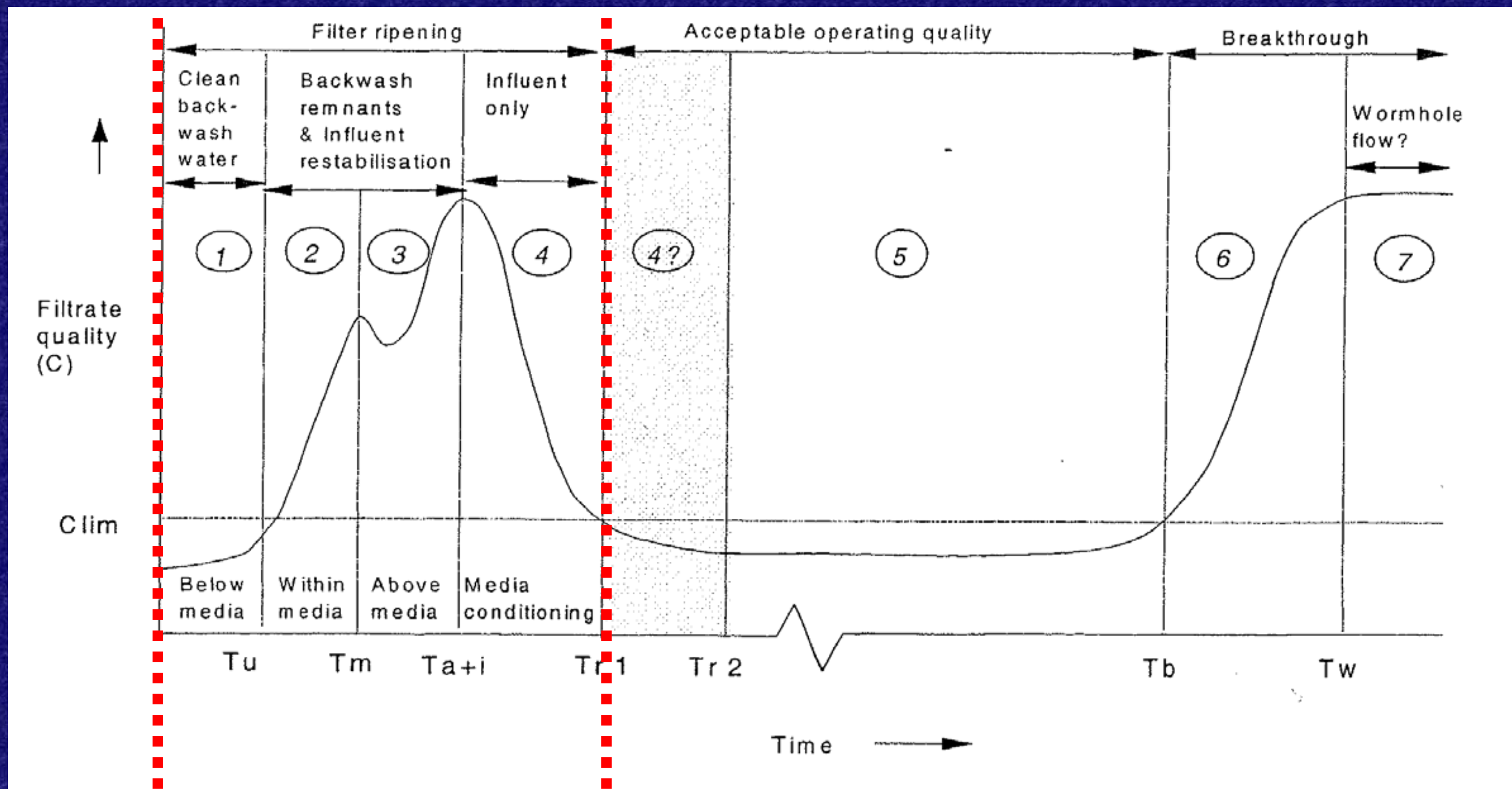

Note: Rates are at 20C, and must be adjusted for other temperatures

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# A Typical Filter Run

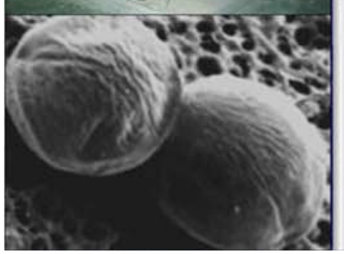



Filter-to-Waste will improve overall filtered water quality

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



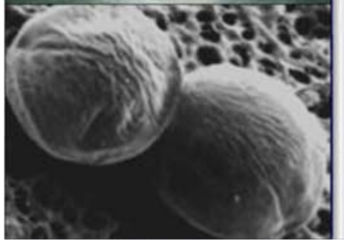


# Granular Media Filtration

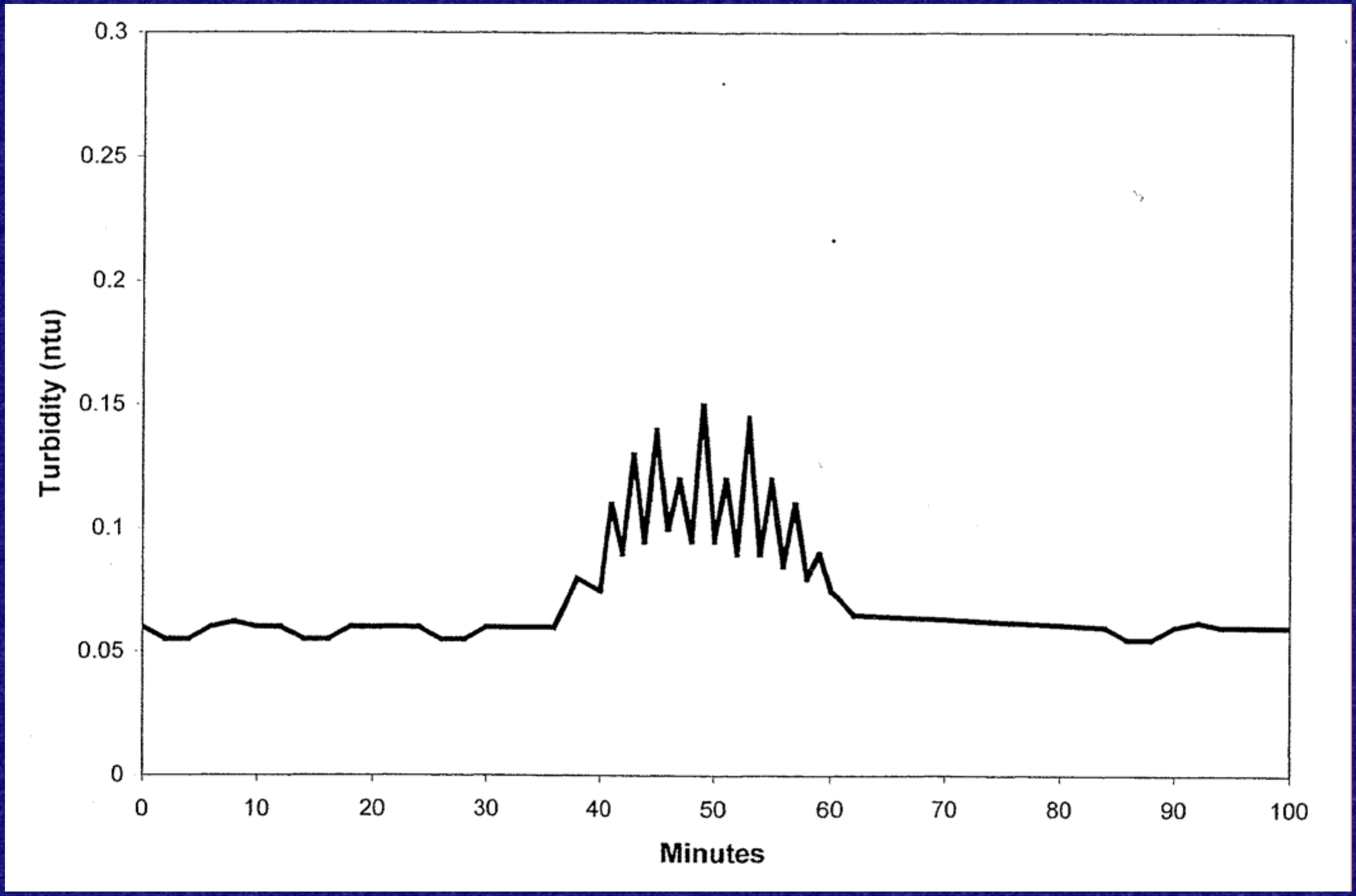
*Common Problems*

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Issues – Valve Hunting

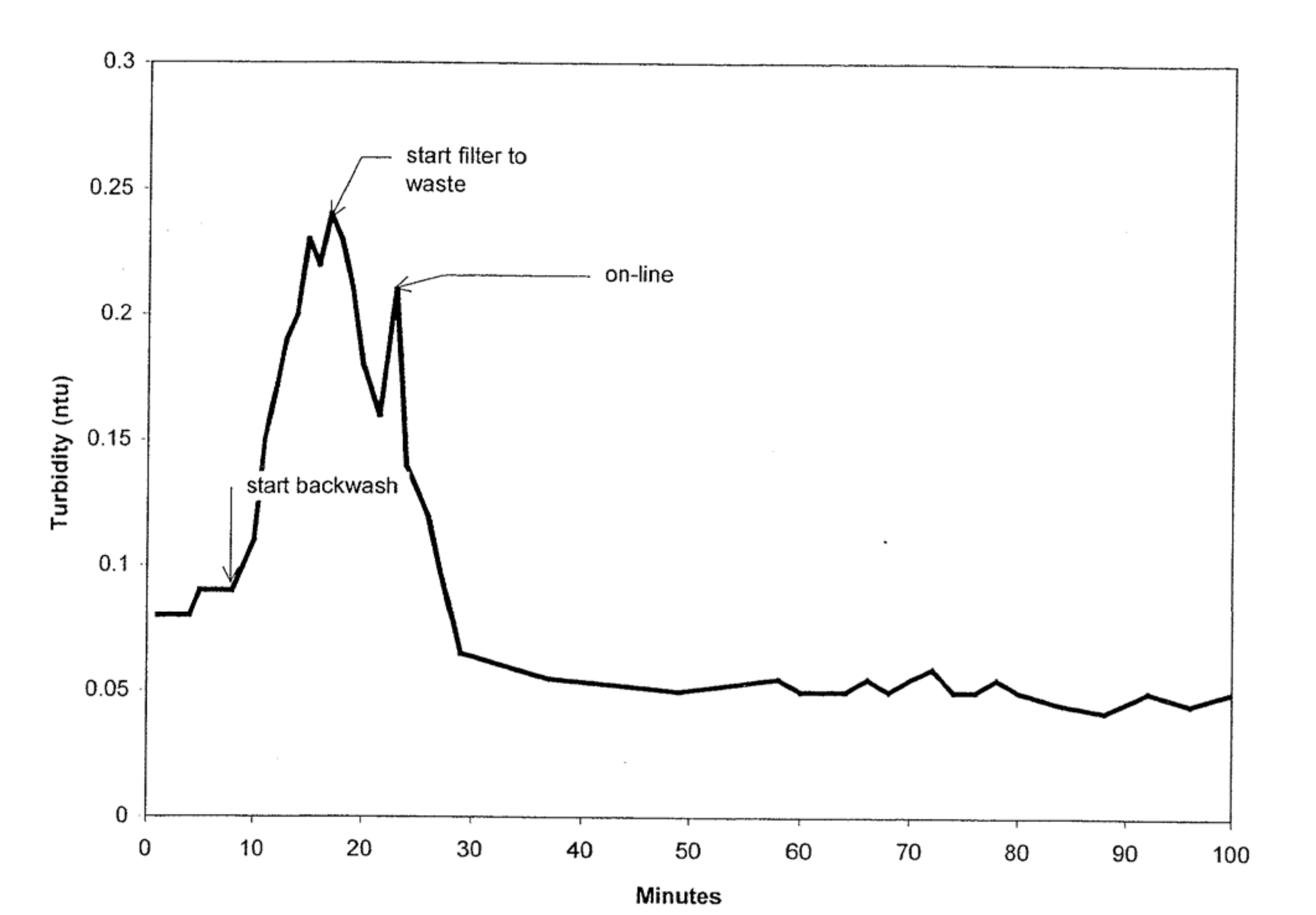


EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

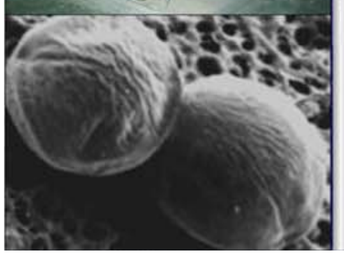
# Filter Issues – Initial Turbidity Spike



