# *Small Water Systems*

**Maryland Center for Environmental Training**
**301-934-7500**
**info@mcet.org**
**www.mcet.org**

**Small Water Systems**

7 contact hours

9 CC10 hours

Operators of small water systems will be introduced to various water treatment processes including raw water sources, treatment plant processes, and chemicals used. Basic principles of plant operations, an in-depth examination of the disinfection process, including various forms of chlorine utilized in the water treatment field will also be discussed. The safe handling of chlorine and the safety features built into cylinders and feed equipment will also be addressed.

1. Identify raw water sources;
2. Discuss the basic principles of plant operations;
3. Demonstrate the correct procedures used when jar testing;
4. Identify the chemicals used in water treatment;
5. Explain the disinfection process; and
6. Demonstrate the safe handling of Chlorine.

Agenda

| | |
|---|---|
| Introduction | .25 Hours |
| Pre-Test | .50 Hours |
| EPA Regulation, SDWA | 1.00 Hours |
| Contamination | 1.00 Hours |
| Treatment Processes | 2.00 Hours |
| Chemical | 1.00 Hours |
| Storage | .75 Hours |
| Post Test | .50 Hours |

# Small Water Systems

**Objectives:**

*To provide informative training for small system operation and maintenance personnel…*

***…And having a good time doing so!***

***Whether you work at a plant that does a million gallons per minute or 500 gallons per day, you need to have certified operators and they need to receive approved training.***

## What is a small system?

- *Very small: 25 – 500*
- *Small: 501 – 3,300*
- *Medium: 3,301 – 10,000*
- *Large: 10,001 – 100,000*
- *Very Large: 100,001+*

## Sanitary Surveys

On site review of the water source, facilities,equipment, operation, and maintenance of a public water system.

- Standard forms provided by state health authority.
- Performed by a qualified person, usually a sanitary engineer.

Sanitary surveys include water sampling from areas considered significant and representative to establish a baseline for future comparison.

## Public Water Supply Regulations

- The Safe Drinking Water Act of 1974 directs the EPA to establish standards and requirements necessary to protect the public from all known harmful contaminants in drinking water.

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

**If you have any questions, ASK!**

**The EPA or your Primacy Agency (MDE, DNREC) will have answers.**

**Every treatment system must test the distribution system to make sure the water is safe for their customers.**

***What dictates how many samples need to be taken on a monthly basis?***

**Coliform Testing will indicate if the water is polluted from:**

- Air
- Ground
- Water

**Fecal Coliform is a specific type of organism that comes from the intestines of warm-blooded animals.**

**Coliform Bacteria is tested for using the *presence or absence* method.**

## MCL vs. SMCL

- **MCL:** Maximum Contaminant Level – Established for health purposes.
- **SMCL:** Secondary Maximum Contaminant Level – Established for aesthetic purposes.

## MCLs

Microorganisms

- *Turbidity* *0.30 ntu (95% of the time)*
- *Crypto.* *2 log (99% removal)*
- *Giardia.* *3 log (99.9% removal)*

## MCLs

Inorganic Chemicals

- *Copper* *1.30 mg/l*
- *Lead* *0.015 mg/l*
- *Fluoride* *4.00 mg/l*
- *Nitrate* *10.0 mg/l*

## SMCLs

- *pH* *6.5 - 8.5*
- *Chloride* *250 mg/l*
- *Fluoride* *2.00 mg/l*
- *Iron* *0.30 mg/l*
- *Manganese* *0.05 mg/l*

## Water Characteristics

- Physical
  - Color, taste, odor, turbidity
- Chemical
  - Calcium, magnesium, sodium, iron
- Biological
  - Bacteria, viruses, algae
- Radiological
  - Radium 226, radium 228 and radon

**Anything more than 2 Hydrogen & 1 Oxygen ($H_2O$), and the water is *contaminated.***

## What if you add another oxygen to $H_2O$?

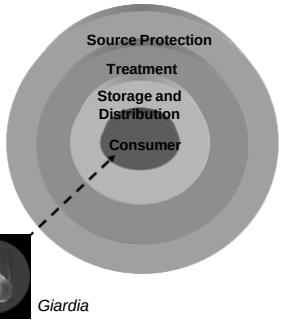
You would have:

$H_2O_2$

*Hydrogen Peroxide*

## Multiple Barriers In Water Supply Protection

- Sources
  - Watershed management programs
  - Intake and wellhead protection
- Treatment
  - C/F/S
  - Filtration
  - Disinfection
- Storage
  - Disinfectant contact time
  - Screens
- Distribution
  - Pressure
  - Disinfection




*Giardia*

## Size Range of Solids

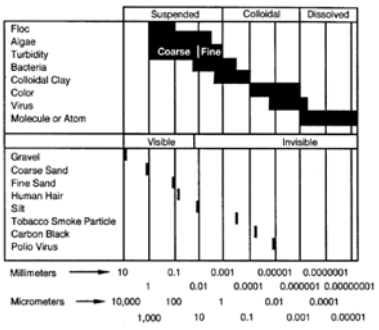



Figure 4-1

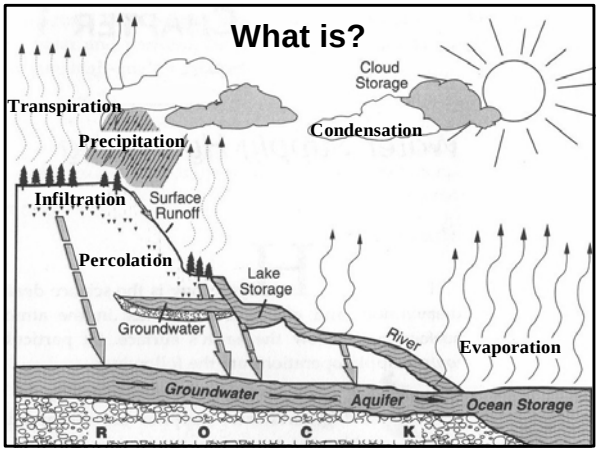
## Types of contaminant dictates type of treatment:

- Aeration.
- Coagulation, sedimentation and filtration.
- Lime softening.
- Ion exchange process.
- Membrane process.
- Disinfection.
- Adsorption.

