Coagulation, Flocculation, Sedimentation, and Filtration

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Coagulation, Flocculation, Sedimentation, and Filtration

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ENVIRONMENTAL, HEALTH, AND SAFETY TRAINING

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Process Training Session

- Before class starts, please sign in on the attendance sheet
- During class, please:
  - Asks questions as we discuss water treatment processes
  - Feel free to get up and leave the classroom at any time (i.e., rest rooms, make phone calls, etc.)
- After class, please fill out a class evaluation form

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Ice Breaker

- Before we start, let's introduce ourselves.
  - Name,
  - What do you do, and
  - What are your training needs?

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Water Treatment - Overview

All Surface Water Treatment Plants:

- ✔ Are subject to Surface Water Treatment Rule (SDWA, Subpart H) requirements for:
  - ➢ Filtration
  - ➢ Disinfection
- ✔ Are dependent on coagulation, flocculation, (sedimentation) and filtration techniques to meet drinking water standards
- ✔ Are subject to Enhanced Surface Water Treatment Rule requirements for Cryptosporidium removals

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Introduction

Definitions

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DEFINITIONS

– COAGULANTS
- Chemicals used to produce unstable particles and to react with turbidity to form larger particles. One can use more than one coagulant e.g., metal (Al or Fe) salts and high charge density polymers. Both are coagulants or dual coagulants.

– FLOCCULANT AIDS
- High Molecular Weight Organic Polymers
- Role is to Bridge Particles Together into Larger Floc Particles; May Also Strengthen Floc

– FILTER AIDS
- High Molecular Weight Organic Polymers
- Role is to Bridge Particles to Filter Grains or to Previously Retained Particles within Filter Bed

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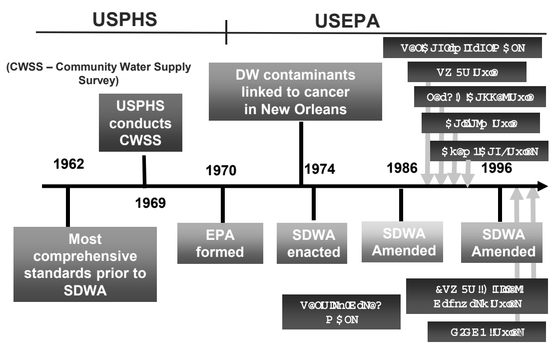
Regulations

Safe Drinking Water Act (SDWA)

Federal Drinking Water Program



SDWA Contaminants

Microbial Risks

- Turbidity (Water quality indicator)
- Coliform Bacteria (Total, Fecal & E. coli)
- Viruses
- Protozoa (Giardia, Cryptosporidium)
- Bacterial Pathogens (Legionella)

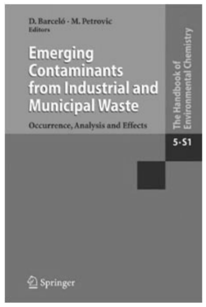
Chemical & Radiological Risks

- Inorganic chemicals (IOCs)
- Volatile organic chemicals (VOCs)
- Synthetic organic compounds (SOCs)
- Disinfectants & Disinfection by products (DBPs)
- Radionuclides (Radium 226/228, Uranium)

Continuing pressure also exists for regulatory change on several fronts.

Emerging Contaminants

- Endocrine Disruptors
- Pharmaceuticals
- Personal Care Products
- Flame Retardants
- Dioxins



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Federal Rules

- Surface Water Treatment Rule (SWTR - 1989)
  - Surface water sources must receive filtration and disinfection
  - Finished water turbidity standard of ≤ 0.5 NTU
  - Concentration and time (C x T) requirements for disinfection
- Enhanced Surface Water Treatment Rules (ESWTR – 1998 - 2006)
  - Finished water turbidity standard of ≤ 0.3 NTU
  - Benchmarking / profiling for Cryptosporidium removal

http://www.epa.gov/safewater/

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Water Treatment

Overview

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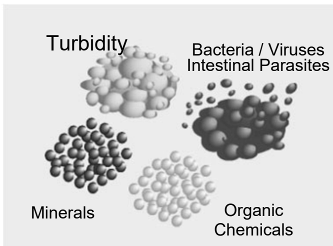
WATER TREATMENT

"The water treatment plant is the **primary** barrier against unsafe water…any malfunction in the treatment process could result in water quality problems."



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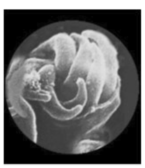
Multiple Barriers

"Barriers" prevent the passage of microorganisms into the distribution system…



Cryptosporidium

Giardia

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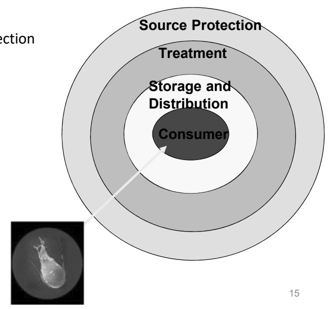
Multiple Barriers
In Water Protection

- Sources
  - Watershed management programs
  - Intake and wellhead protection
- Treatment
  - Coagulation, flocculation, sedimentation
  - Filtration
  - Disinfection
- Storage
  - Disinfectant contact time
  - Screens
- Distribution
  - Pressure
  - Disinfection



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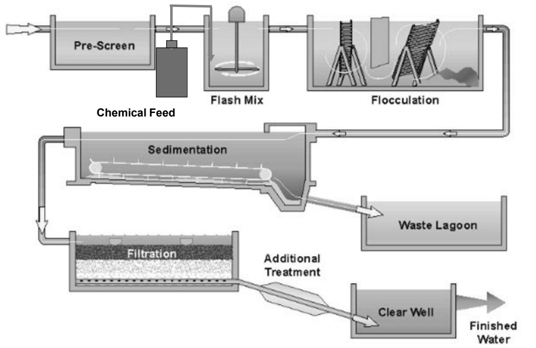
Conventional Water Treatment



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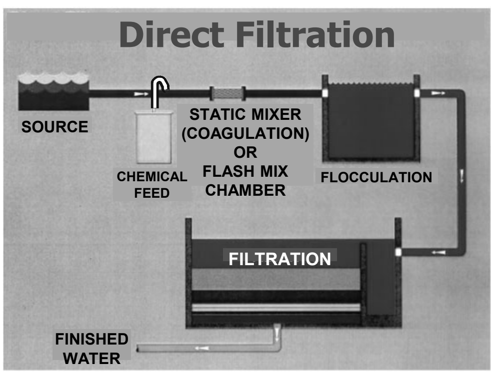

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Enhanced Solids Removal

Turbidity

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Bench-top Turbidimeter

- Measurement of "cloudiness" in the water
- Expressed in NTU (Nephelometric Turbidity Units)
- Basis for regulatory compliance and process control
- Turbidimeters must be calibrated to maintain accuracy

Bench-top Turbidimeter & Primary Standards

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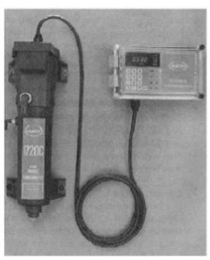
ON-LINE TURBIDIMETERS



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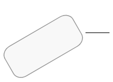
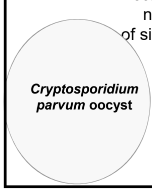
Classes of Microorganisms: The Microbial World

Viruses: smallest (0.02-0.3 µm diameter); simplest: nucleic acid + protein coat (+ lipoprotein envelope)



Bacteria: 0.5-2.0 µm diameter; prokaryotes; cellular; simple internal org.; binary fission.