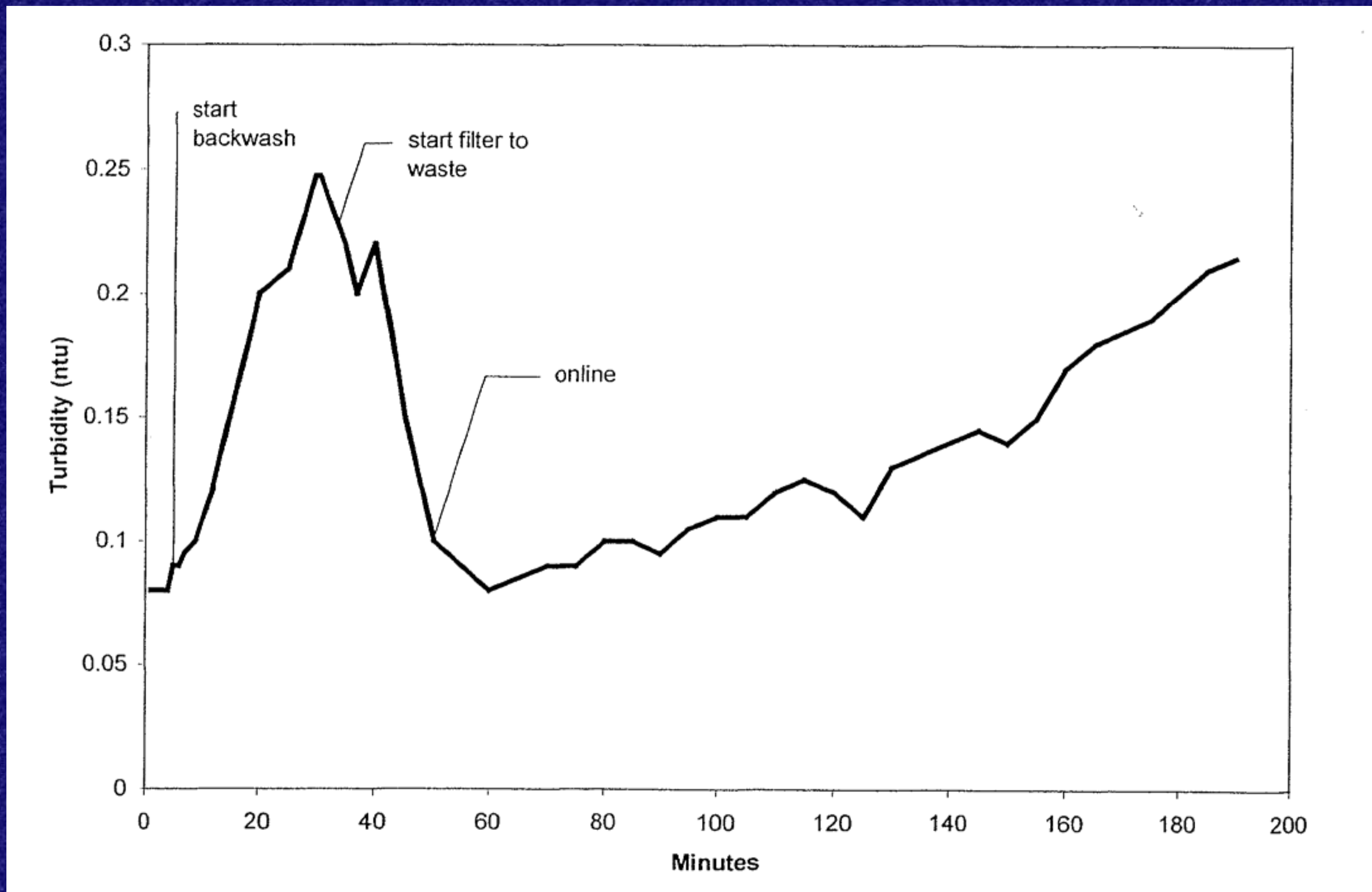
Earth Tech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Issues – Effluent Turbidity "Creep"

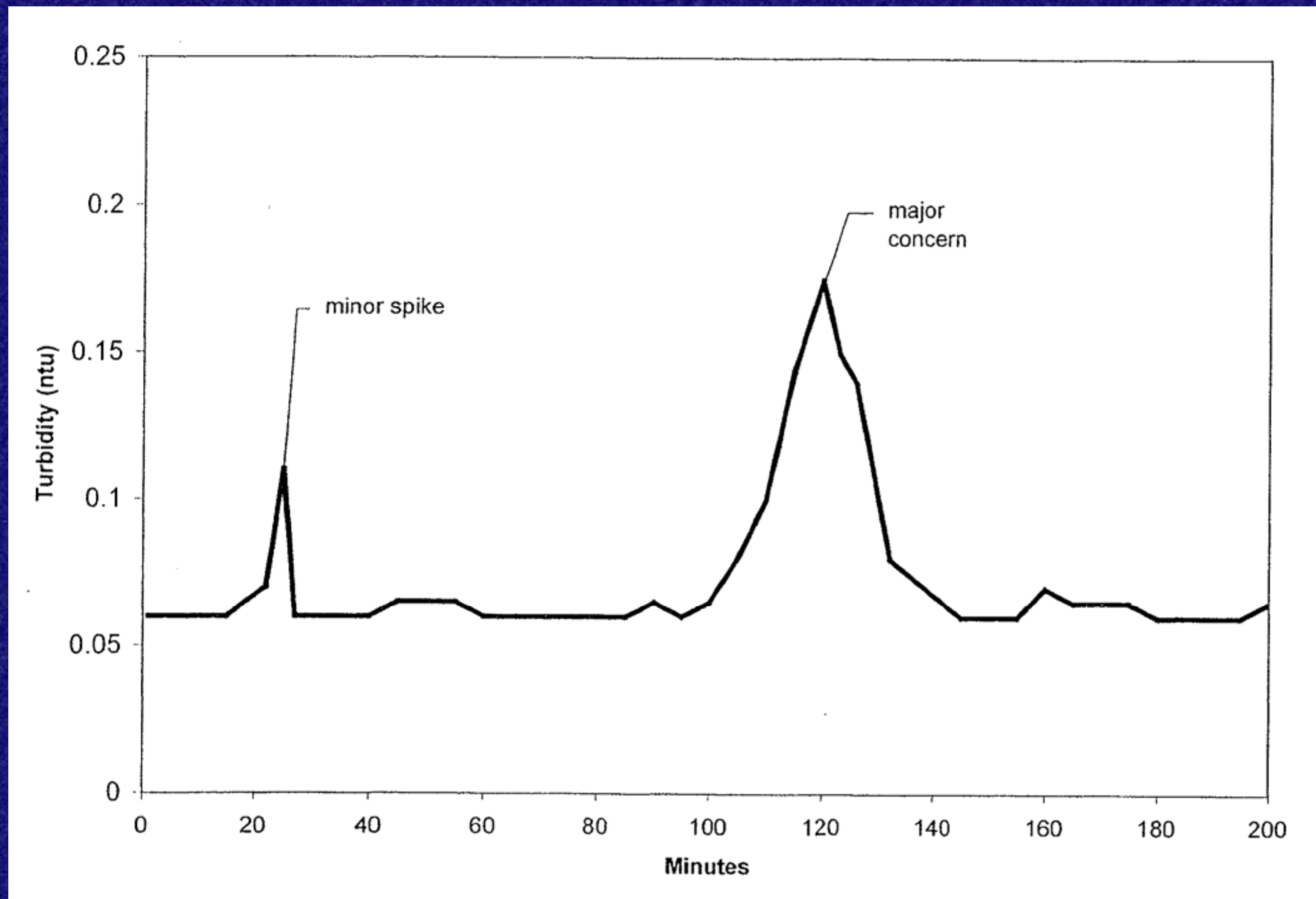


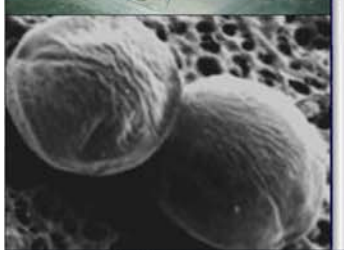
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

# Filter Issues – Spiking during Run

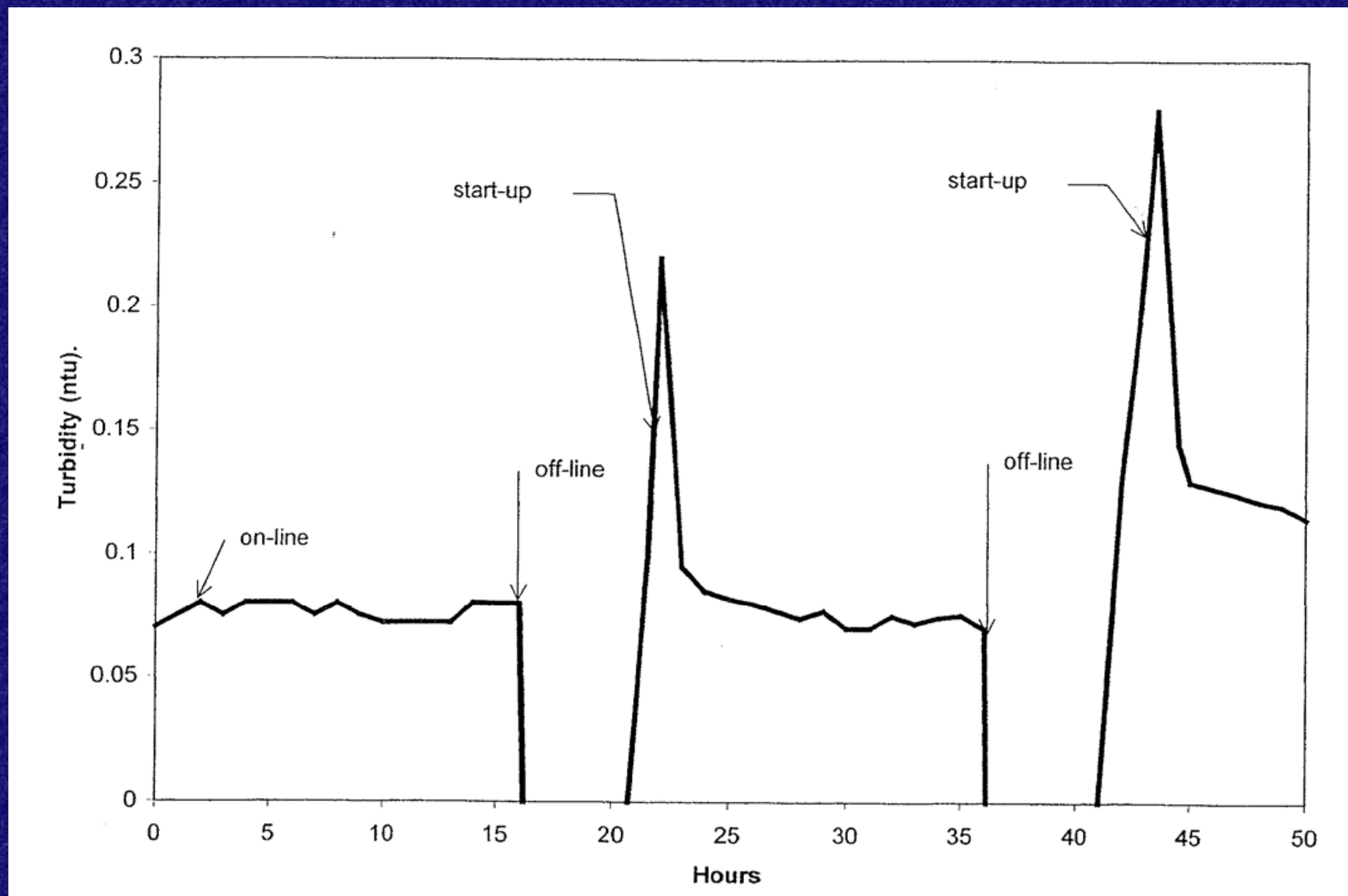


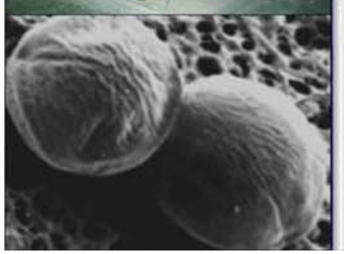



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

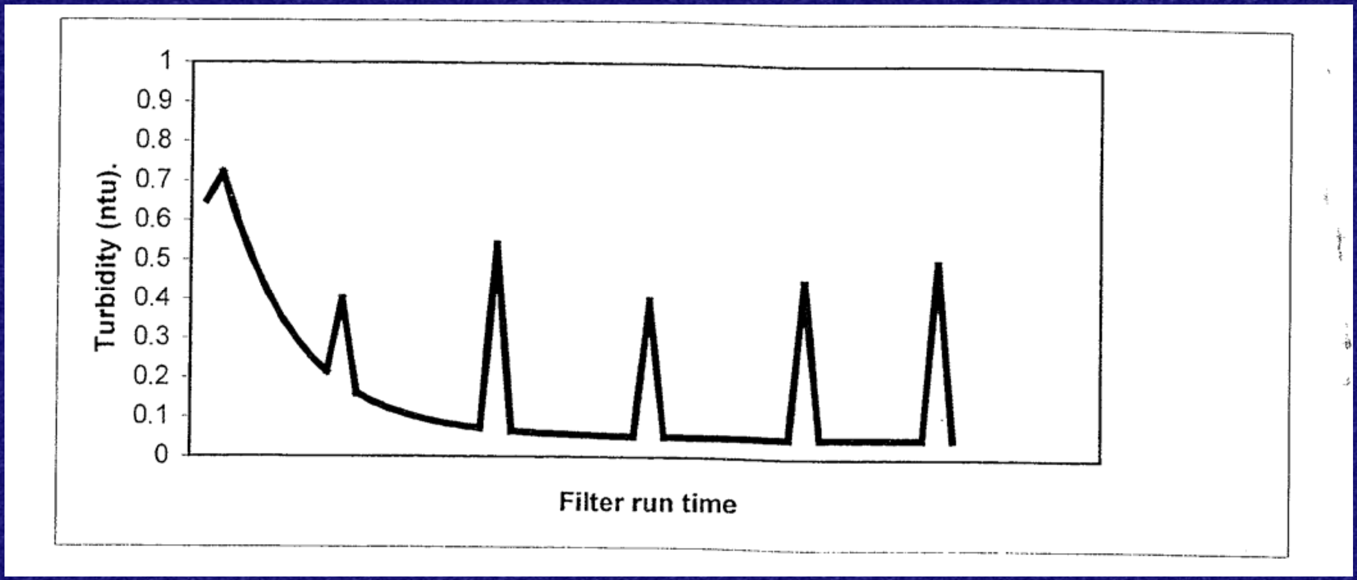
# Filter Issues – Hydraulic “Shock”