## Surface Water Treatment...

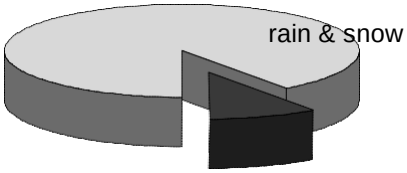
- All surface water is considered contaminated.
- Surface water must receive proper treatment to kill and inactivate harmful microorganisms .

## What is?



## Amount impurities:

surface runoff




***Precipitation that does not infiltrate into the soil or evaporate will travel across the land to a surface water body.***

## Surface water usually carries a high level of turbidity.

- Turbidity is made up of:
  - microbiological contamination.
  - sand.
  - silt.
  - algae.
  - other types of suspended matter.
- Turbidity is aesthetically displeasing and interferes with the disinfection process.

## During this travel a variety of materials may be dissolved or taken into suspension:

- Turbidity.
- Limestone.
- Salt.

## Examples of surface water impurities:

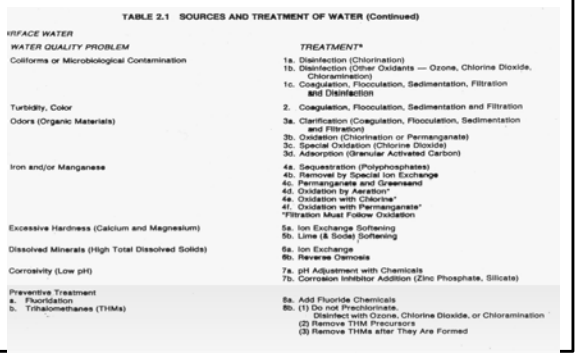


TABLE 2.1 SOURCES AND TREATMENT OF WATER (Continued)

*IRFACE WATER*

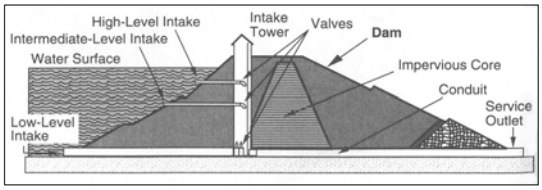
| *WATER QUALITY PROBLEM* | *TREATMENT** |
|---|---|
| Coliforms or Microbiological Contamination | 1a. Disinfection (Chlorination)<br>1b. Disinfection (Other Oxidants — Ozone, Chlorine Dioxide, Chloramination)<br>1c. Coagulation, Flocculation, Sedimentation, Filtration and Disinfection |
| Turbidity, Color | 2. Coagulation, Flocculation, Sedimentation and Filtration |
| Odors (Organic Materials) | 3a. Clarification (Coagulation, Flocculation, Sedimentation and Filtration)<br>3b. Oxidation (Chlorination or Permanganate)<br>3c. Special Oxidation (Chlorine Dioxide)<br>3d. Adsorption (Granular Activated Carbon) |
| Iron and/or Manganese | 4a. Sequestration (Polyphosphates)<br>4b. Removal by Special Ion Exchange<br>4c. Permanganate and Greensand<br>4d. Oxidation by Aeration*<br>4e. Oxidation with Chlorine*<br>4f. Oxidation with Permanganate*<br>*Filtration Must Follow Oxidation |
| Excessive Hardness (Calcium and Magnesium) | 5a. Ion Exchange Softening<br>5b. Lime (& Soda) Softening |
| Dissolved Minerals (High Total Dissolved Solids) | 5a. Ion Exchange<br>6b. Reverse Osmosis |
| Corrosivity (Low pH) | 7a. pH Adjustment with Chemicals<br>7b. Corrosion Inhibitor Addition (Zinc Phosphate, Silicate) |
| Preventive Treatment<br>a. Fluoridation<br>b. Trihalomethanes (THMs) | 8a. Add Fluoride Chemicals<br>8b. (1) Do not Prechlorinate, Disinfect with Ozone, Chlorine Dioxide, or Chloramination<br>(2) Remove THM Precursors<br>(3) Remove THMs after They Are Formed |

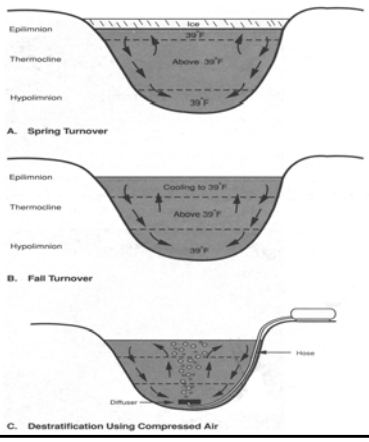
## Water storage:

- Natural means.
- Recharging of aquifers.
- **Impoundments.**

## Impoundments or Dams.

- Embankment Dam - Constructed out of earth and rock with a impermeable inner core.