Protozoa: most >2 µm - 2 mm; eucaryotic; uni-cellular; non-photosynthetic; flexible cell membrane.; wide range of sizes and shapes; hardy cysts and oocysts; flagellates (*Giardia* sp.), amoebae, ciliates, sporozoans (*Cryptosporidium* sp.) and microsporidia.



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Settling Rate for Small Particles

TABLE 4-1 Natural settling rates for small particles

Particle Diameter, *mm*	Representative Particle	Time Required to Settle in 1-ft (0.3-m) Depth
		Settleable
10	Gravel	0.3 seconds
1	Coarse sand	3 seconds
0.1	Fine sand	38 seconds
0.01	Silt	33 minutes
		Considered Nonsettleable
0.001	Bacteria	55 hours
0.0001	Color	230 days
0.00001	Colloidal particles	6.3 years
0.000001	Colloidal particles	63-year minimum

Source: Water Quality and Treatment. *3rd ed. 1971.*

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Particles in raw water resist settling due to…………

1) Particle Size

- Suspended Solids
  - ➢ non-settleable solids
  - ➢ settleable solids
- Colloidal Solids
- Dissolved Solids

2) Natural Forces

- Zeta Potential
- Van der Waals Force

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Types of particles

- Inorganic
  - – Clays
  - – Metal oxides and hydroxides
    - $Al(OH)_3$ floc in coagulation
    - $Fe(OH)_3$ floc from oxidation of FeII & coagulation
    - MnO_2 from oxidation of MnII
    - SiO_2 (silica)
  - – Carbonates
    - $CaCO_3$ and $CaMgCO_3$

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Types of particles

- Organic particles:
  - Microoganisms
    - Virus
    - Bacteria
    - Algae
    - Protozoa (*Giardia* & *Cryptosporidium*)
  - Organic debris
  - Humic substances

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Water Treatment

Coagulation

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Coagulation – Process Description

- Adding and rapid mixing of chemical coagulants into the raw water.
- The process of adding a chemical or combination of chemicals to neutralize the electrostatic charges on suspended particles in raw water so that they will attract to form larger particles.

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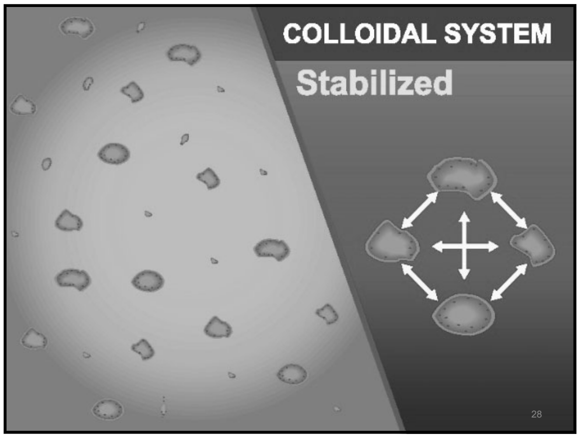
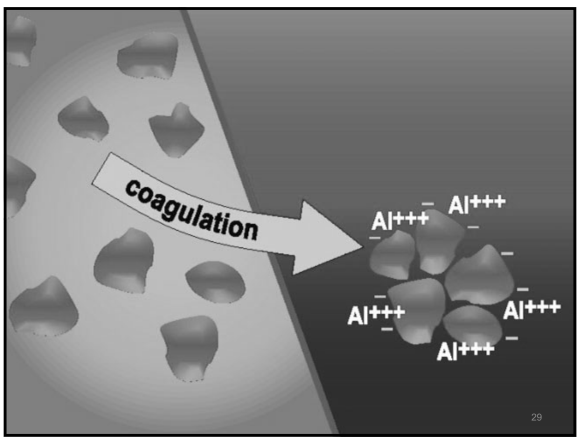
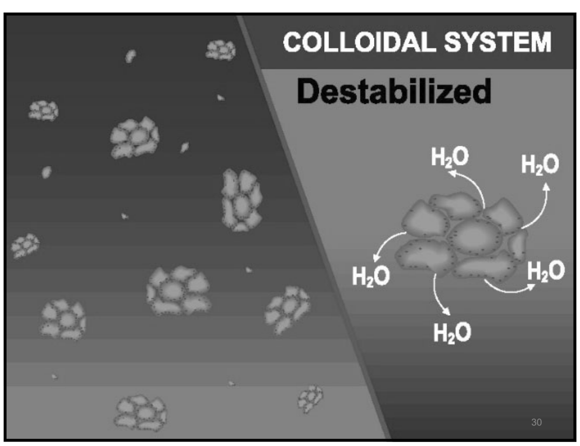
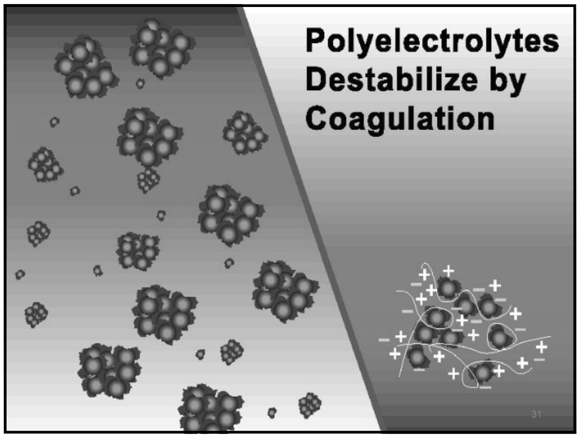

COLLOIDAL SYSTEM
Stabilized
28


coagulation
Al+++
Al+++
Al+++
Al+++
Al+++
29


COLLOIDAL SYSTEM
Destabilized
H₂O
H₂O
H₂O
H₂O
H₂O
30



Primary Coagulants

TABLE 4-2 Common coagulation chemicals

Common Name	Chemical Formula	Comments
Aluminum sulfate	$Al_2(SO_4)_3 \cdot 14(H_2O)$	Most common coagulant in the United States; often used with cationic polymers
Ferric chloride	$FeCl_3$	May be more effective than alum in some applications
Ferric sulfate	$Fe_2(SO_4)_3$	Often used with lime softening
Ferrous sulfate	$Fe_2(SO_4)_3 \cdot 7H_2O$	Less pH dependent than alum
Aluminum polymers	—	Include polyaluminum chloride and polyaluminum sulfates
Cationic polymers	—	Synthetic polyelectrolytes; large molecules
Sodium aluminate	$Na_2Al_2O_4$	Used with alum to improve coagulation
Sodium silicate	$Na_2O \cdot (SiO_2)_x$	x can range from 0.5 to 4.0; ingredient of activated silica coagulant aids

Source: Adapted from *Water Treatment Plant Design. 1990.*

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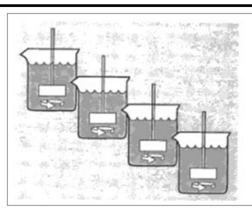
Jar Test



- Simulates C / F / S processes
- Used to evaluate…..
  - ➢ coagulant chemicals type, combination, order of application and optimum dose
  - ➢ flash mix intensity and detention time
  - ➢ flocculator speed and detention time
  - ➢ Settling velocity (for sedimentation basin)

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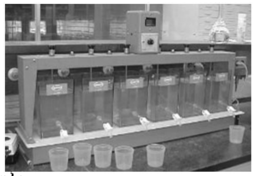
Jar Test



- Should be conducted….
  - using raw water as sample
  - whenever there are changes in raw water quality (turbidity, color, pH, alkalinity, temperature)
  - at least once per day
- Modified version of of jar test should be conducted in-plant to verify results

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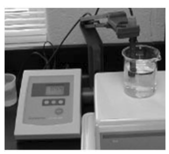
pH and Alkalinity Tests



- Should be conducted on raw water and in conjunction with jar test
- Indicates if pH / alkalinity needs to be adjusted for improved coagulation
- Requires pH meter, burette, and H_2SO_4

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Effects of <u>pH & Alkalinity</u> on Coagulation

Aluminum and Ferric based coagulants…..