# Filter Issues – Spiking during Backwash

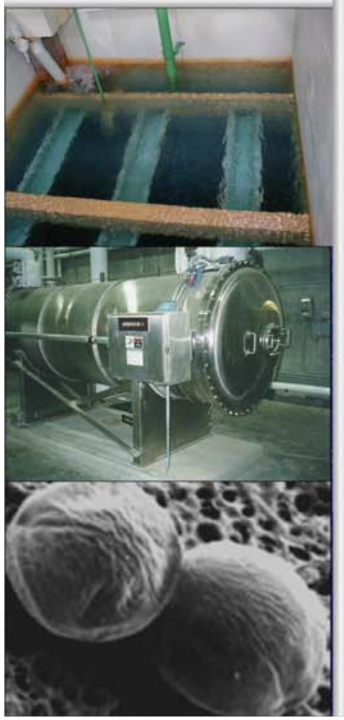
- Backwashing of other filters increases flow to remaining filters
- Short term hydraulic shock dislodges particles





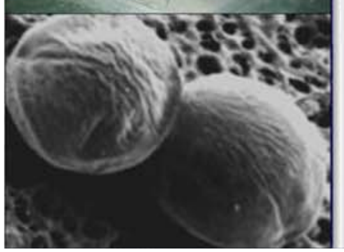

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



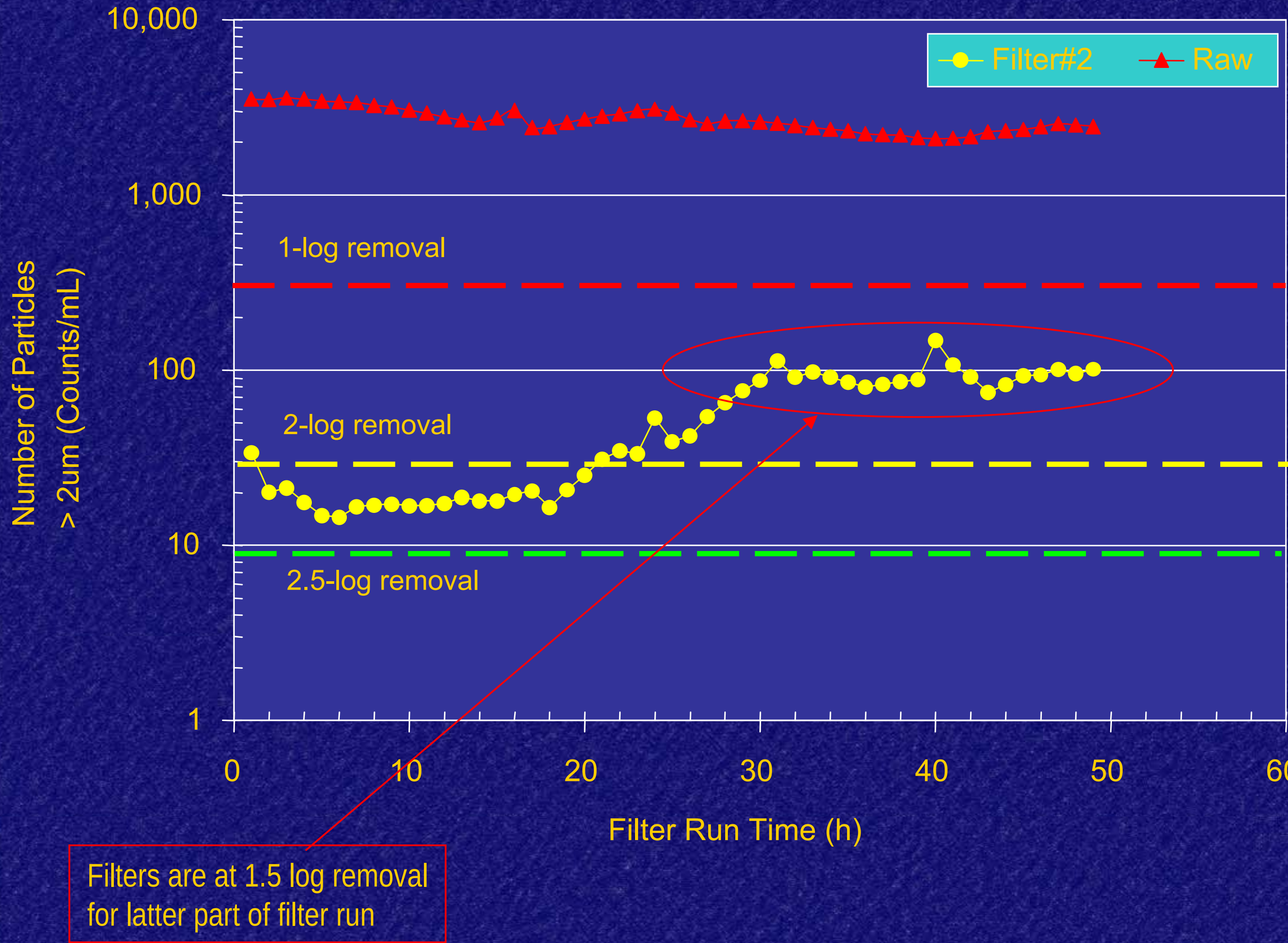
# Premature Particle Breakthrough

- Increases in filtered water particle concentrations are common near the end of a filter run – Well before turbidity breakthrough
- Passage of pathogens may occur before a turbidimeter “notices”
- Particle counting may be a more appropriate trigger for backwashing than turbidity measurements

# Particle Count Data is particularly sensitive for filter monitoring

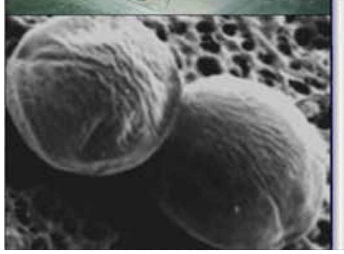
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

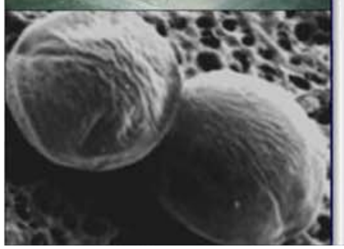


# Common Causes for Poor Filter Performance

- Poor clarifier performance – Excessive solids loading
- Excessive operational loading rates
- Lack of FTW capability
- Sudden changes in flow to filter – Hydraulic "shock"
- Filter media loss or upset
- Filter underdrain damage or failure
- Poor cleaning effectiveness
  - Mudballing
  - Short circuiting

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



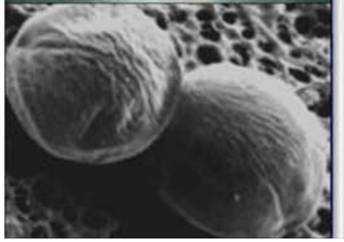
# Granular Media Filtration
*Evaluation & Optimization*

EarthTech
A Tyco International Ltd. Company

ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Granular Media Filters Evaluation Techniques

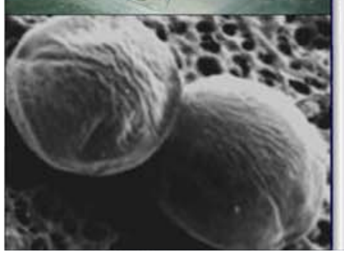
- Visual Inspection
- Filter Surveying
  - Filter Indices
  - Unit Filter Run Volume
  - Filter “Efficiency”
- Filter Core Sampling
- Backwash Waste Characterization
- Floc Retention Profiling
- Backwash Trough Level Check

- Remember – SAFETY FIRST

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



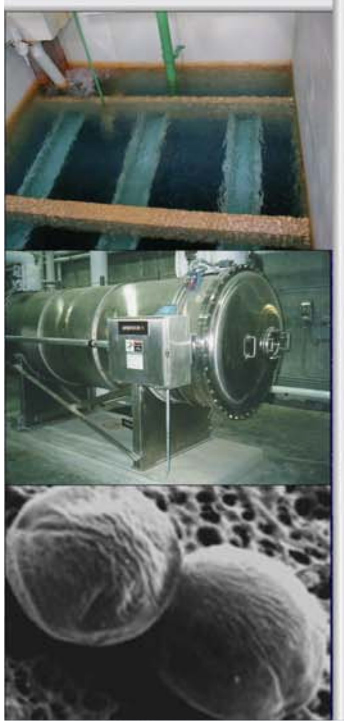
# Filter Evaluation Safety Issues

- Never walk directly on filter media
- Ensure filter is FULLY drained before entering filter box
- Beware of filter appurtenances – Wear a hard hat
- Use a safety harness where applicable, particularly during bed fluidization testing

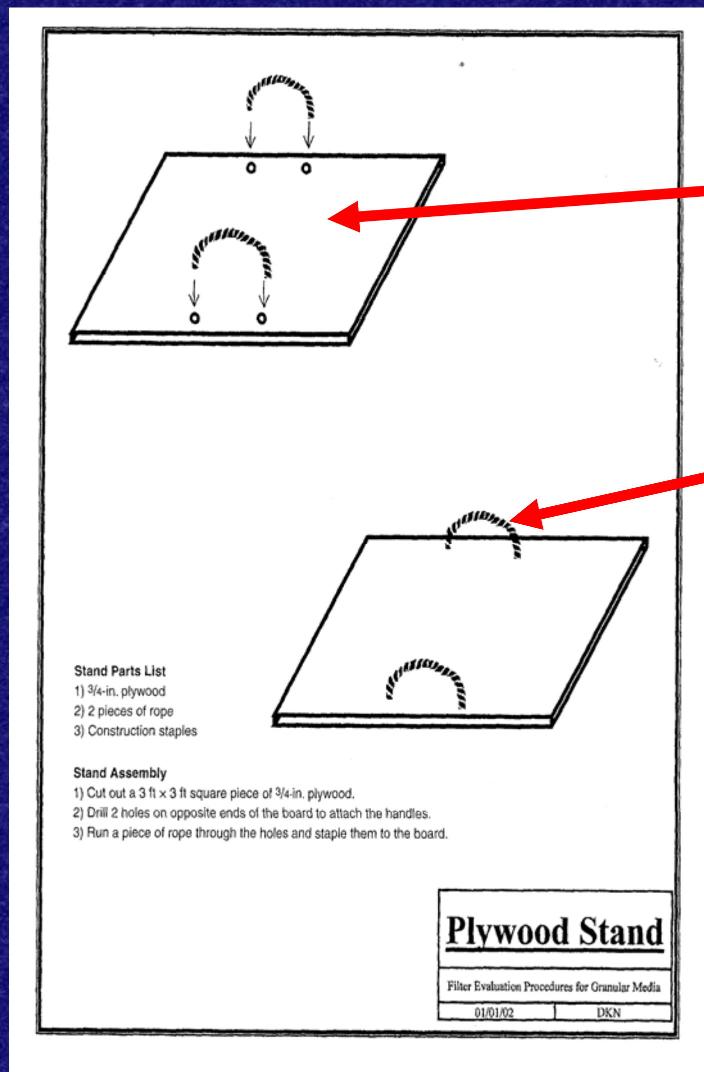
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Homemade Device for Walking on Filter Media



Stand Parts List
1) 3/4-in. plywood
2) 2 pieces of rope
3) Construction staples

Stand Assembly
1) Cut out a 3 ft x 3 ft square piece of 3/4-in. plywood.
2) Drill 2 holes on opposite ends of the board to attach the handles.
3) Run a piece of rope through the holes and staple them to the board.