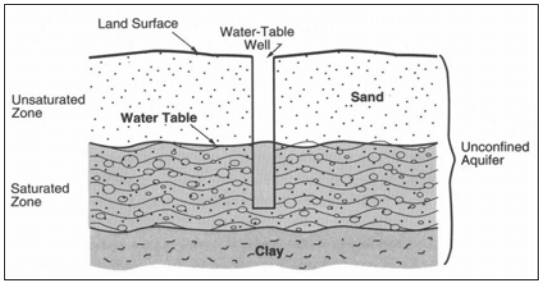


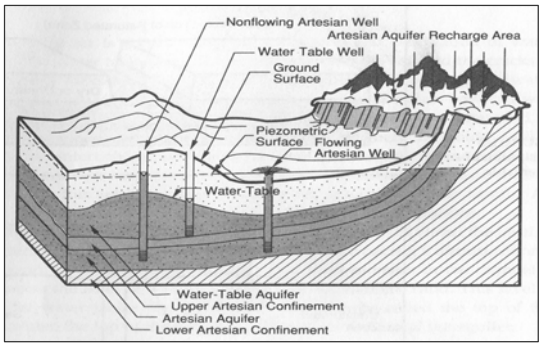

## Examples of ground water impurities:

| GROUNDWATER<br>WATER QUALITY PROBLEM | TREATMENT* |
|---|---|
| 1. Coliforms or Microbiological Contamination | 1. Disinfection (Chlorination) |
| 2. Sulfide Odors (Rotten Egg) | 2a. Aeration<br>2b. Oxidation (Chlorination)<br>2c. Desulfuration (Sulfur Dioxide) |
| 3. Excessive Hardness (Calcium and Magnesium) | 3a. Ion Exchange Softening<br>3b. Lime (& Soda) Softening |
| 4. Iron and/or Manganese | 4a. Sequestration (Polyphosphates)<br>4b. Removal by Special Ion Exchange<br>4c. Permanganate and Greensand<br>4d. Oxidation by Aeration*<br>4e. Oxidation with Chlorine*<br>4f. Oxidation with Permanganate*<br>*Filtration Must Follow Oxidation |
| 5. Dissolved Minerals (High Total Dissolved Solids) | 5a. Ion Exchange<br>5b. Reverse Osmosis |
| 6. Corrosivity (Low pH) | 6a. pH Adjustment with Chemicals<br>6b. Carbon Dioxide Stripping by Aeration<br>6c. Corrosion Inhibitor Addition (Zinc Phosphate, Silicate) |
| 7. Preventive Treatment (Fluoridation) | 7. Add Fluoride Chemicals |
| 8. Sand | 8. Sand Separators |
| 9. Nitrate | 9. Anion Exchange |

## Unconfined Aquifer.




## What is an Artesian Well?




## Types of wells:

- Dug wells
- Bored wells
- Drilled wells
- Driven wells
- Jetted wells

- Dug wells
- Drilled wells

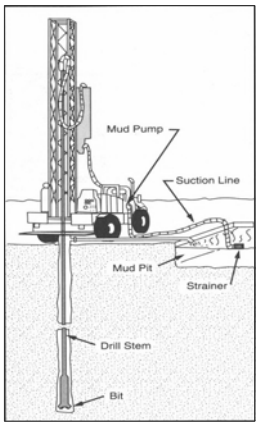
## Dug wells (found in rural areas).

- Do not penetrate much below water table.
- May fail during drought conditions.
- Protection from surface contamination difficult.
- Only type of well **always** treated as a surface water source.

## Drilled wells most commonly found in public water supply.

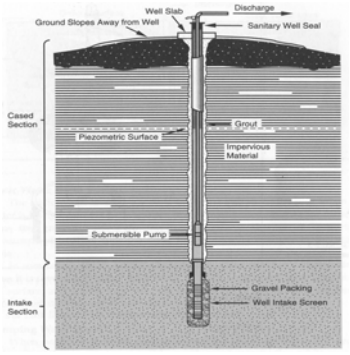
- Benefit - they can reach extreme depths and have large well diameters. (Up to 4 feet and larger.)

## Drilling Rig

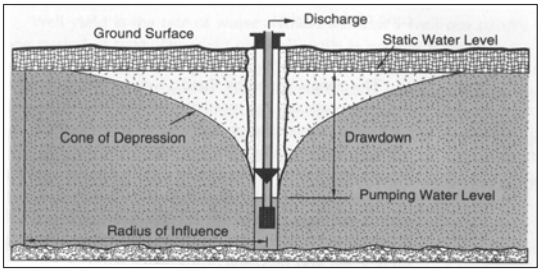


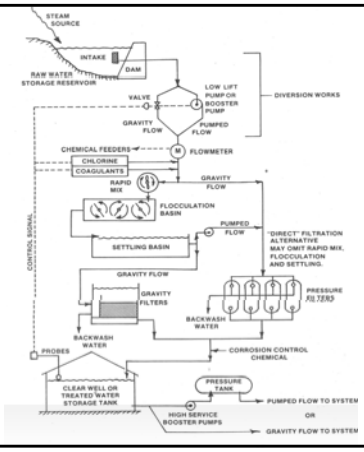

**Mud Pit**

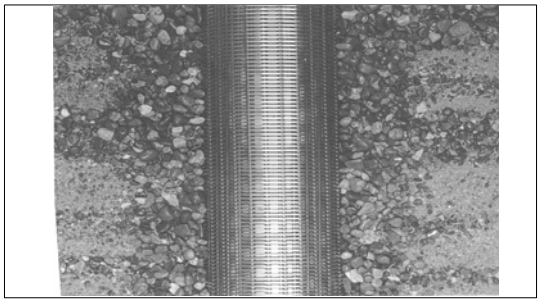
**Highlight well casing, well slab, well grout, well screen.**




**Highlight static water level, pumping water level, draw-down, cone of depression.**





## Disinfection !

*The one process that we can't do without.*

Gastroenteritis

Typhoid

Dysentery

Cholera

Hepatitis

## How do we know the disinfection process is working?

- Coliform testing
  - State and Federal law requires testing.
  - Number of tests is based of population served.
- Federal Surface Water Treatment Rule
  - Requires all surface water to use a "treatment technique" to remove or inactivate disease causing organisms.