- react better in waters within a certain pH range and alkalinity range.
  - Alum: 5.5 – 7.5
  - Ferric: 5.0 – 8.5
- require adequate alkalinity for optimum coagulation
  - Alum: 1 mg/L converts 0.5 mg/L of $CaCO_3$
  - Ferric: 1 mg/L converts 0.75 mg/L of $CaCO_3$
- are very acidic and will reduce pH / alkalinity

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Effects of Water Temperature on Coagulation

- Warm Water = Improved Coagulation
- Cold Water = Reduced Coagulation

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Effects of Turbidity on Coagulation

- Low turbidity
  - Sometimes difficult to form a proper floc
  - More coagulant may be needed
  - Coagulant aid / weighting agent may need to be applied
- Fluctuating turbidity
  - coagulant dose must be adjusted

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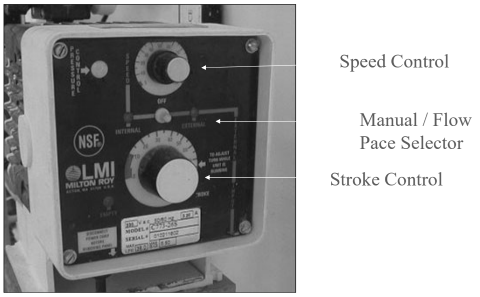
Coagulation – Chemical Feed Systems

- Liquid Chemical Feeders
  - diaphragm pumps
  - perastaltic (hose) pumps
- Dry Chemical Feeders
  - volumetric feeders
  - gravimetric feeders

Diaphragm-Type Metering Pump



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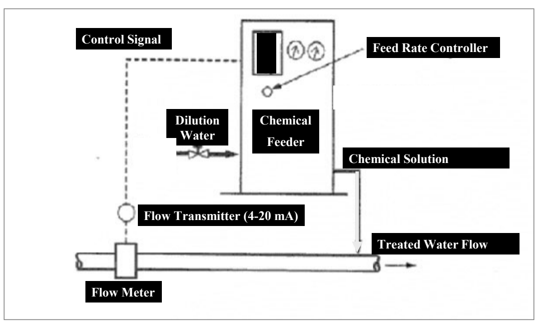
Flow Paced Control



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Degree of coagulation with different zeta potential ranges

Average Zeta Potential	Degree of Coagulation
+3 to 0	Maximum
-1 to -4	Excellent
-5 to -10	Fair
-11 to -20	Poor
-21 to -30	Virtually none

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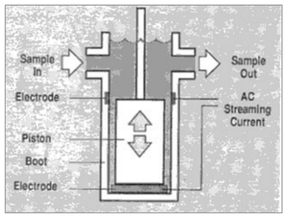
Streaming Current Monitor



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COAGULANT ADDITION IN RAPID MIXING

PIPE STATIC MIXERS (www.chemineer.com)

RAPID MIX TANK

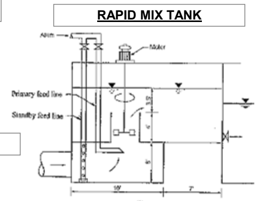

Figure 3.2.3-8 Flash mixing tank and inlet channel to the flocculation tank.
From Kawamura (2000)

CHANNEL STATIC MIXER (www.statiflo.net)

- Initial coagulant chemical reactions are rapid occurring in seconds or less. Thus, processes have short detention times of ~ 1 min or less.
- For some coagulants, precipitation reactions occur that take minutes. These begin in Rapid Mixing and continue in Flocculation

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Factors Affecting Rapid Mix

- Adequate mixing intensity is critical immediately upon addition of coagulant chemical
- Detention time typically 1 – 30 seconds
- Good process control begins with regular monitoring of the raw and settled water quality

Poor mixing intensity

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Safety Factors – Chemical Feed Systems

- Hazard Communication Program & MSDS
- Alum and Ferric based chemicals have a very low pH (acidic)
- Sodium hydroxide has a very high pH (basic)
- Incompatible chemicals if mixed together in concentrated form can generate tremendous heat and cause an explosion.
    - Examples: dry alum and quicklime
- Liquid polymers spilled on floor presents falling hazard
- Proper storage and handling of chemicals is critical

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Safety Factors – Chemical Feed Systems

- Chemical storage areas:
    - Kept dry
    - Well ventilated
    - Heated (where liquid chemicals are stored)
    - Used ***only*** for the storage of chemicals
    - Secondary containment provided
    - “Incompatible chemicals” stored separately
    - No cross-connections

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Water Treatment

Flocculation

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Flocculation – Process Description

- Gentle stirring of the water (after coagulation has been accomplished) to bring suspended particles together so that they will form larger, more settleable clumps called floc.
- Detention time typically 10 – 30 minutes
- Flow through velocity typically 0.5 – 1.5 ft/sec

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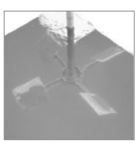
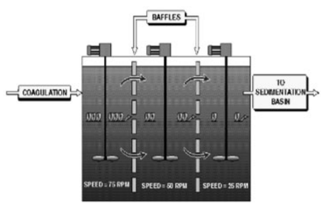
Factors Affecting Flocculation

- Coagulation Efficiency
- Detention Time
- Flocculator Speed





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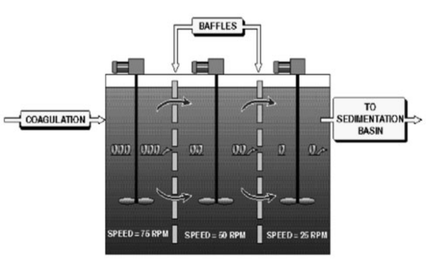
Flocculation Equipment



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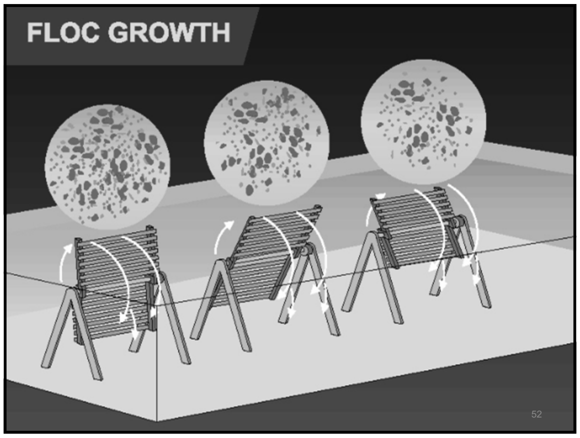
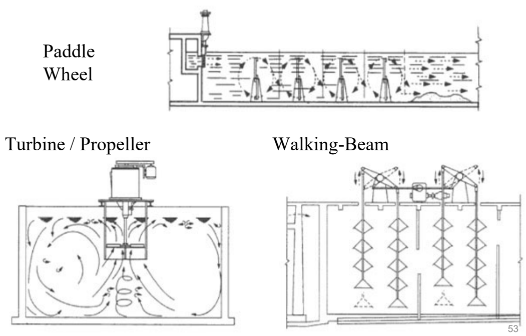
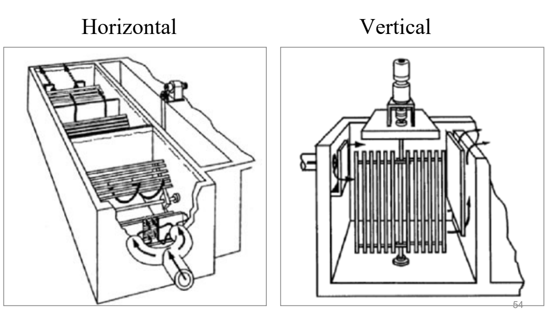