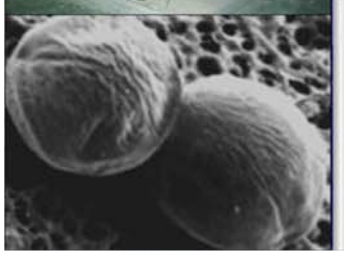
| | |
|---|---|
| Plywood Stand | |
| Filter Evaluation Procedures for Granular Media | |
| 01/01/02 | DKN |

¾” Plywood Sheeting

Rope Handles

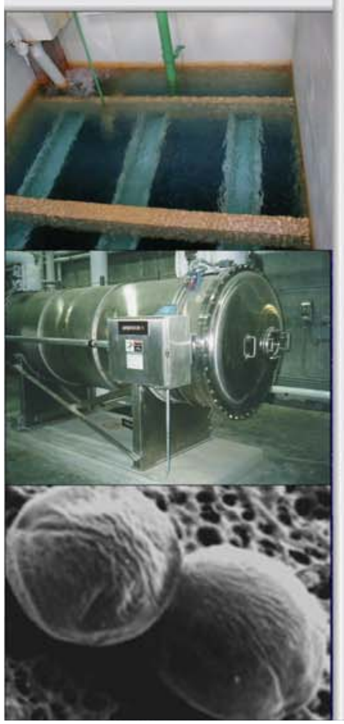
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Indices

- Unit Filter Run Volume (UFRV)
  - A measure of **NET** filter production per unit filter area per filter run
  - UFRV = Filtration Rate (m/hr) x Filter Run (hr)
  - UFRV of 300 – 500 $m^3/m^2$ is desirable
- L/d Ratio
  - Ratio of Filter Bed Depth to Media Nominal Diameter
  - In theory filters with the same L/d should perform equally under similar conditions
  - L/d ratio > 1,000 for conventional filters, > 1,200 if using filter aid
- Filter Efficiency – Similar to UFRV, but accounts for losses as waste. Filters should typically produce 2 – 4 % as waste



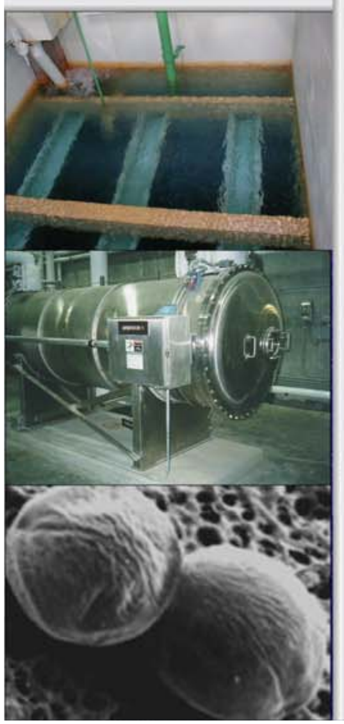
# Visual Observation of Filters

- The first line of defence in filter monitoring and evaluation
- Look for easy to recognize issues:
  - Media boiling during wash
  - Uneven wash distribution
  - Uneven overflow into BW troughs
  - Cratering in media surface
  - Visible mudballs
- Create a map of the filter and track observations for future mitigation

EarthTech
A Tyco International Ltd. Company

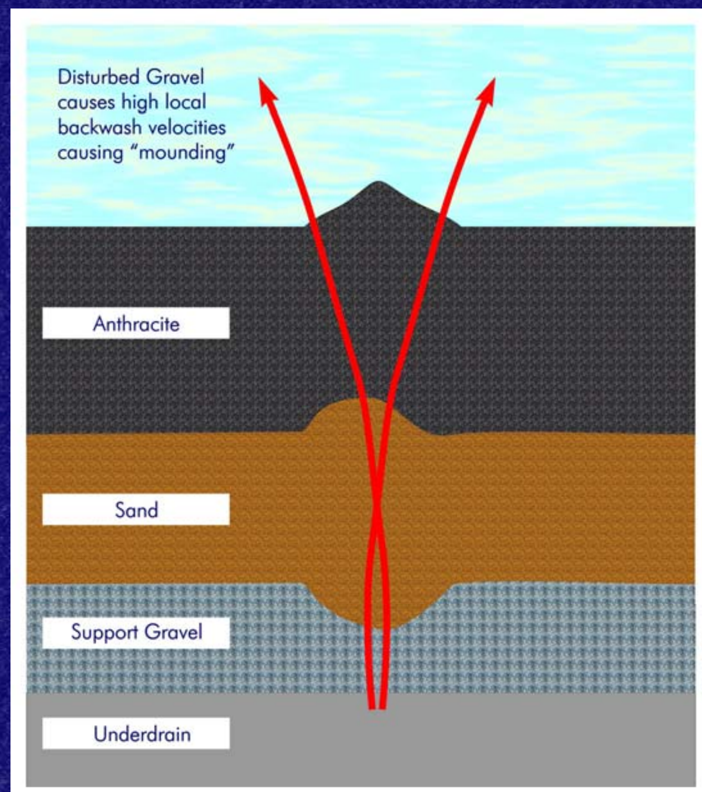
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



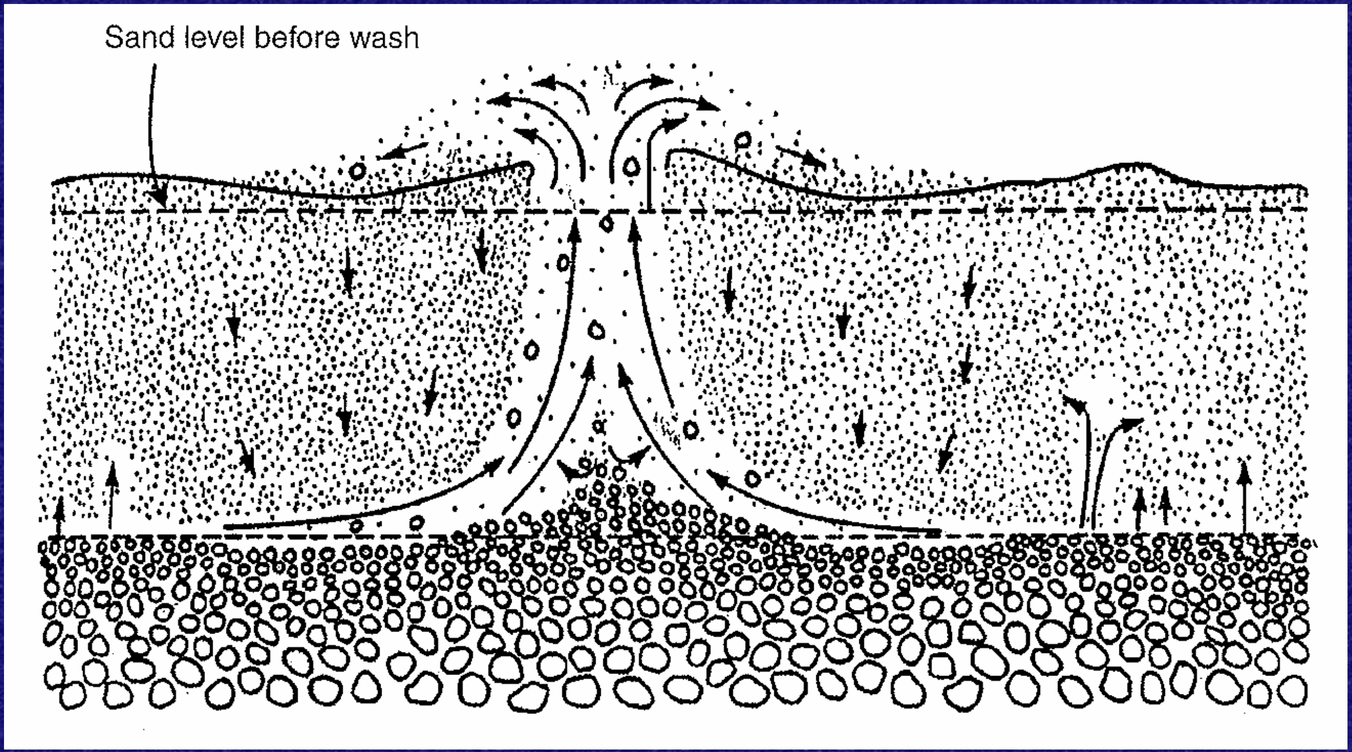
# Visual Inspection - Mounding

- “Mounding” of filter media surface – Suggests possible disturbance in gravel layer – High localized flow



# Filter "Boiling"

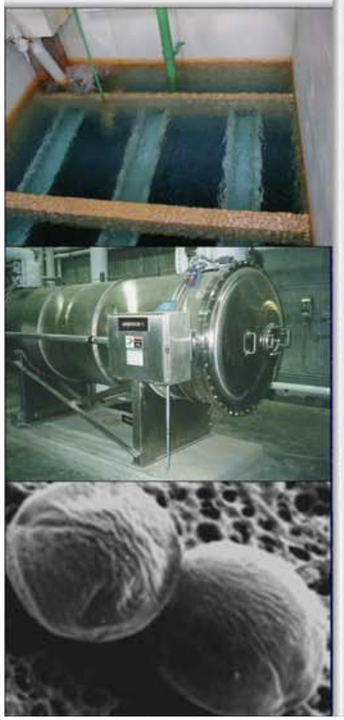
- Boiling is usually clearly visible during the early stages of backwash




EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

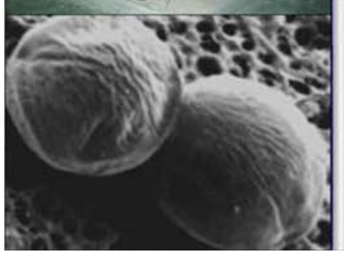
Banff, Alberta
March 15, 2006



EarthTech
A Tyco International Ltd. Company

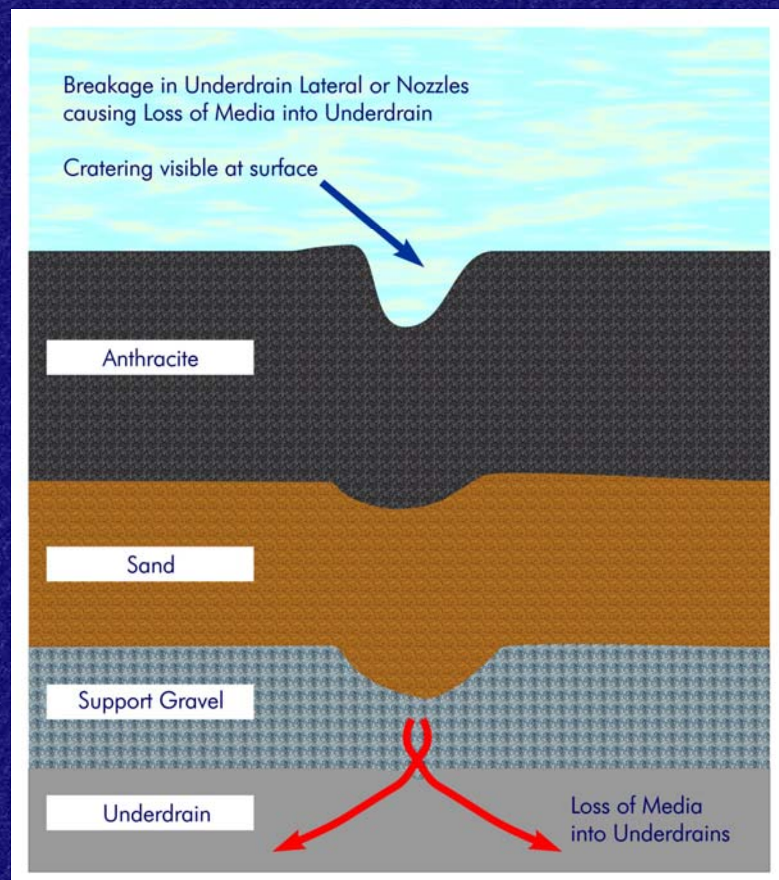
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



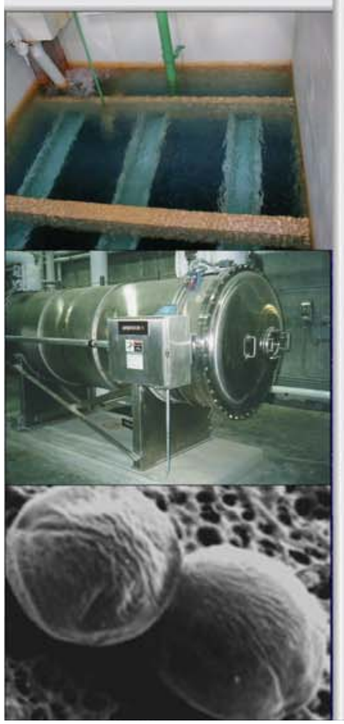
# Visual Inspection - Cratering

- Cratering of filter media surface – Suggests possible damage to underdrain



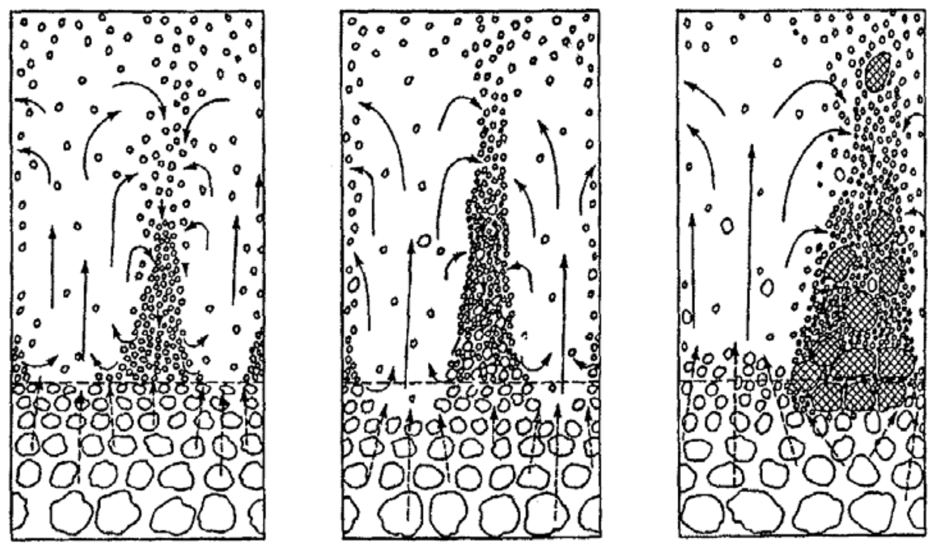
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Visual Inspection - Mudballs