## Chlorine Chemicals

- Chlorine, $Cl_2$ 100%
  - Gas compressed to liquid
- Calcium Hypochlorite, $Ca(OCl)_2$ 65%
  - HTH used in swimming pools
- Sodium Hypochlorite, NaOCl 12% -15%
  - Household bleach, 1% – 5 %

## Chlorination Chemistry

- Cl2 + H2O -> HOCl + HCl
- *Which one is the bacteria killer?*
  - **hypochlorous acid = HOCL "Killer"**
- HOCl -> H+ + OCl-

  0……7……14

  **pH**
- *How does pH effect the disinfection process?*

**As pH goes up the amount of HOCl drops off.**

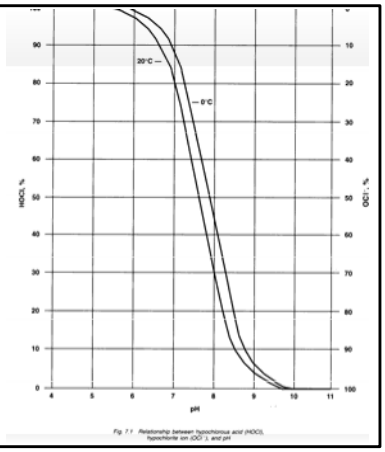



Fig. 7.1 Relationship between hypochlorous acid (HOCl), hypochlorite ion ($OCl^-$), and pH

## Chlorination Chemistry

- As pH goes up, HOCl tends to break apart and weakens the disinfection action.
- Other factors important in the disinfection process include:
  - Concentration of Chlorine
  - Contact time
  - Temperature of water
  - pH of the water
  - Substances in the water, organic or inorganic

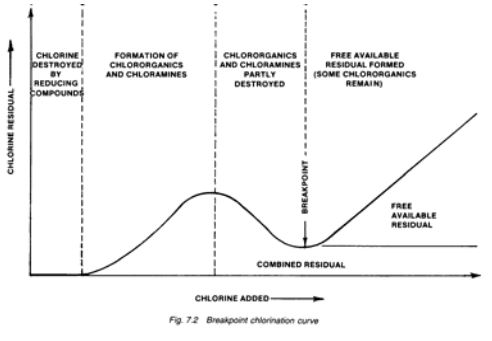



Fig. 7.2 Breakpoint chlorination curve

[10] Breakpoint Chlorination. Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint.
[11] Free Available Residual Chlorine. That portion of the total available residual chlorine composed of dissolved chlorine gas ($Cl_2$), hypochlorous acid (HOCl), and/or hypochlorite ion ($OCl^-$) remaining in water after chlorination. This does not include chlorine that has combined with ammonia, nitrogen, or other compounds.
[12] Chlororganic (klor-or-GAN-ick). Organic compounds combined with chlorine. These compounds generally originate from, or are associated with, life processes such as those of algae in water.
[13] Chloramines (KLOR-uh-means). Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.

**Simple vacuum controlled chlorinator**

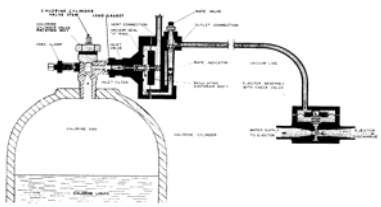
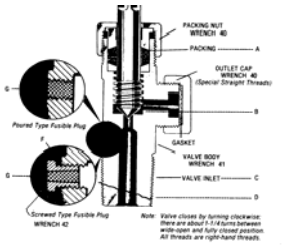


Fig. 7.16 Direct cylinder mounted connection from chlorine gas supply to chlorinator

**Cylinder valves are a common area for leaks.**

**Fusible plugs melt at 158 – 165 degrees F.**

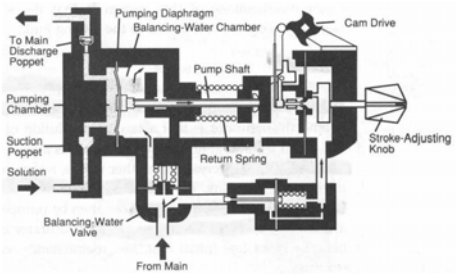



**TYPICAL VALVE LEAKS OCCUR THROUGH . . .**

| | |
|---|---|
| A - VALVE PACKING GLAND | E - VALVE BLOWN OUT* |
| B - VALVE SEAT | F - FUSIBLE PLUG THREADS |
| C - VALVE INLET THREADS | G - FUSIBLE METAL OF PLUG |
| D - BROKEN OFF VALVE | H - VALVE STEM BLOWN OUT* |

*Not shown on above drawing.

Fig. 7.20 Standard chlorine cylinder valve



## Important Terms

Dosage – the amount of chlorine added mg/l or ppm

Demand – the amount of chlorine required to react with the organic and inorganic substances.

Residual - Dose ( - ) Demand = Residual

The amount remaining after contact time.

Free Residual – Exists as Hypochlorous acid or hypochlorite

Combined Residual – Chlorine which has combined with ammonia to form Chloramines.