Mechanical Flocculators



Paddle-Wheel Flocculators



Flocculation – Operational Considerations

- Floc building in size / density through the process
  - Paddle speed adjusted to prevent shearing or settling of the floc
  - All paddles intact and all flocculators operating
  - Look for indicators of short circuiting
  - Speed adjusted as temperature (water density) changes
  - Adequate number of units in service

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Water Treatment

Sedimentation

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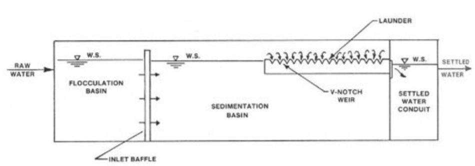
Conventional Basin Designs - Rectangular



- Flow Distribution

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Sedimentation / Clarification – Process Description

- Reducing the velocity of water in basins so that suspended material (floc) can settle out by gravity.
  - Detention time typically 1.5 – 3.0 hours
  - Flow through velocity typically 2 – 4 ft/min
  - Surface loading rate 500 – 1,200 GPD/ft^2
- Sludge, the residue of solids and water, accumulates at the bottom of the basin and must then be pumped out of the basin for disposal.

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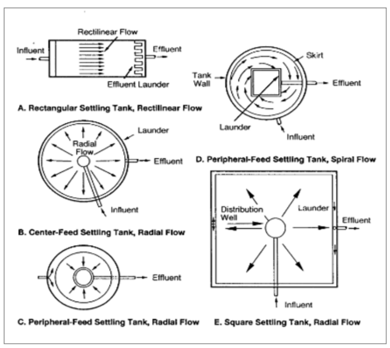
Sedimentation / Clarification – Equipment



Flow Patterns in Sedimentation Basins

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Circular Sedimentation Basin

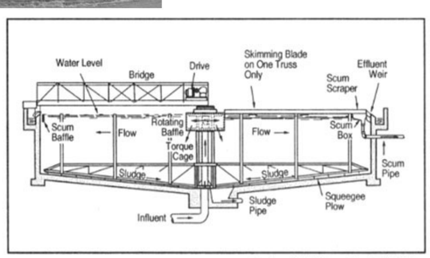

FIGURE 5-5 A typical circular sedimentation basin

Courtesy of FMC Corporation, MHS Division

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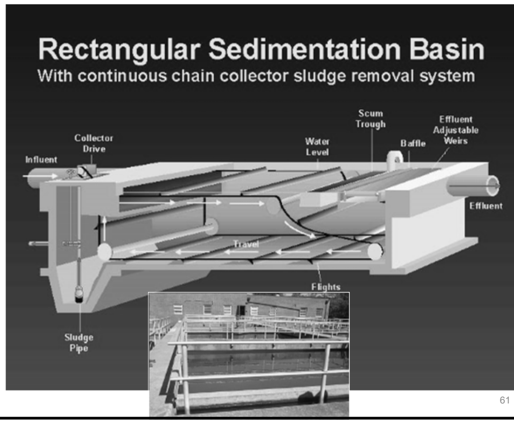

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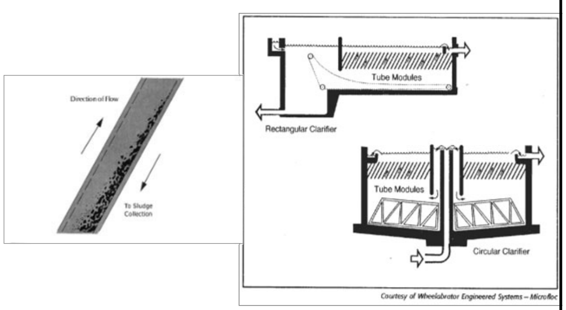
Counter Current Flow Tube Settlers



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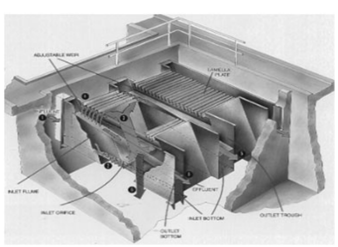
Clarification: Plate Sedimentation



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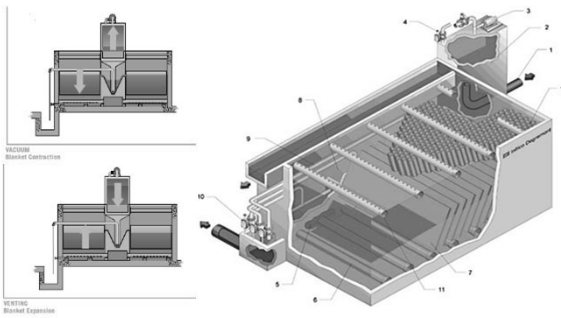
Super Pulsator®



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How Does Solids Contact Clarification Work?

- Particles in Water are Pulsed Into Contact with Floc in the Sludge Blanket
  - Agglomeration of particles
  - Can intercept particles
- Key is to Balance Floc Size and Density with the Upflow Velocity
  - Controlled in multiple stages

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Performance Goals - Sedimentation

- Turbidity ≤ 2 NTU 95% time when source turbidity > 10 NTU
- Turbidity ≤ 1 NTU 95% time when source turbidity ≤ 10 NTU
- Factors affecting sedimentation
  - Efficiency of C/F Processes
  - Detention Time
  - Surface Loading Rate
  - Weir Overflow
  - Temperature
  - Density Currents
  - Wind
  - Sludge Build-up

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Water Treatment

Filtration

Filtration

- Process Description
  - ➢ Removal of suspended matter by passing the water through a granular porous medium such as sand, anthracite coal, or a membrane.
- Overall Goals:
  - Surface Water Treatment Rule (SWTR)
    - ➢ Surface sources must receive filtration and disinfection
    - ➢ Finished water turbidity standard of 0.5 NTU
  - Interim Enhanced Surface Water Treatment Rule (IESWTR)
    - ➢ Finished water turbidity standard of 0.3 NTU
    - ➢ Benchmarking / profiling for Cryptosporidium removal

Approaches to Filtration

- Filtration by Granular Media
  - ➢ Conventional Treatment
  - ➢ Direct Filtration
  - ➢ Slow Sand Filtration
- Diatomaceous Earth Filtration
- Bag and Cartridge Filtration
- Membrane Filtration
- Reverse Osmosis (RO)

Filtration Process Variables

- Filter media
  - Grain size
  - Shape
  - Density
  - Composition
  - Porosity
- Filtration Rate
- Allowable Head Loss
- Liquid Characteristics (e.g., temperature)

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Filtration Process Variables (cont)

- Influent Characteristics
- Suspended solids concentration
- Particle size
- Particle charge

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Water Filtration

Media

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Filter Efficiency

- Filter media qualities
  - Effective size
  - Uniformity coefficient
  - Specific gravity

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Filter Media

- A sand filter bed with a relatively uniform grain size can provide effective filtration
- Dual media filter beds usually use anthracite and sand
- Multimedia filter beds generally use anthracite, sand, and garnet
- Advantages of dual and multimedia filters are:
  - Higher filtration rates
  - Ability to filter a water with higher turbidity
  - Possibly longer filtration runs