- Insufficient Wash Velocities to remove heavier mud and silts
- Effectively blocks off filter area and increases local loading rates



(a) Newly constructed bed

(b) After several washes

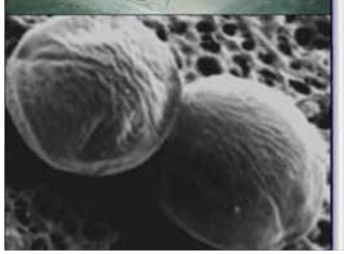
(c) Mudballs forming clogged area

EarthTech
A Tyco International Ltd. Company

ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

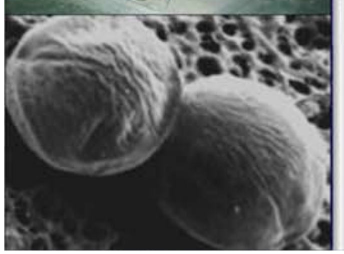


# Visual Inspection – Other Issues

- “Cracking” at media surface
- Sand separation at filter walls
- Visible algae growth
- Filter media in troughs
- Has scaling or fouling changed the backwash characteristics of the media ?
- Depth of Media – Is it uniform ?
- Are the washwater troughs level ?
- Freeboard – Top of media to underside of trough
- Does surface wash effectively reach the corners ?

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



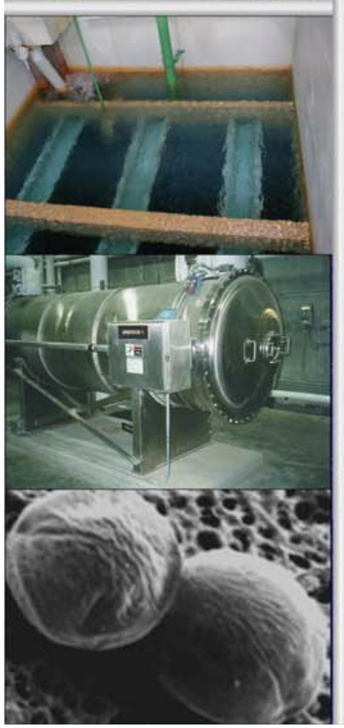
# Detailed Filter Evaluation

- A number of techniques can be used to diagnose filter performance issues
  - Filtration Rate Checking
  - Backwash Rise Rate Checking
  - Floc Retention Profiling
  - Backwash Waste Characterization
  - Gravel profiling
  - Sieve testing of media size
  - Media bed depth checking
  - Bed Fluidization Checking
- Tests are relatively easy, and can use home-made testing equipment

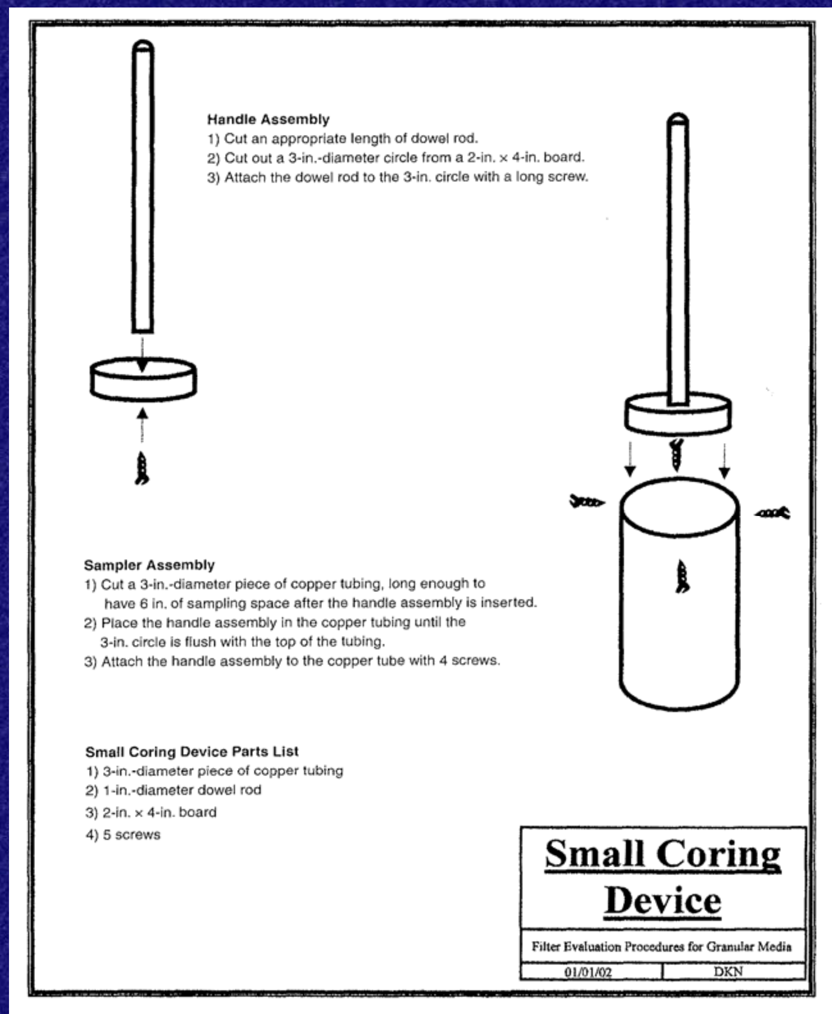
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Core Sampling Coring Device



**Handle Assembly**
1) Cut an appropriate length of dowel rod.
2) Cut out a 3-in.-diameter circle from a 2-in. × 4-in. board.
3) Attach the dowel rod to the 3-in. circle with a long screw.

**Sampler Assembly**
1) Cut a 3-in.-diameter piece of copper tubing, long enough to have 6 in. of sampling space after the handle assembly is inserted.
2) Place the handle assembly in the copper tubing until the 3-in. circle is flush with the top of the tubing.
3) Attach the handle assembly to the copper tube with 4 screws.

**Small Coring Device Parts List**
1) 3-in.-diameter piece of copper tubing
2) 1-in.-diameter dowel rod
3) 2-in. × 4-in. board
4) 5 screws

| Small Coring Device | |
|---|---|
| Filter Evaluation Procedures for Granular Media | |
| 01/01/02 | DKN |

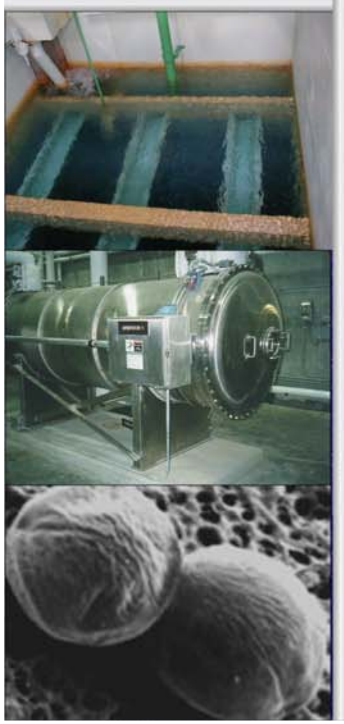
- **Source:** Filter Maintenance & Operations Guidance Manual, AWWARF, 2002

EarthTech
A Tyco International Ltd. Company

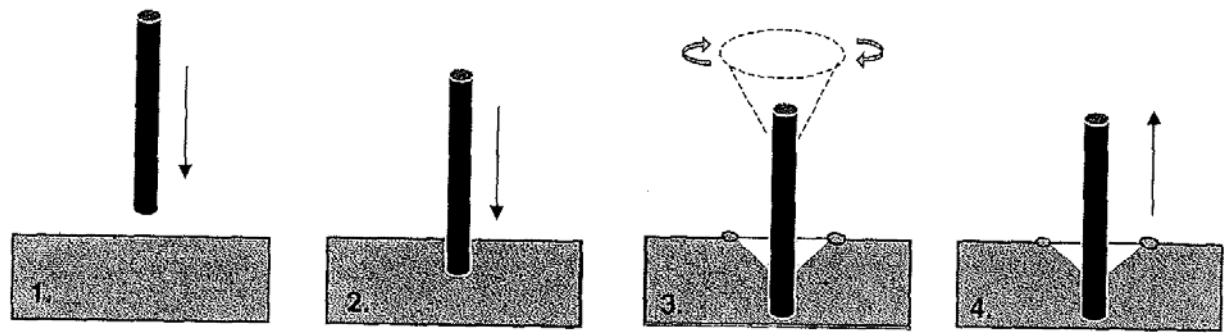
ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION

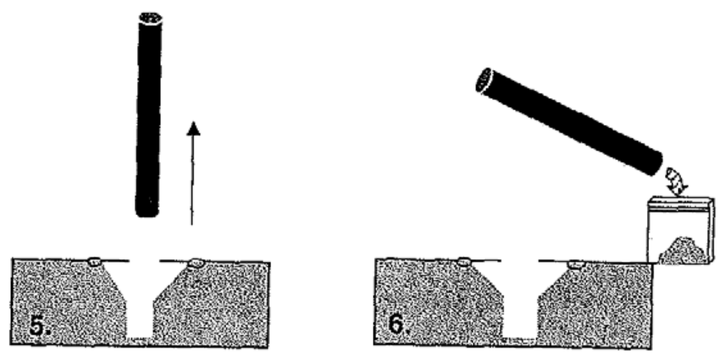
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Core Sampling Procedure



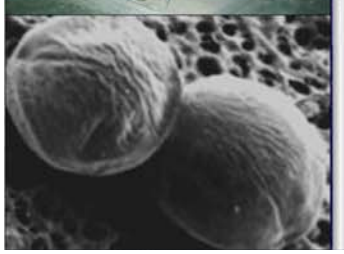




1. Begin by gently pushing the sampler into the media.
2. Push until the sampler is at the desired depth.
3. Gently swivel the top of the sampler to make a cone at the top of the hole.
4. Placing a hand over the top of the sampler, slowly raise it from the hole.
5. Continue to raise the sampler until it is clear of the hole.
6. Empty the contents of the sampler in the correctly labeled bag.

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Backwash Waste Characterization

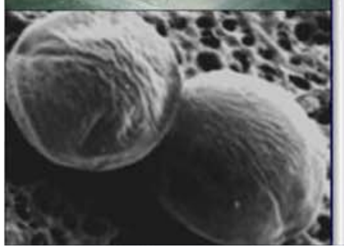
- There is such a thing as over-washing a filter !!!
- Backwash waste characterization can help assess the “right” duration
- Perform timed sampling of backwash waste to determine solids content
- Use data to asses when to terminate washing
- May allow reduction in water wastage, and residuals volumes