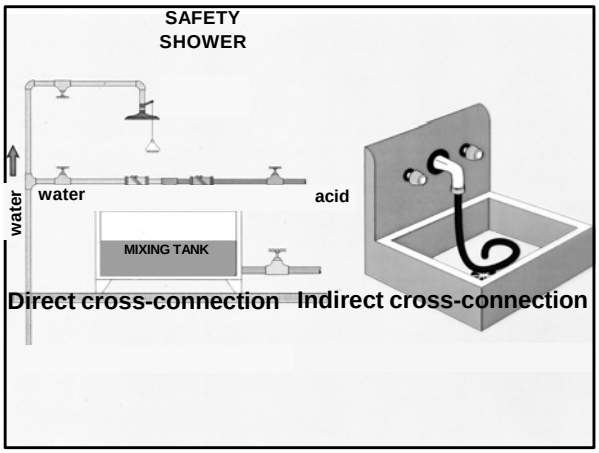
Total Residual – Is the sum of free and combined residual

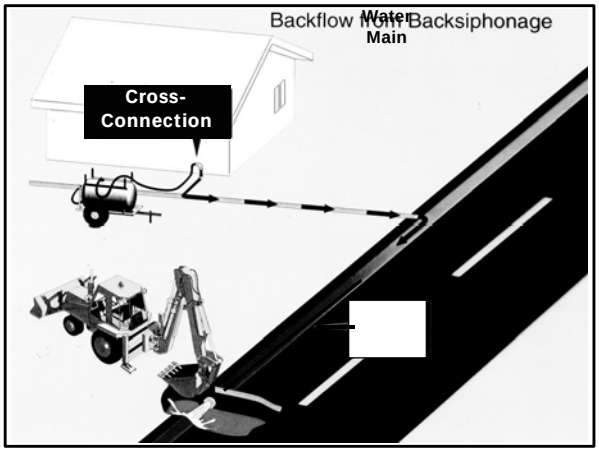
## Incompatible Chemicals

- 6 broad compatibility groups:
  - *Group I: Acids*
  - *Group II: Bases*
  - *Group III: Salts and polymers*
  - *Group IV: Adsorption powders*
  - *Group V: Oxidizing powders*
  - *Group VI: Compressed gasses*

## Cross Connections

*"An actual or potential physical connection or arrangement between otherwise separate piping systems containing potable water and any contaminant, whereby water may flow between the two systems."*



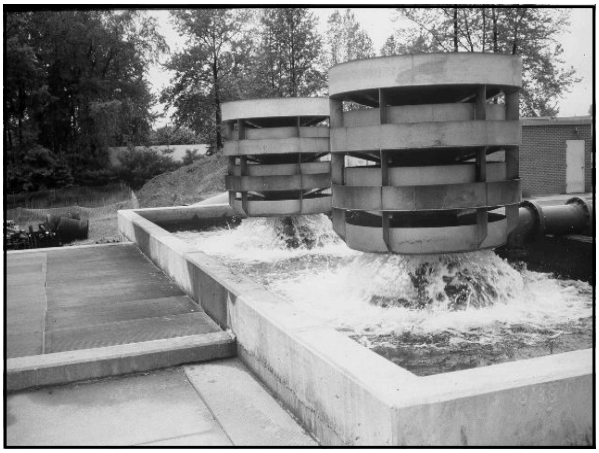




## Aeration:

- Process used to remove dissolved gases.
- Process to change solids from a dissolved form to a suspended form so they can be removed.
- *Example:* $Fe_2$ (Ferrous) to $Fe_3$ (Ferric)

## What are the two ways to aerate water?

- Pass the water through air
- Pass the air through water



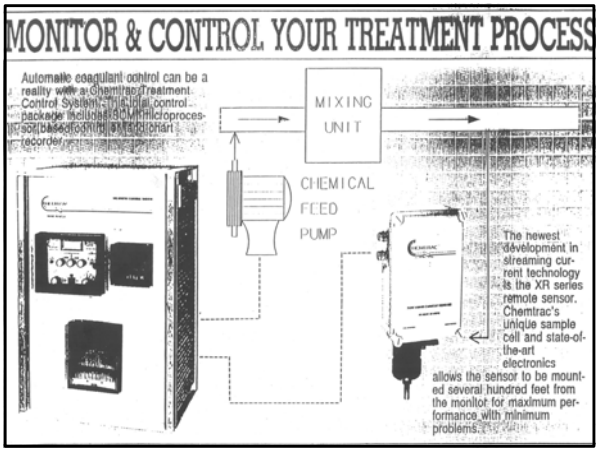
## Are Coagulation and Flocculation the same treatment processes?

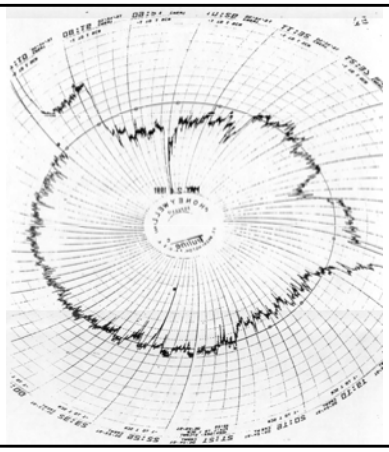
## Settling Rate for Small Particles

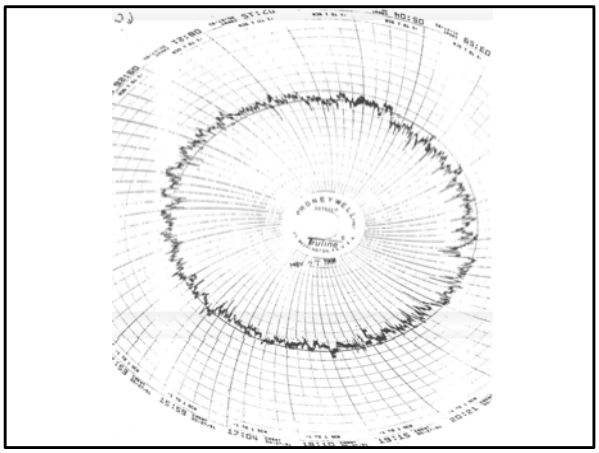
**TABLE 4-1 Natural settling rates for small particles**