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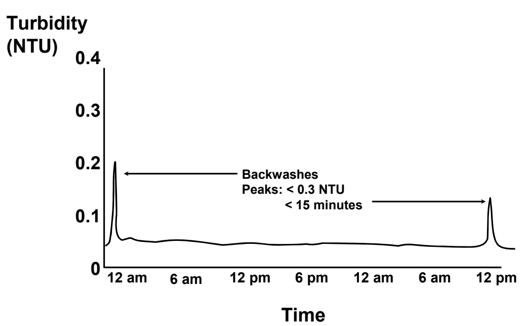
Filter Profile – Good Performance



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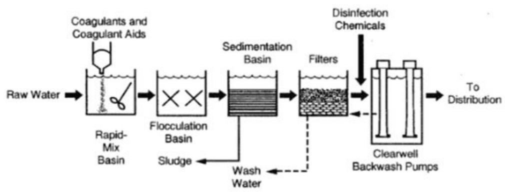
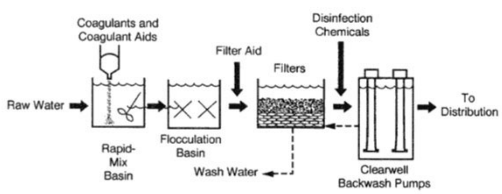
Conventional Treatment



76

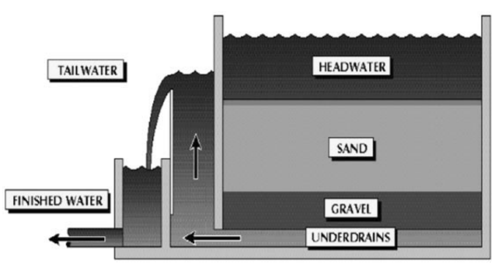
Direct Filtration



Applicable to raw water with turbidity typically below 25 NTU and Color below 25 color units.

77

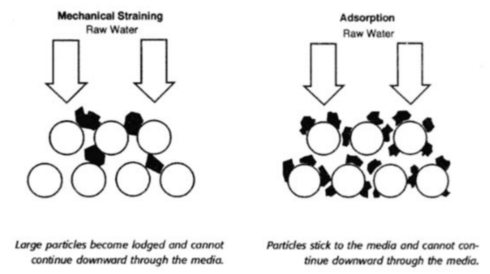
Gravity Filters



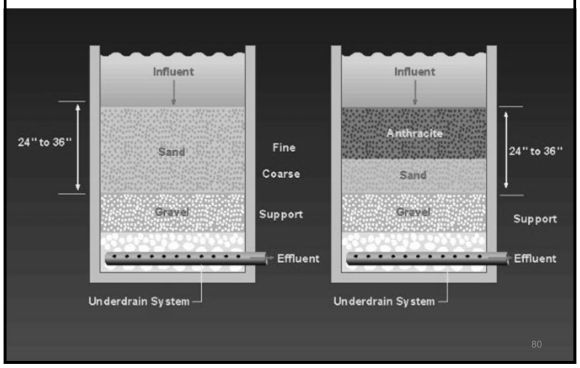
Gravity Operated Filter

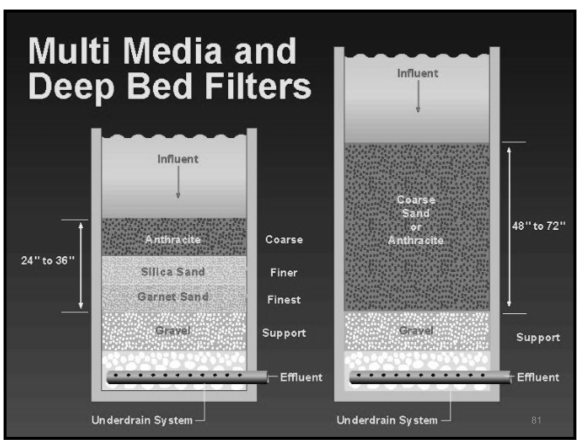
78

The Filtration Process

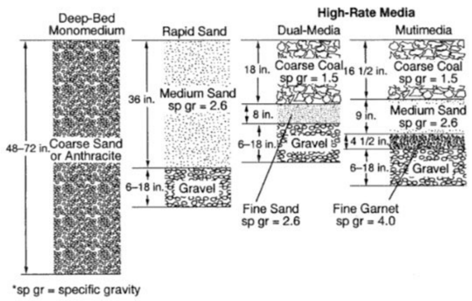


Single and Dual Media Filters





Comparison of Gravity Filter Characteristics



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Comparison of Gravity Filter Characteristics

Characteristic	Slow Sand Filters	Conventional Rapid Sand Filters	High-Rate Filters
Filtration Rate:	0.05 gpm/ft^2	2 gpm/ft^2	3-8 gpm/ft^2
Media:	Sand	Sand	Sand and Coal or Sand, Coal, & Garnet
Media Distribution:	Un-stratified	Stratified	Stratified
Filter Runs:	20-60 days	12-36 hours	12-36 hours
Loss of Head:	0.2 feet initial to 4 feet final	1 foot initial to 8 or 9 feet final	1 foot initial to 8 or 9 feet final
Amount of Backwash Water Used:	No Backwash	2-4% of water filtered	6% of water filtered

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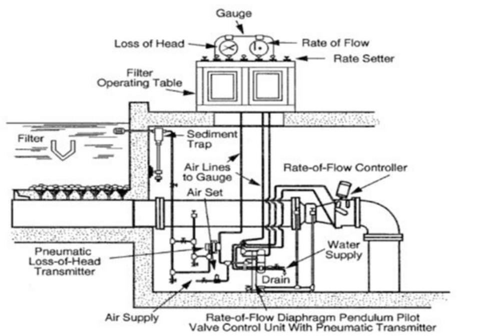
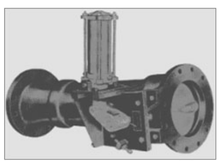
Filter Flow Control Equipment