EarthTech
A Tyco International Ltd. Company

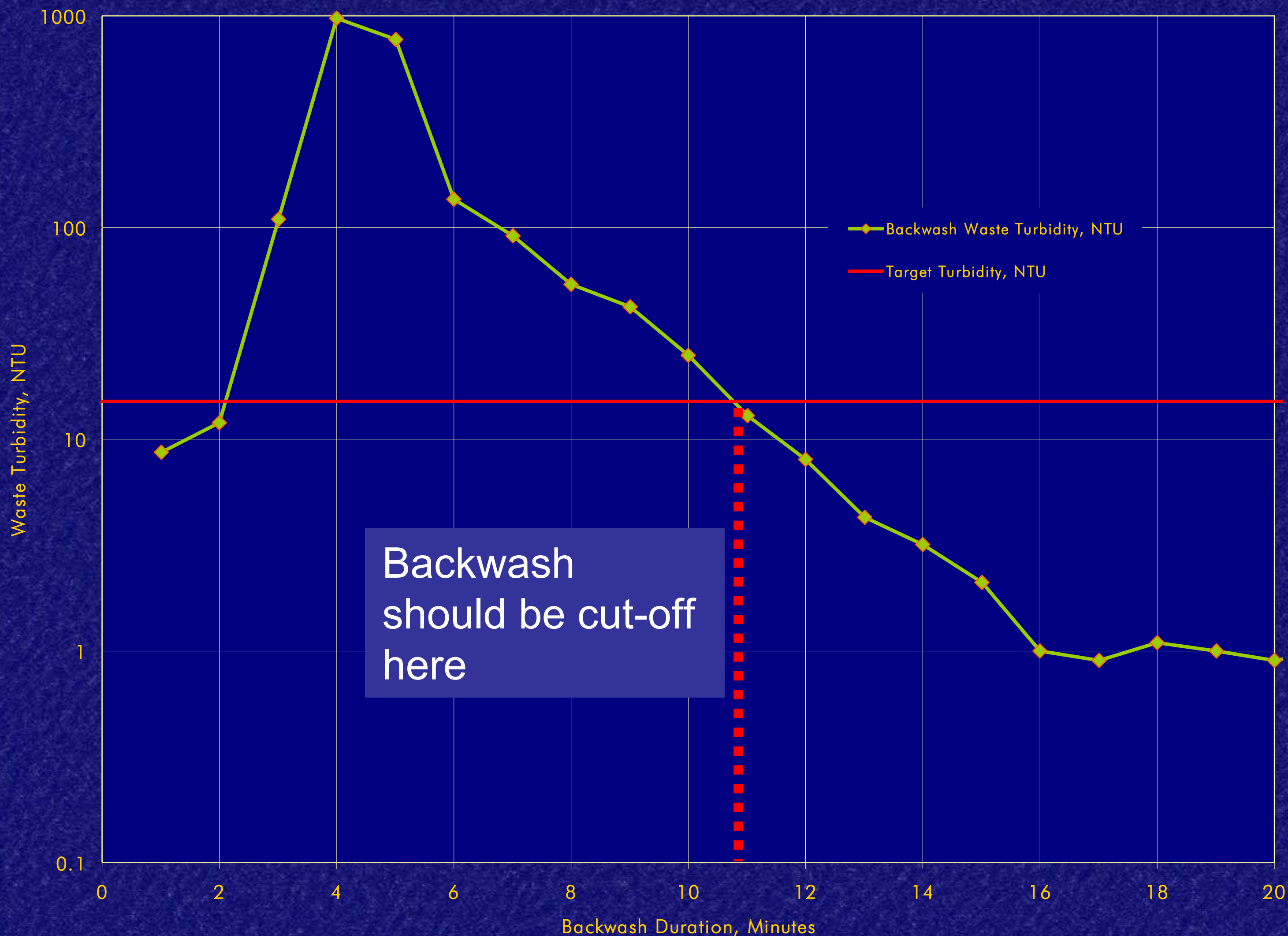
"ALBERTA WATER AND WASTEWATER OPERATORS ASSOCIATION"

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

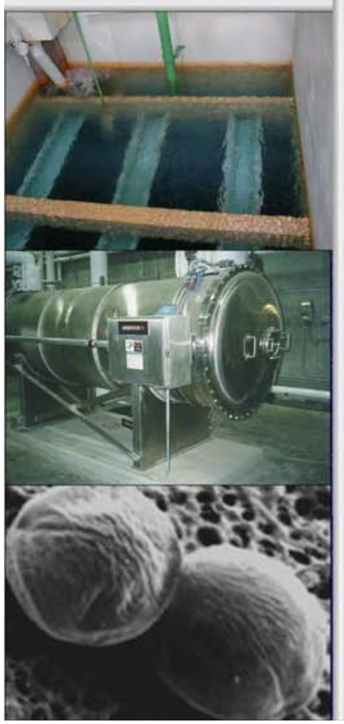


# Typical Waste Evaluation



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



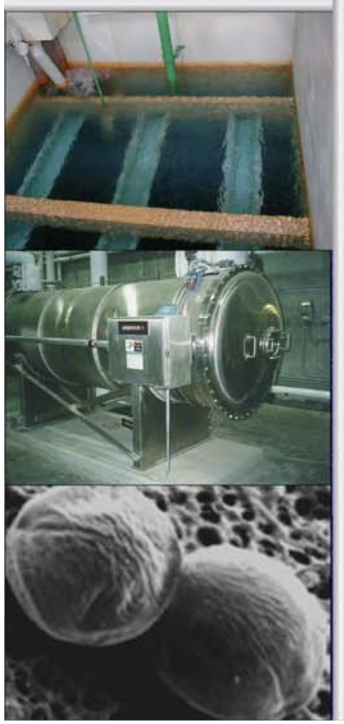
# Floc Retention Profiling

- Take a core sample
- Sub-divide the core into depth fractions
- Rinse each fraction using a known volume of water, to clean solids off the media
- Measure turbidity in each fraction, before and after washing of filter
- Measures how well solids are being removed from the bed

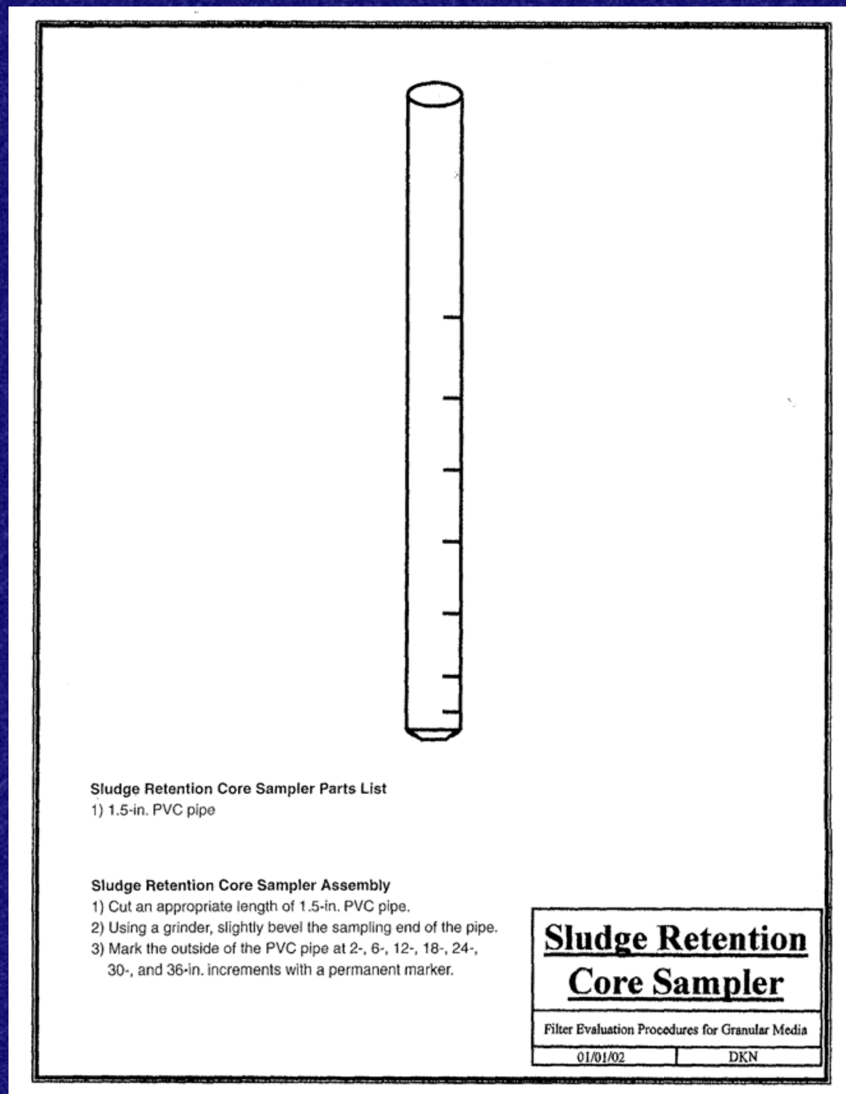
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Floc Retention Profile Sampler



Sludge Retention Core Sampler Parts List
1) 1.5-in. PVC pipe

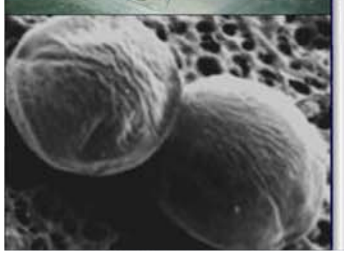
Sludge Retention Core Sampler Assembly
1) Cut an appropriate length of 1.5-in. PVC pipe.
2) Using a grinder, slightly bevel the sampling end of the pipe.
3) Mark the outside of the PVC pipe at 2-, 6-, 12-, 18-, 24-, 30-, and 36-in. increments with a permanent marker.

| | |
|---|---|
| Sludge Retention Core Sampler | |
| Filter Evaluation Procedures for Granular Media | |
| 01/01/02 | DKN |

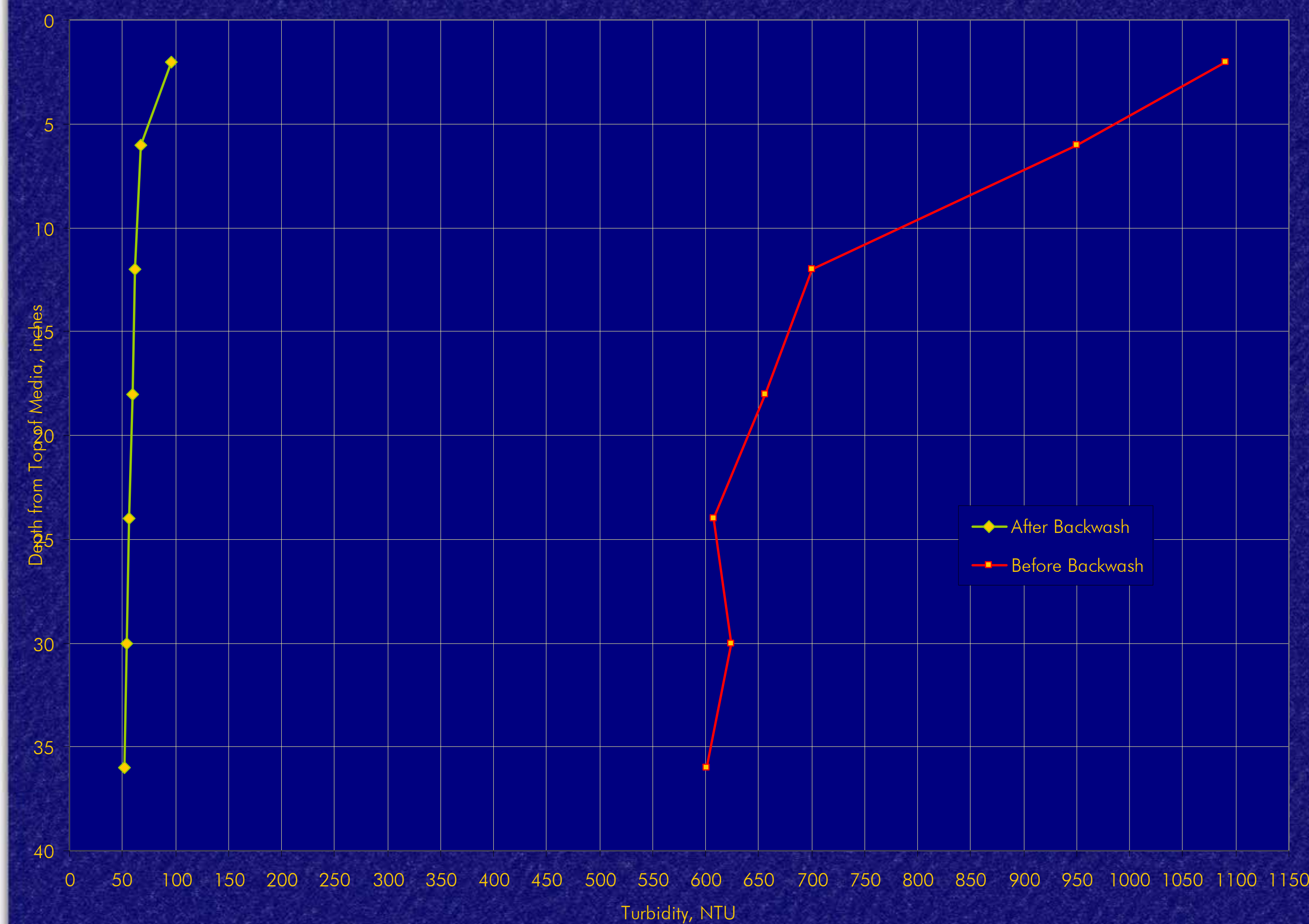
- **Source:** Filter Maintenance & Operations Guidance Manual, AWWARF, 2002