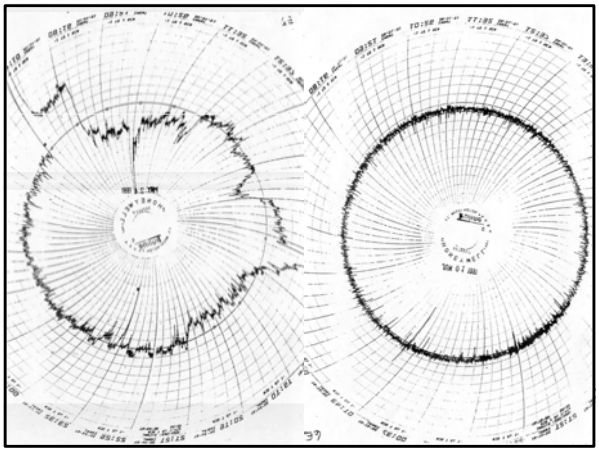
| Particle Diameter, *mm* | Representative Particle | Time Required to Settle in 1-ft (0.3-m) Depth |
|---|---|---|
| | | **Settleable** |
| 10 | Gravel | 0.3 seconds |
| 1 | Coarse sand | 3 seconds |
| 0.1 | Fine sand | 38 seconds |
| 0.01 | Silt | 33 minutes |
| | | **Considered Nonsettleable** |
| 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.*



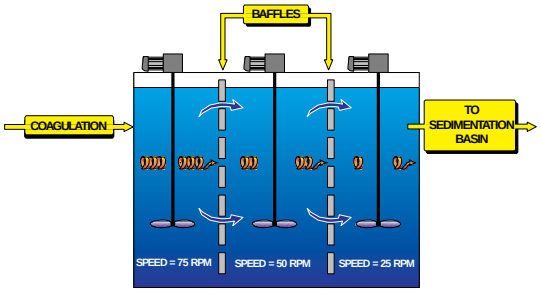


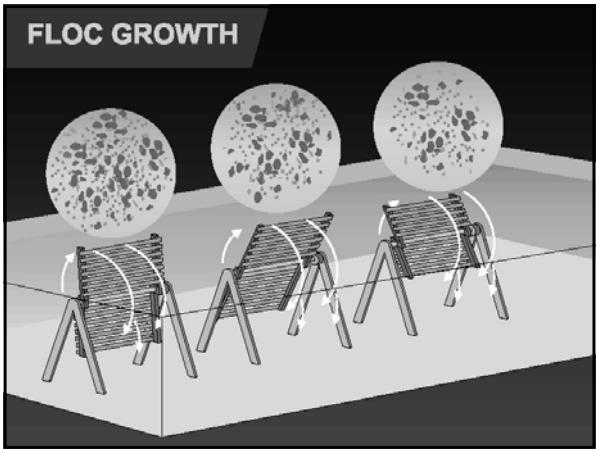


## Coagulation Chemicals

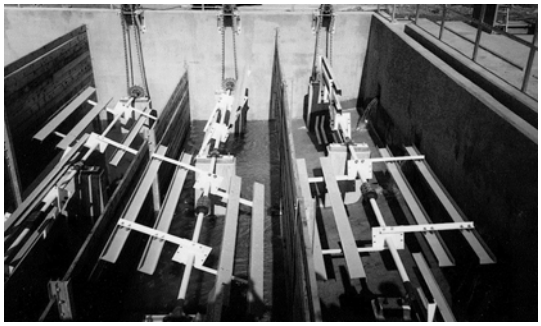
- **Alum (aluminum sulfate)**
- **Ferric Chloride**
- **Ferric Sulfate**
- **Polymers (may be used as a coagulant aid)**
- **PACL (polyaluminum chloride)**
- **PAS (polyaluminum sulfate)**