- Loss-of-Head Indicator
- Rate-of-Flow Controller
- On-line Turbidimeter

Loss-of-Head Indicator



Rate-of-Flow Controller

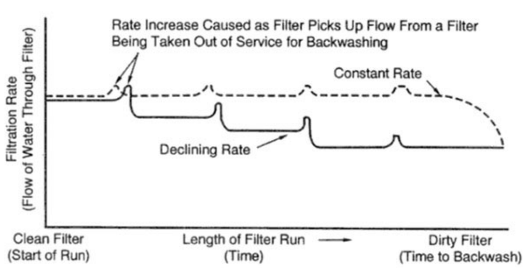


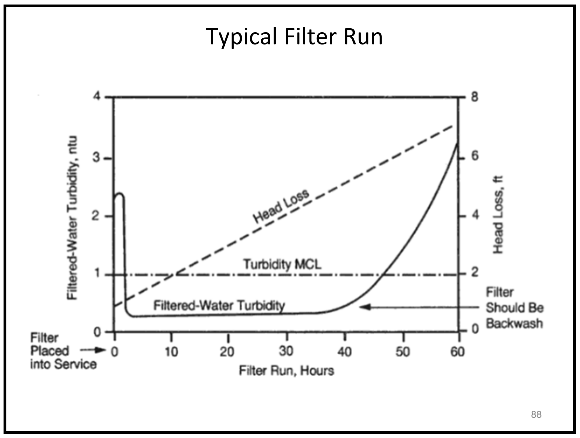
Constant Rate

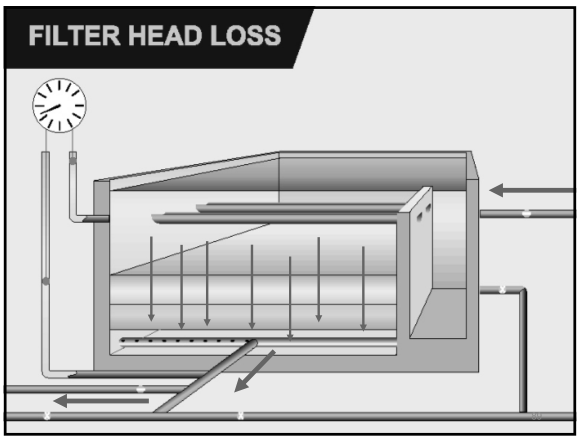
Utilizes Rate-of-Flow Controller

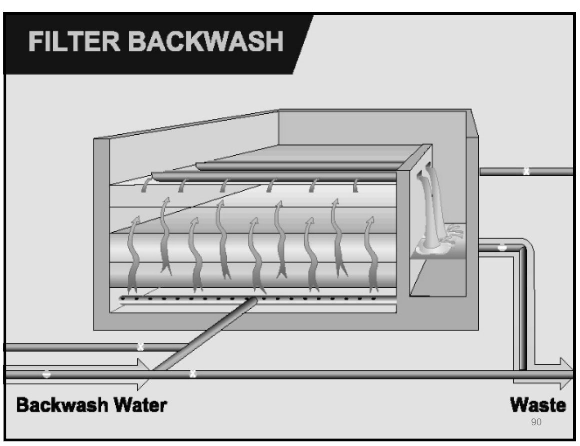
- Declining Rate
  - Does not use Rate of Flow Controller

Declining Rate Filtration

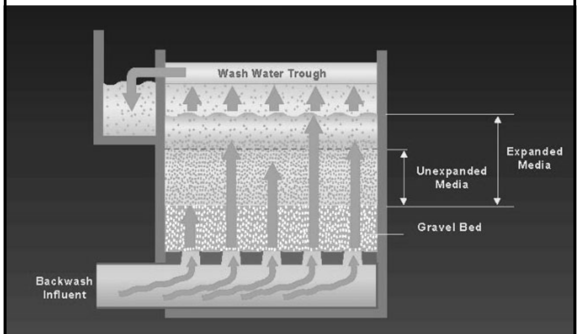



Typical Filter Run
Filtered-Water Turbidity, ntu
Head Loss, ft
Head Loss
Turbidity MCL
Filtered-Water Turbidity
Filter Should Be Backwash
Filter Placed into Service
Filter Run, Hours
88

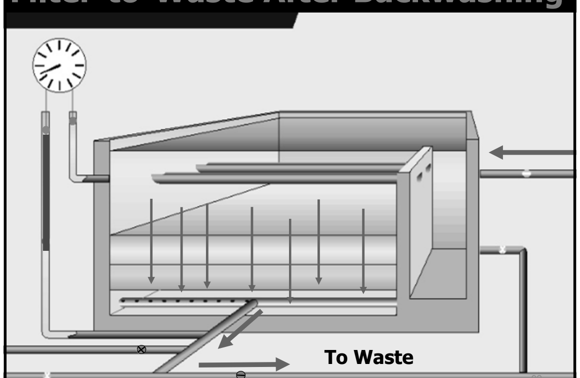

FILTER HEAD LOSS


FILTER BACKWASH
Backwash Water
Waste
90

Filter Bed Expansion



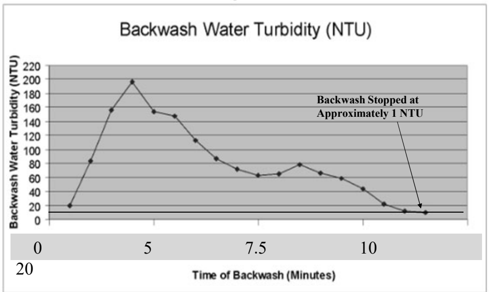
Filter-to-Waste After Backwashing



Filter Backwash Evaluation

- Watch the backwash
  - ➢Boils (uneven flow distribution)
  - ➢Media carryover
  - ➢Clarity of wash water (turbidity)
- Observe filter media following backwash
  - ➢Cracks and evenness

Acceptable Backwash Waste Turbidity Profile



Water Filtration

Operational Issues

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Visual Inspection of Filter

Media in wash water Troughs

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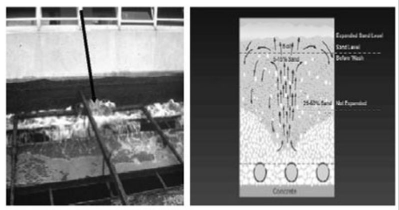
Visual Inspection of Filter

Sand boil in filter bed



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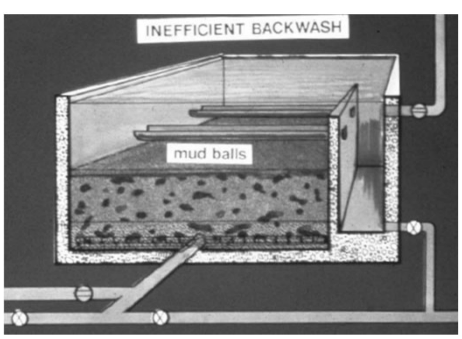
Results of Improper Backwashing

- Turbidity Breakthrough
- Short filter runs
- Air binding
- Mudball formation
- Filter bed shrinkage
- Gravel displacement
- Damage to underdrains
- Media loss

98

Results of Ineffective Backwashing



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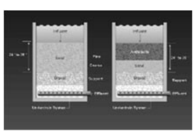
Water Filtration

Filter Profiling

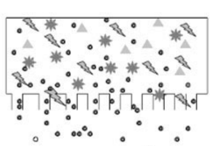
SDWA Individual Rules

- **Filter Backwash Recycling Rule (FBRR)**
  - Reduces risks from recycling contaminants removed during filtration
  - Affects systems that recycle spent filter backwash water, thickener supernatant, or liquids from dewatering

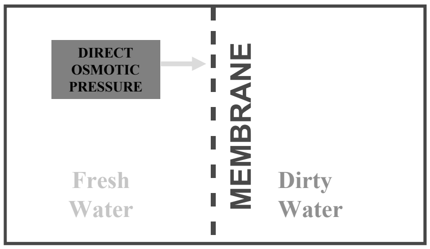


Membrane Filter Technology

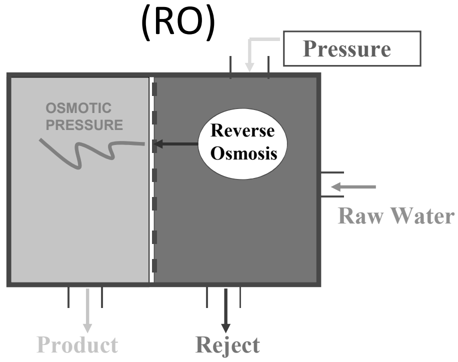
- A membrane is a thin material that has pores (holes) of a specific size
- Membranes trap larger particles that won't fit through the pores of the membrane, letting water and other smaller substances through to the other side



Principle of Osmotic Pressure



Principle of Reverse Osmosis (RO)



OSMOTIC PRESSURE

osm pres = 1 psi /100 mg/L OF TDS (divalant rich waters)

osm pres = 1.2 psi /100 mg/L OF TDS (salt NaCl waters)