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

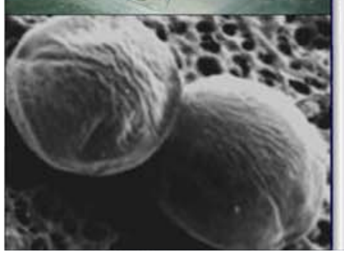


# Floc Retention Profile Graph



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

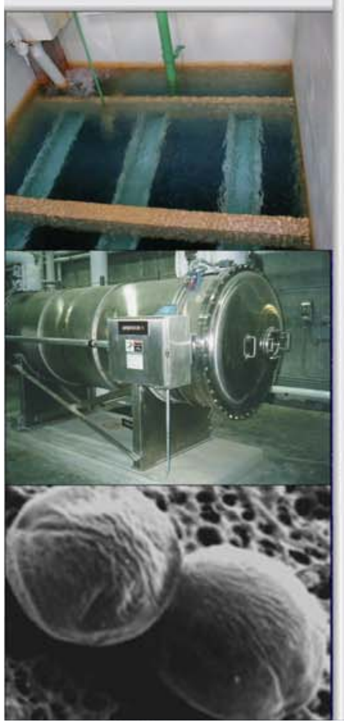


# Floc Retention Profile Results

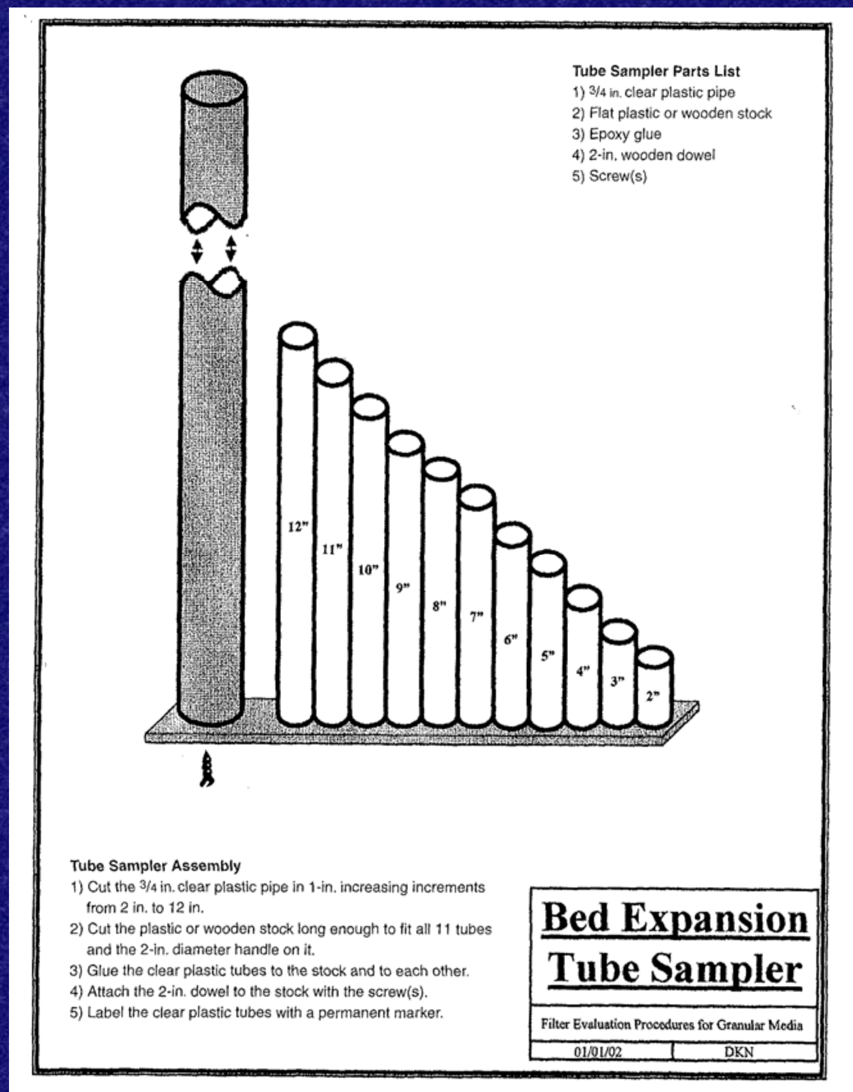
| Turbidity, NTU | Filter Media Condition |
|---|---|
| 0 - 30 NTU | Clean - Unripened filter – Long ripening time |
| 30 - 60 NTU | Clean - Ripened Filter |
| 60 - 120 NTU | Slightly dirty, Still OK |
| 120 - 300 NTU | Dirty - Re-Evaluate Backwashing |
| > 300 NTU | Mudball Problems |

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Filter Bed Fluidization Testing Equipment

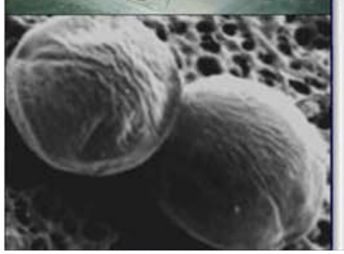



- **Source:** Filter Maintenance & Operations Guidance Manual, AWWARF, 2002

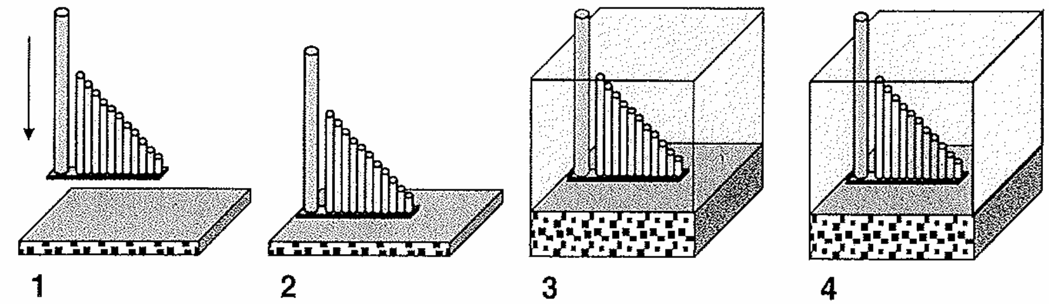
EarthTech
A Tyco International Ltd. Company

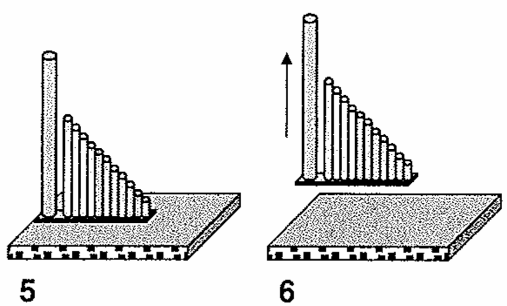
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Bed Fluidization Protocol

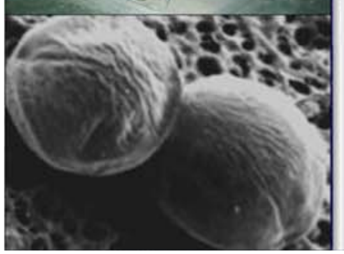




1. Lower the tube sampler onto the filter surface.
2. Once it is resting on the surface, tightly secure the sampler to a stationary object.
3. Initiate a filter backwash.
4. The tubes will begin to fill with media during the backwash.
5. Terminate the backwash at its standard time.
6. Withdraw the tube sampler and record the tallest tube that is full of media.

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



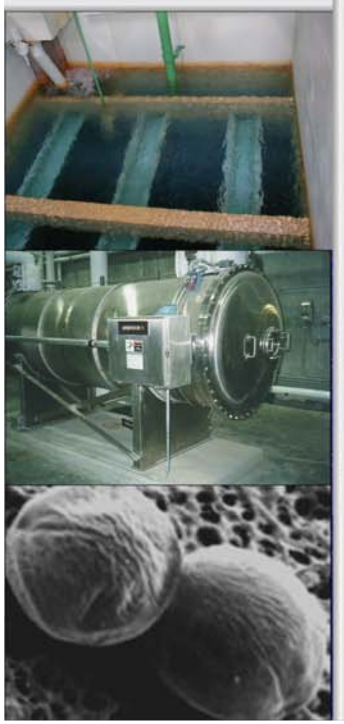
# Compare backwash rate and fluidization

| Backwash Flow Rate | Bed Expansion | Notes |
|---|---|---|
| Below required | < 20% | Increase backwash rate and repeat test |
| Below required | 20 - 30% | Increase backwash rate and repeat test |
| Below required | > 30% | Check water temperature |
| Correct Flow | < 20% | Check for Polymer Buildup on Filter |
| Correct Flow | 20 - 30% | No Action Required |
| Correct Flow | > 30% | Check Media Specs. |
| Above Required | < 20% | Check for Polymer Buildup on Filter |
| Above Required | 20 - 30% | Check for Polymer Buildup on Filter |
| Above Required | > 30% | Reduce Backwash Rate and Repeat Test |

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

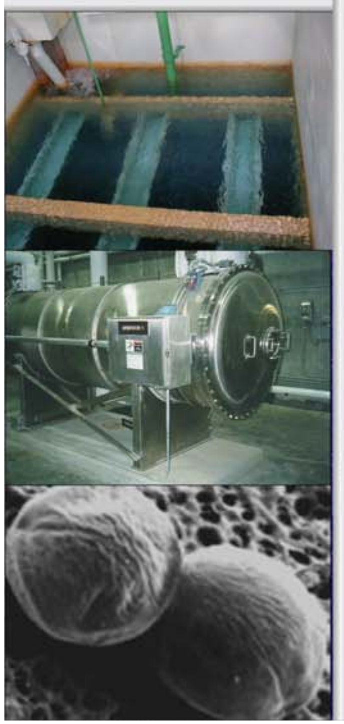
Banff, Alberta
March 15, 2006



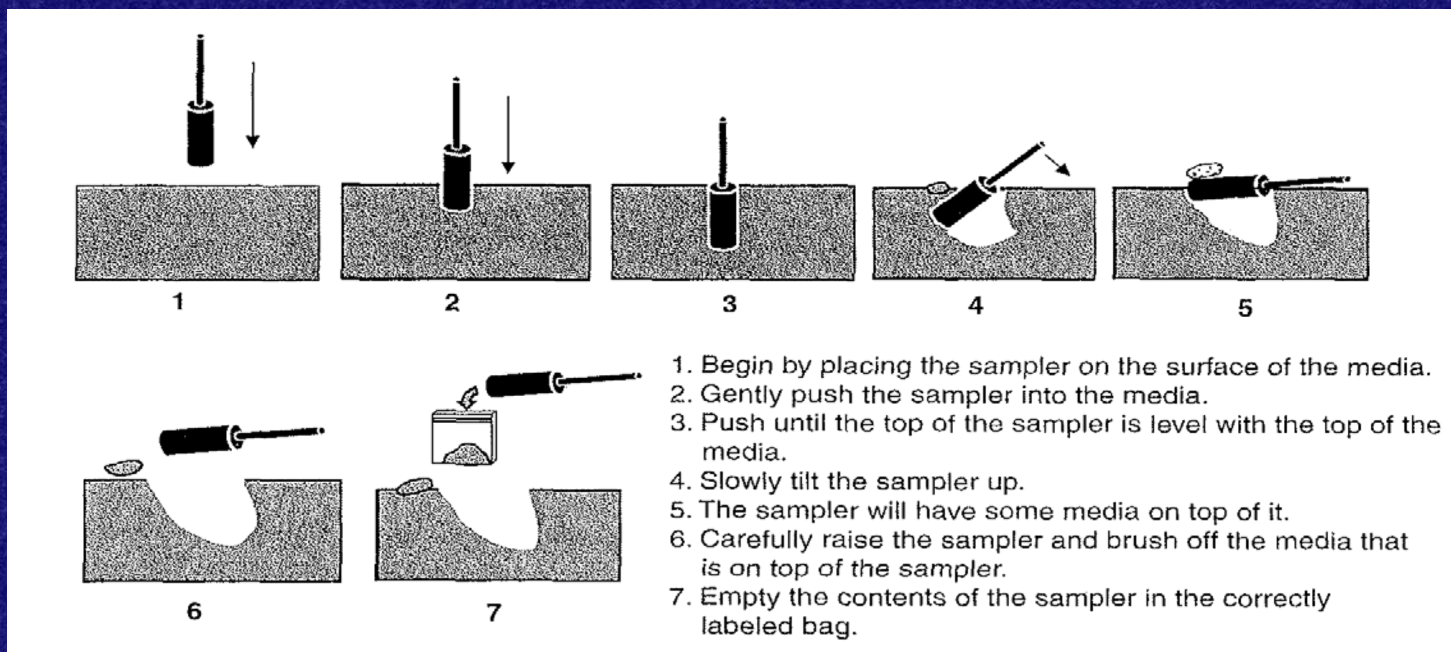
# Mudball Analysis

- Used to physically determine the extent of filter mudballing due to chronic underwashing
- Collect 6” Core Samples
- **Gently** sieve the samples to separate mudballs from media
- Place mudballs into a 250 mL graduated cylinder

| Percent Mudballs | Filter Condition |
|---|---|
| 0 - 0.1% | Excellent |
| 0.1 - 0.2% | Very good |
| 0.2 - 0.5% | Good |
| 0.5 - 1.0% | Fair |
| 1.0 - 2.5% | Fairly Bad |
| 2.5 - 5% | Bad |
| Over 5% | Very Bad |