## Flocculation Equipment



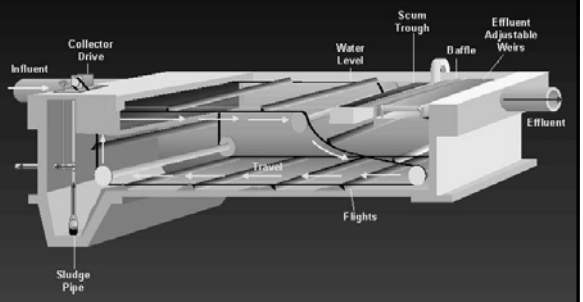




## Paddle Wheel Flocculators



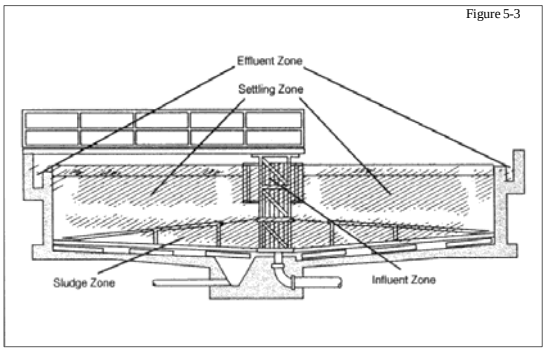
## Rectangular Sedimentation Basin

With continuous chain collector sludge removal system

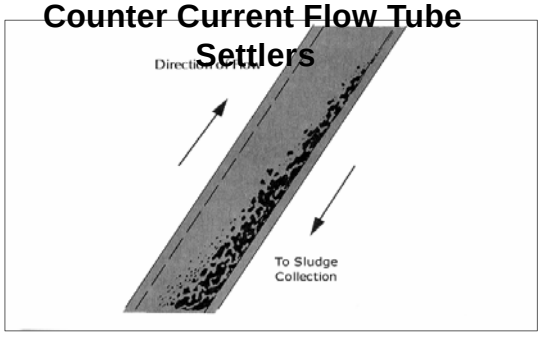



## Zones in a Sedimentation Basin

Figure 5-3

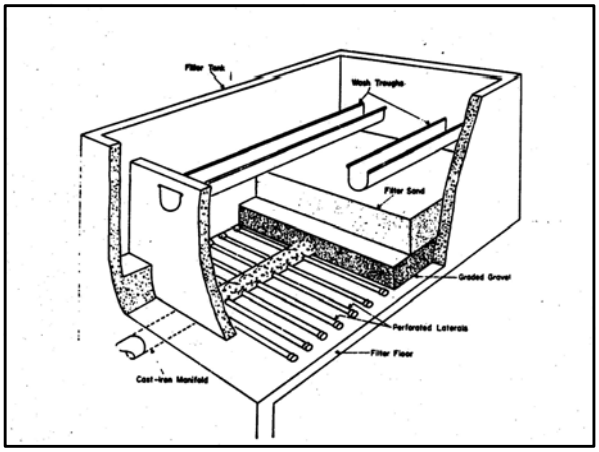



## Counter Current Flow Tube Settlers



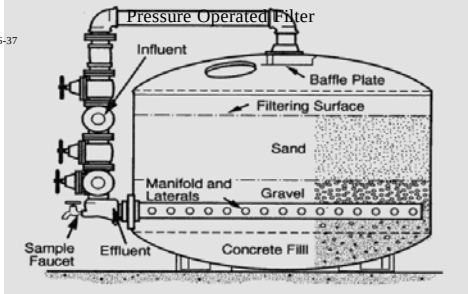
## Importance of baffling:

- Provides a uniform flow across a basing while preventing short circuiting.
- Detention time?
  2 - 4 hours
- What other things can cause short circuiting in a sedimentation basin?