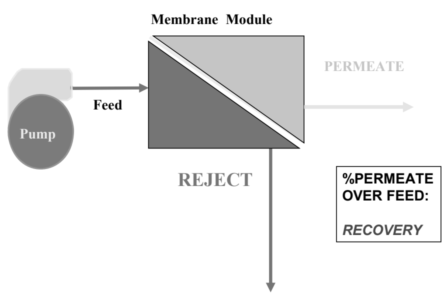
DEFINITIONS & TERMINOLOGY

RECOVERY: (PERMEATE FLOW / FEED FLOW)*100

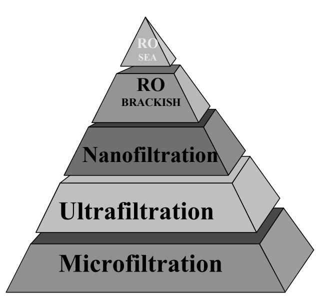
FLUX: PERMEATE FLOW / MEMBRANE SURFACE AREA
GALLONS PER SQUARE FOOT PER DAY (GFD)

CONCENTRATION POLARIZATION: CONCENTRATION INCREASE AT THE IMMEDIATE SURFACE OF MEMBRANE

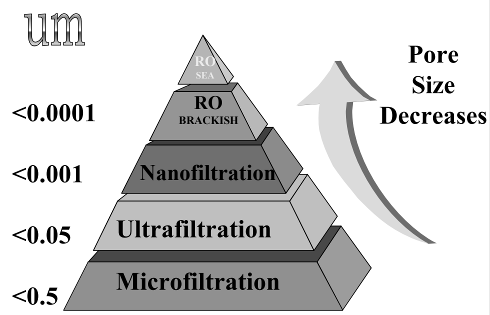
SIMPLIFIED SCHEMATIC



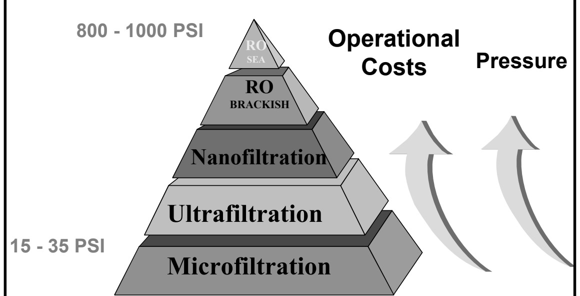
There are five basic membrane systems.



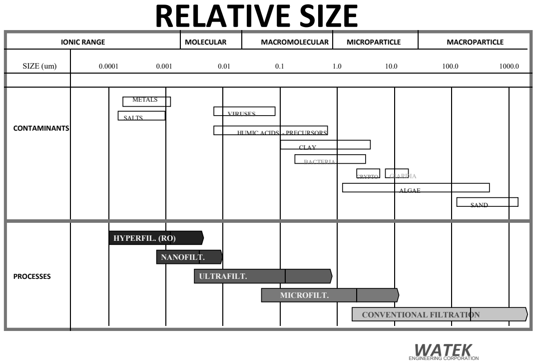
PORE SIZES



How do they compare?



SEPARATION PROCESSES RELATIVE SIZE



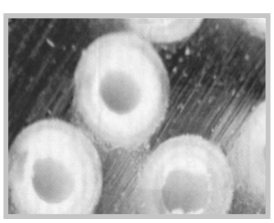
MEMBRANE COSTS

TYPE	PRESSURES psi	EQUIPMENT COST $M/MGD	O&M COST $/KGAL	WATER COST $/KGAL
MF	10- 30	0.5 - 1	0.3 - 0.4	0.4 - 0.6
UF	20- 75	0.5 - 1.1	0.3 - 0.6	0.4 - 0.7
NF	80 - 150	0.8 - 1.2	0.4 - 0.7	0.6 - 0.9
BWRO	200 - 700	0.9 - 1.5	0.8 - 1.5	1.0 - 2.0
SWRO	700 - 1200	2.0 - 6.0	2.0 - 4.0	2.0 - 4.0

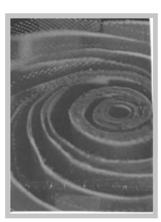
PACKAGED IN DIFFERENT CONFIGURATIONS

- SPIRAL WOUND
  HOLLOW FIBER
- TUBULAR
- PLATE & FRAME
- CERAMIC & DISCS
- IMMERSED / SUCTION

CLOSE - UP VIEW

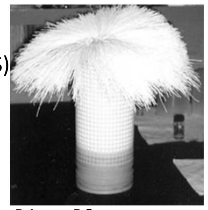


HOLLOW FIBER



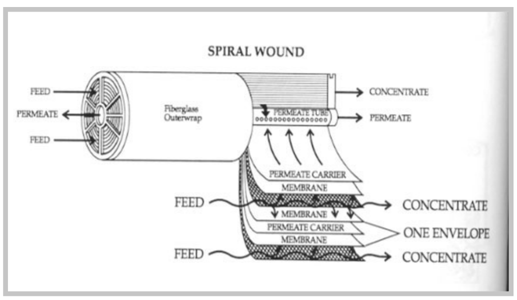
SPIRAL WOUND

Membrane Materials



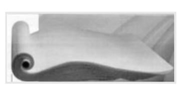
- Cellulose Acetate (CA)
- Poly(ether)sulphone (PS or PES)
- Polypropylene (PP)
- Polyamide (PA)
- Polyvinylidienefloride (PVDF)
- Combinations
  - ►Thin film composites (TFC) e.g. PA on PS
  - ►Mixtures as solutions or matrices e.g. PVDF +CA

SPIRAL WOUND SYSTEM

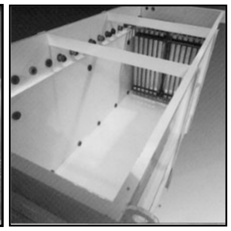


RO/NF Equipment

- Membrane elements
- Pressure vessels
- RO Skids
- Feed pumps
- Piping
- Instrumentation
- Pre/Post treatment