# Mudball Sampling Protocol



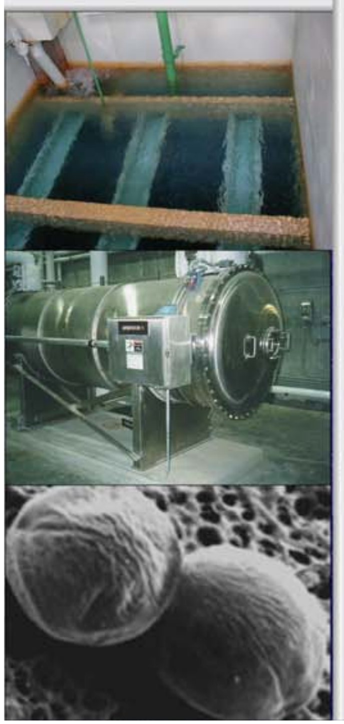

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

EarthTech
A Tyco International Ltd. Company

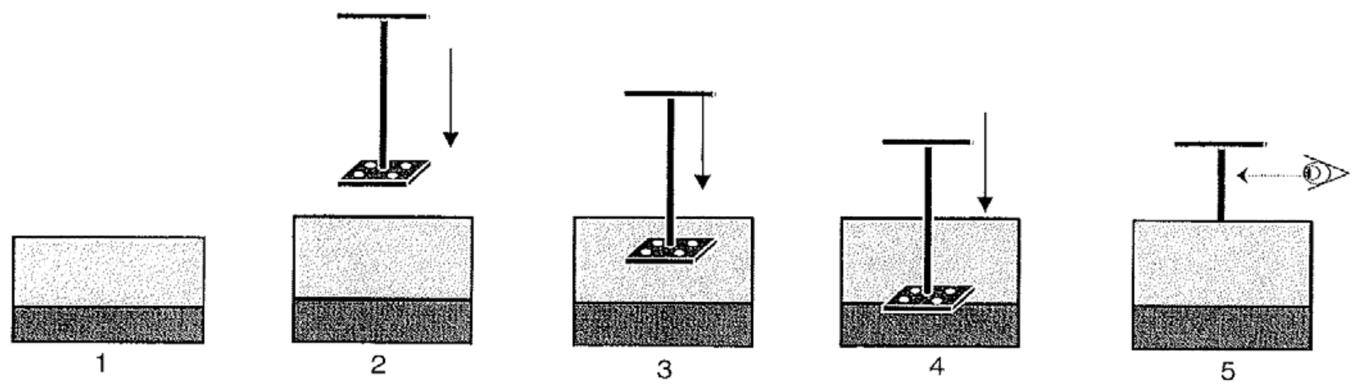
AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Gravel Profiling

- Manual measurement of gravel depth at various locations in the filter
- Variation should be no more than ± 25 mm

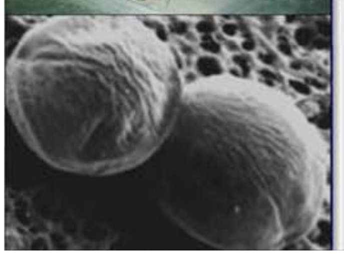



1. Determine the sampling area.
2. Begin the backwash and start to lower the punch plate into the fluidized media.
3. Continue to press the punch plate down through the media, until ...
4. ... it comes to rest on the gravel layer.
5. Take a reading off of the punch plate and move to the next location.

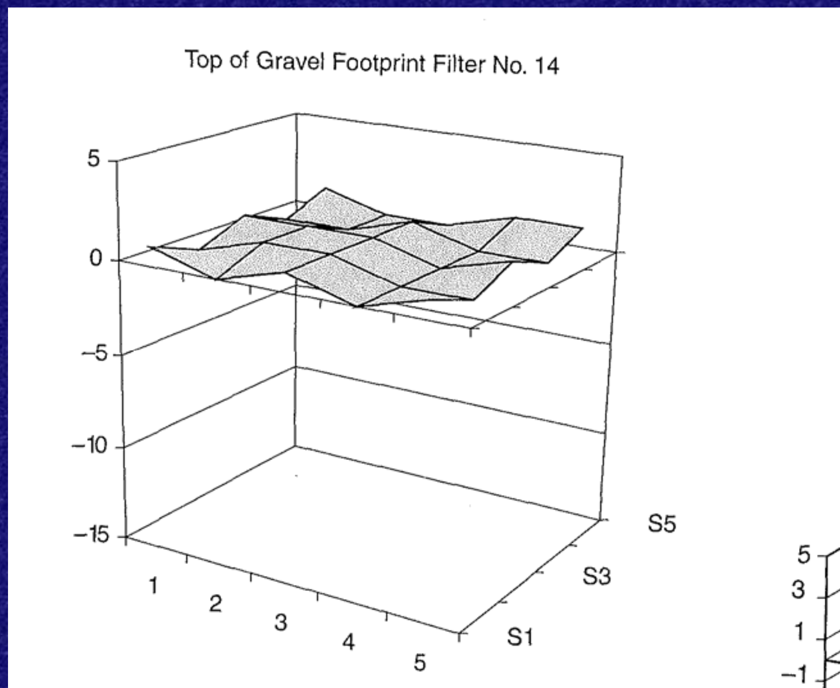
EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

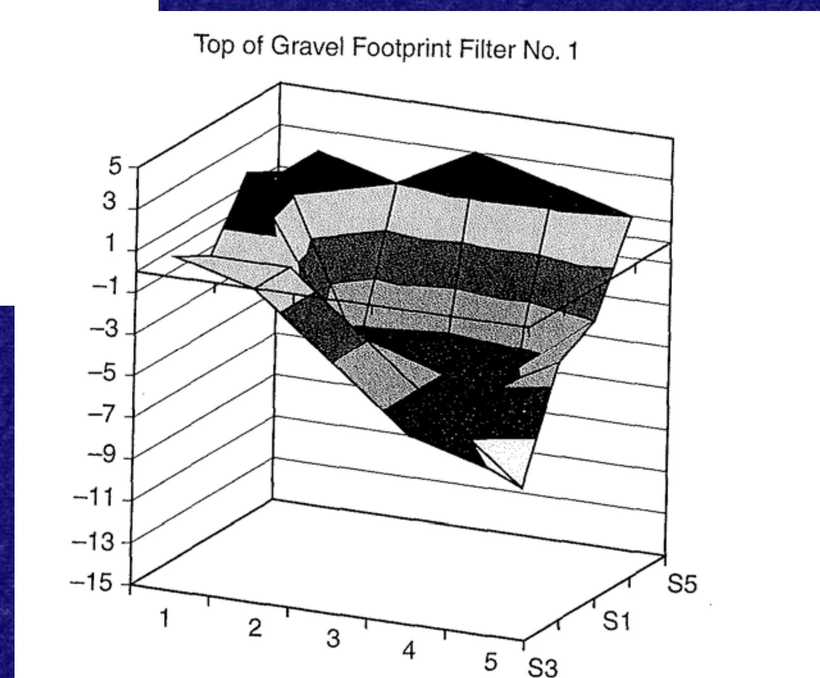
Banff, Alberta
March 15, 2006



# Gravel Profile Examples



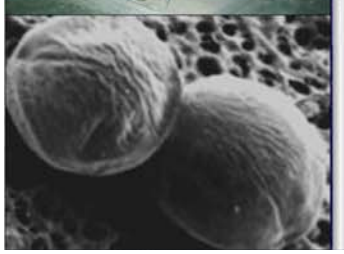

**Good**




**Severe**

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006

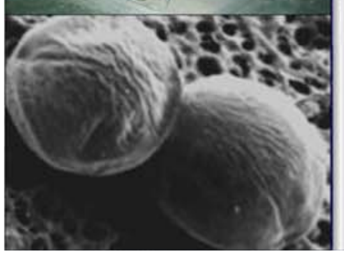


# Possible Solutions for Poor Filter Performance

- Optimization of Filter Backwashing
  - Even distribution of flow
  - Selection of Appropriate Wash Rates
  - Levelling of Wash Trough Crests
  - Air Scour
  - Surface Wash
- Addition to Filter-to-Waste
- Use of filter aid polymers
- Addition of coagulant or other chemicals to backwash water

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



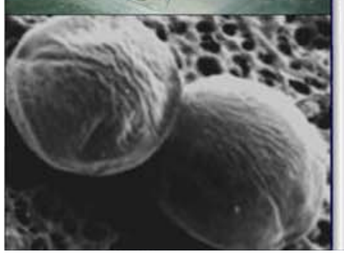
# Dealing with badly fouled media

- Filters which exhibit significant fouling problems, mudballing, cracking, etc. are very difficult to rectify
- Lancing is a possible solution, but be very careful if support gravel is in place
- Replacement of the media may be the only solution

EarthTech
A Tyco International Ltd. Company

AWWOA Annual Seminar

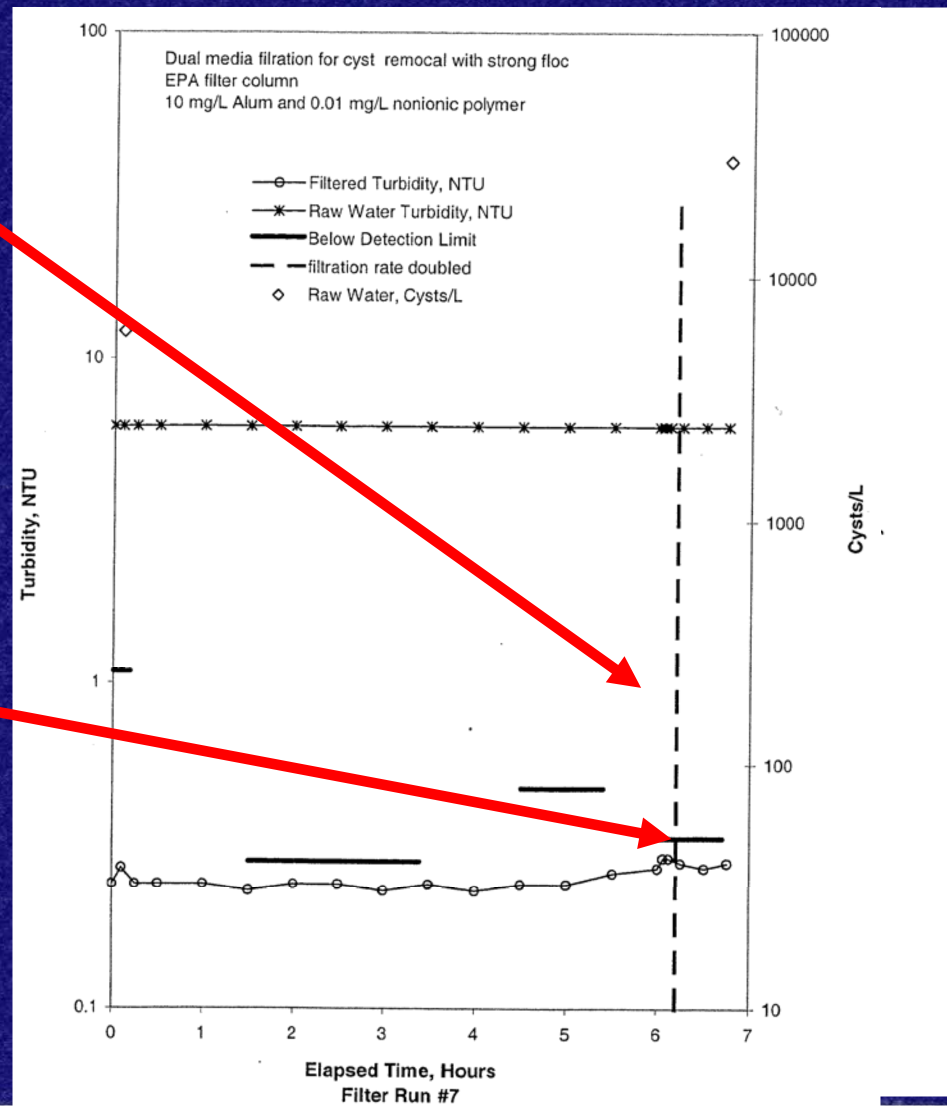
Banff, Alberta
March 15, 2006



# Filter Aid Polymer can reduce turbidity spiking

- Note turbidity spike due to flow change

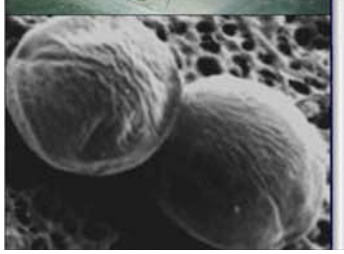
- Use of filter aid strengthens floc, and eliminates spiking



AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



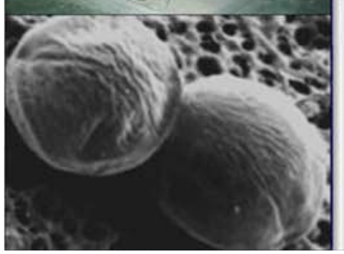


# Excellent Resources

- AWWA Std. M37 – "**Operational Control of Coagulation and Filtration Processes**", 2000
- AWWARF, "**Filter Maintenance and Operations Guidance Manual**", 2002
- AWWARF, "**Self Assessment Guide for Surface WTP Optimization**", 1997
- AWWA, "**Filter Evaluation Procedures for Granular Media**", 2002
- AWWARF, "**Design & Operation Guidelines for Optimization of the High-Rate Filtration Process – Plant Survey Results**", 1989
- AWWA, "**Filter Troubleshooting & Design Handbook**", 2005

AWWOA Annual Seminar

Banff, Alberta
March 15, 2006



# Questions ??


Contact: Simon Breese, M.A.Sc., P.Eng.

Technical Practice Leader, Drinking Water, Earth Tech

simon.breese@earthtech.ca

(519) 570-2102