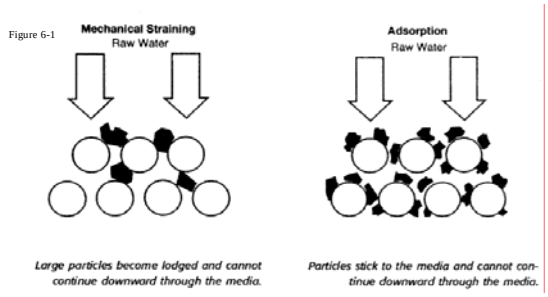



## Pressure Filters

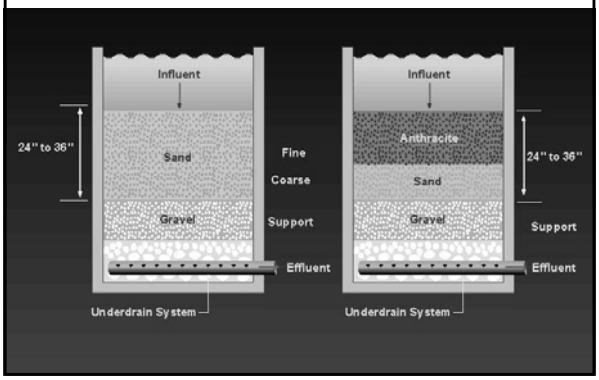
Figure 6-37



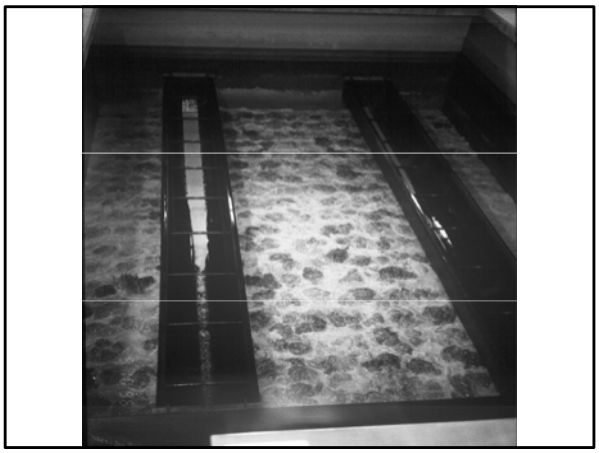
## The Filtration Process

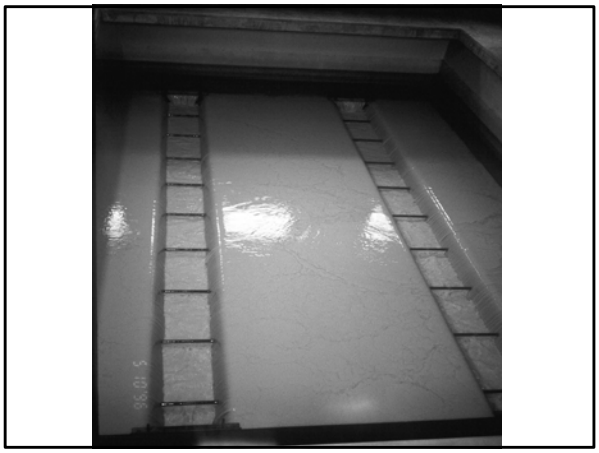



## Single and Dual Media Filters




## Surface Wash System

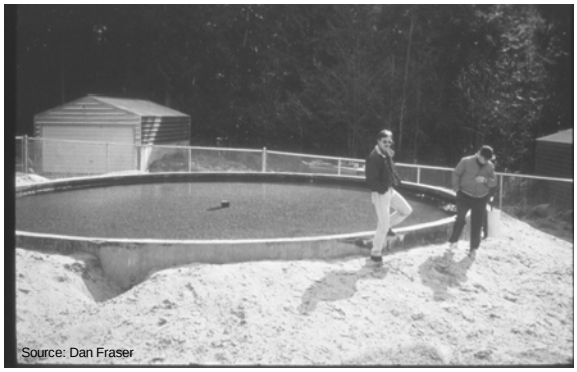





Medial
Core Sampling

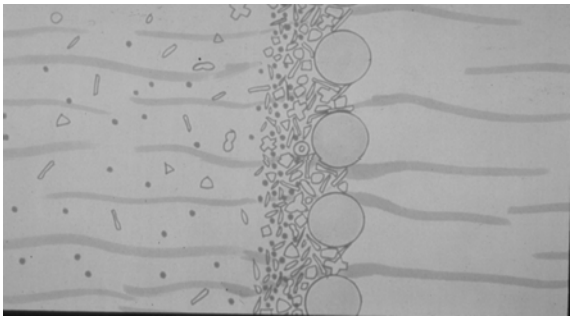
## Filter Probing

## Slow Sand Filter



Source: Dan Fraser

## Diatomaceous Earth Filter

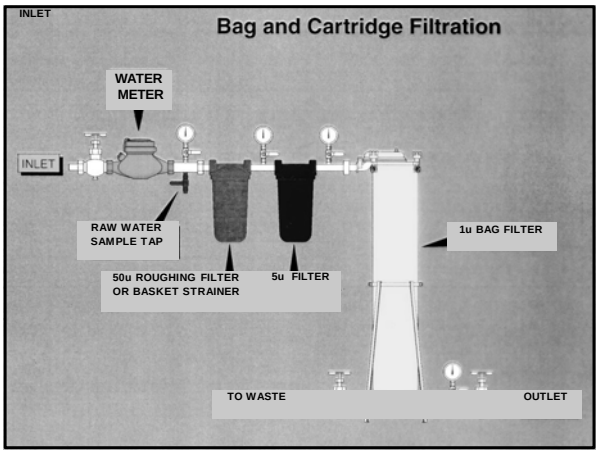


## Diatomaceous Earth Filtration

Figure 6-39

## Diatomaceous Earth Filtration

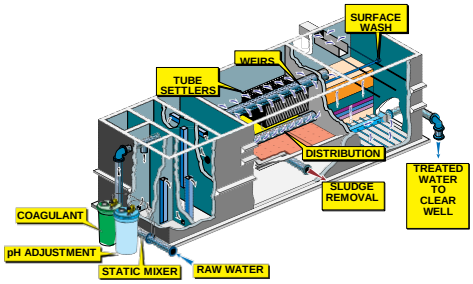
Figure 6-38




## Bag Filters

## Cartridge System

## Package Treatment Plants




Conventional Treatment Package Plant

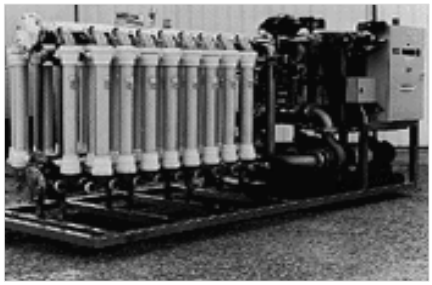
## Package Treatment Plants

*Neptune Microfloc Trident*® Package Plant

## CITY OF FREDERICK
## Emergency UF Plant

1 MGD CAPACITY
HIGH COLIFORM
HIGH TURBIDITY
LEASE (TEMP. PLANT)
EXTREMELY FAST SCHEDULE

## FULLY AUTOMATED PACKAGED PLANTS AVAILABLE



## Beware!

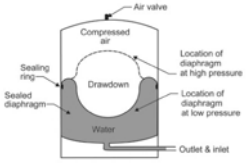
- Many package plants and other treatment processes provided by vendors claim “automatic” or “hands off” controls.
- These systems still need to have scheduled maintenance performed on a regular basis to reduce all failures.

## Organics Removal– Carbon Adsorption

- Carbon adsorption methods
  - Powdered activated carbon
  - Granular activated carbon

## Organics Removal– Other Methods

- Enhanced coagulation and enhanced softening
- Ozone with biologically active filters (BAT)
- Membranes




## What is hard water?

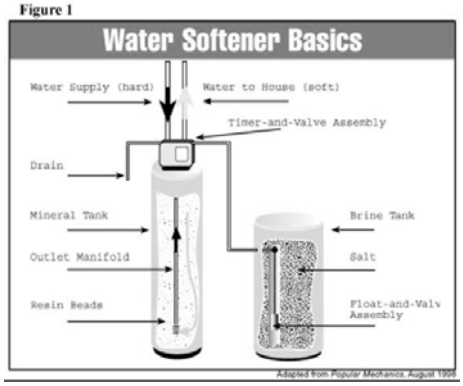
- Water having high concentrations of calcium and magnesium ions.

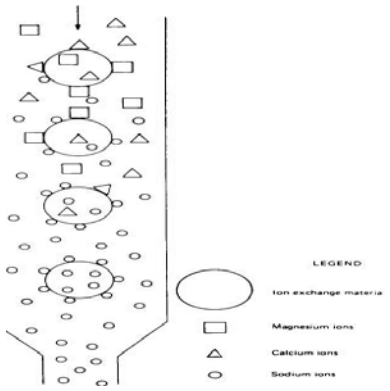
- *0-60 mg/l $CaCO_3$ – Soft Water*
- *61-120 mg/l $CaCO_3$ – Moderately Hard Water*
- *121-180 mg/l $CaCO_3$ – Hard Water*
- *>180 mg/l $CaCO_3$ – Very Hard Water*

## What are some treatment techniques for reducing hardness?

- Ion-exchange softening
- Lime/soda ash softening
- Membrane filtration

Figure 1




## What are the 4 cycles of an ion exchange process?

- Softening
- Backwashing
- Regeneration
- Rinsing

## Run your facilities to the best of their abilities.

- Always keep up on:
  - Maintenance (Spare parts)
  - Training
  - Feedback from other managers and operators

## But Never Falsify!

- If you can't meet you regulatory requirements mandated by the EPA or your Primacy Agency, **never** falsify documents.

## Remember:

- If you need any assistance, don't be afraid to call someone!
  - State Primacy Agencies (MDE, DNREC)
  - Rural Water Associations
  - Another water system
  - WWOA, CWEA, CSAWWA
  - Instructors (Eddie Cope 410-222-8408 x-2)