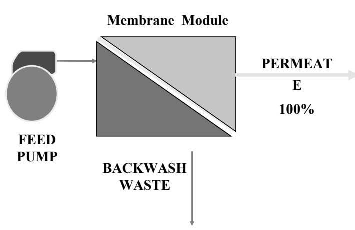



SUBMERGED MEMBRANES ARE THE ANSWER FOR TOUGHER RAW WATERS



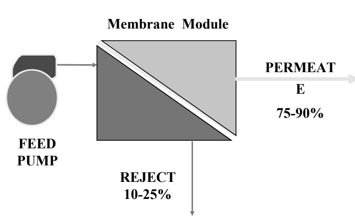
TWO DIFFERENT MODES OF OPERATION

DEAD END WITH FREQUENT BACKWASH

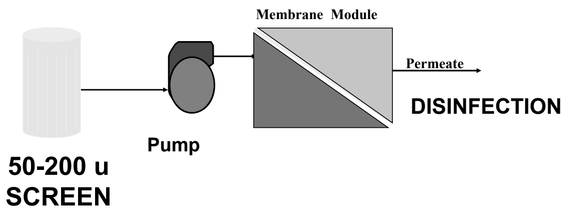


TWO DIFFERENT MODES OF OPERATION

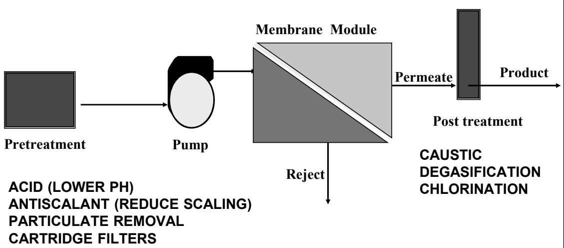
CONTINUOUS CROSS FLOW



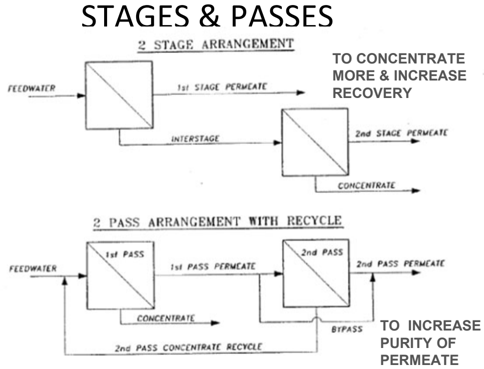
PRE/POST TREATMENT
MF / UF

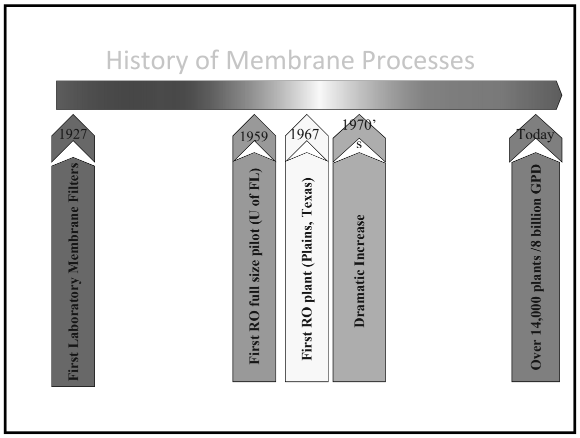


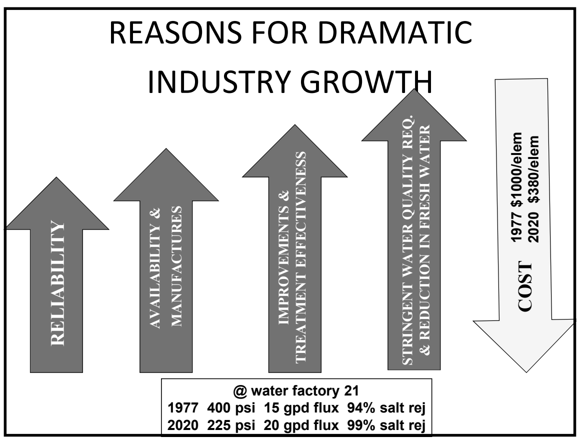
PRE/POST TREATMENT
RO



STAGES & PASSES

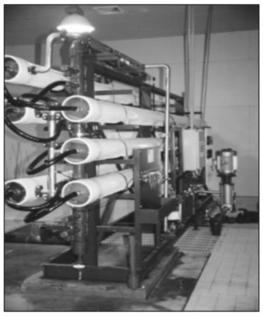



History of Membrane Processes
1927
First Laboratory Membrane Filters
1959
First RO full size pilot (U of FL)
1967
First RO plant (Plains, Texas)
1970's
Dramatic Increase
Today
Over 14,000 plants /8 billion GPD


REASONS FOR DRAMATIC INDUSTRY GROWTH
RELIABILITY
AVAILABILITY & MANUFACTURES
IMPROVEMENTS & TREATMENT EFFECTIVENESS
STRINGENT WATER QUALITY REQ. & REDUCTION IN FRESH WATER
COST
1977 $1000/elem
2020 $380/elem
@ water factory 21
1977 400 psi 15 gpd flux 94% salt rej
2020 225 psi 20 gpd flux 99% salt rej


OTHER REASONS FOR GROWTH
FRESH WATER SOURCES LONG DISTANCE AWAY
NATIONAL SECURITY/CONFLICTS/INDEPENDENCE
(22 COUNTRIES DEPEND ON OTHERS FOR WATER)
NON-SMART GROWTH
(50% POP. INCREASE IN FL/TX/CA IN NEXT 20 YEARS)
SOMETIMES CHOSEN BECAUSE OF SMALL FOOTPRINT & AESTHETICS

CURRITUCK, NORTH CAROLINA



0.2 MGD
EXPAND TO 0.5
NF SOFTENING
W/ CONV TO BW RO
90% RECOVERY
155 PSI

KILL DEVIL HILL PLANT, NC

3.0 MGD
EXPANDABLE TO 8
FEED TDS: 3,800
3 TRAINS

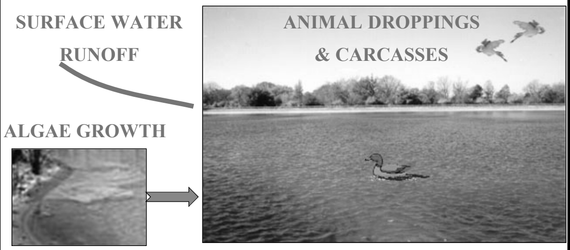
FORT MYERS, FLORIDA

12 MGD
EXPAND TO 20
3-4 MGD SKIDS
NF SOFTENING
90% RECOVERY
155 PSI, W/BWRO CONVERSION PLANNED

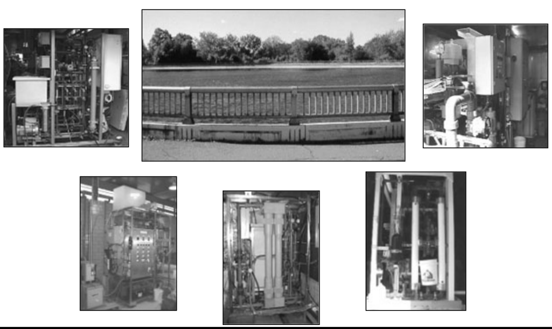
PITTSBURGH

MANDATE “Cover all finished water reservoirs”

- Public Health Issues - Microbial Contamination

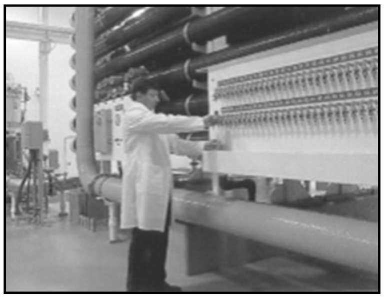


PITTSBURGH 25 MGD POST TREATMENT



HOLLOW FIBER, 8 RACKS

VERO BEACH, FLORIDA



6 MGD

EXPAND TO 10

3-2 MGD SKIDS

LOW PRES. BWRO

85% RECOVERY

175 PSI

GE Zenon Membrane Systems

ZW 500 Series
High Solids / TOC

- Coagulation
- Conventional plant residuals treatment
- Second stage/high recovery applications
- MBR membrane bioreactor

ZW 1000 Series
Low Solids / TOC

- Surface water filtration
- Settled/floated water polishing
- Sea water pretreatment to RO
- Secondary effluent

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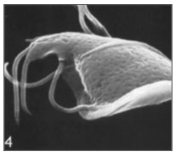
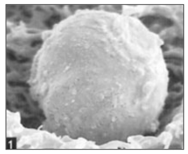
UNIQUE FEATURES OF MEMBRANES

- IT IS A BARRIER
- IT IS MODULAR
- EASY TO OPERATE
- CAN BE MADE ATTRACTIVE

CHALLENGE TESTS IN MF & UF PILOT TRIALS HAVE SHOWN SUCCESS BEYOND PENDING REGULATIONS

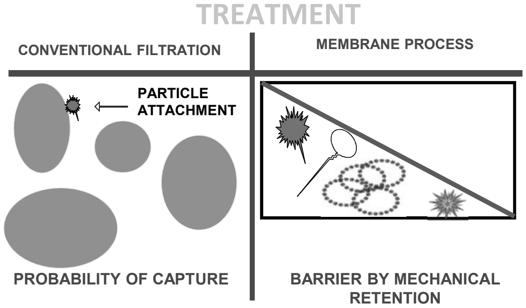


Giardia Cysts



Cryptosporidium Oocysts

COMPARISON TO CONVENTIONAL TREATMENT



99.6% CREDIT

99.99% CREDIT

Questions?

October 2014

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