Water Treatment

Water Concerns in 2016 GBRC

May 25, 2016

Fabian Heaney
City of Houston
Public Works and Engineering
Drinking Water Operations Lab

In General

➢History of Water Treatment

- 2000 BC Greeks boiled water and used charcoal
- 2000 BC Egyptians practice type of coagulation
- 300 BC Romans pipe water via aqueduct from purer sources (New York City today)
- 1800 AD Municipal sand filtration in Scotland
- 1881 Municipal coagulation in England.
- 1905 Commercial water softening in Germany
- 1908 Jersey City first US city to use chlorination

In General

- **Laws and Regulations**

The Process

Public concerns and/or a recognition of link between cause and effect

↓

Law

↓

Regulations

In General

➢Federal Water Laws

- 1899 Rivers & Harbors Act
- 1948 Water Pollution Control Act
- 1956 Federal WPCA (1972)
- 1965 Water Quality Act
- 1974 Safe Drinking Water Act (1986, 1996)
- 1977 Clean Water Act
- 1977 Soil & Water Resources Conservation Act
- 1987 Water Quality Act
- EPA Rules based on SDWA 1996 (LT2SWTR, UCMR, GWR, DBPR)

➢Texas Water Laws

- TCEQ Title 30 Chapter 290
- TCEQ Title 30 Chapter 311

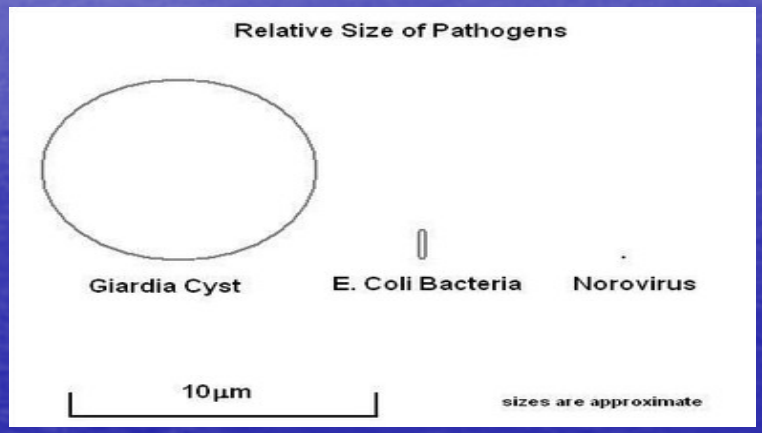
In General

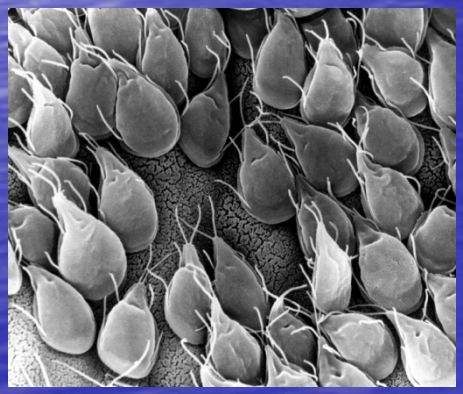
- **EPA Currently Regulates:**
  - 6 microbiological contaminants
  - 1 physical parameter
  - 5 disinfection by-products
  - 3 disinfectants
  - 16 inorganic contaminants
  - 53 organic contaminants
  - 4 radiological contaminants
  - COH monitors 25+ other "unregulated contaminants"

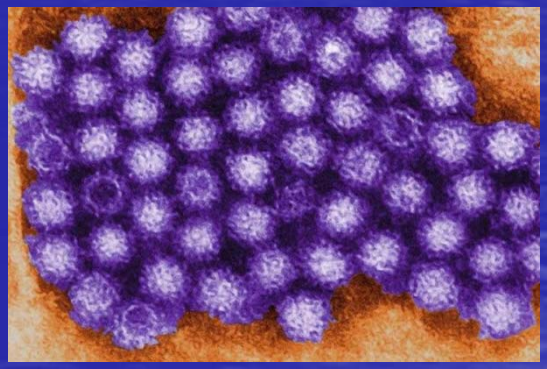
In General

➢Causes of Waterborne Diseases

- Protozoa
- Bacteria
- Viruses



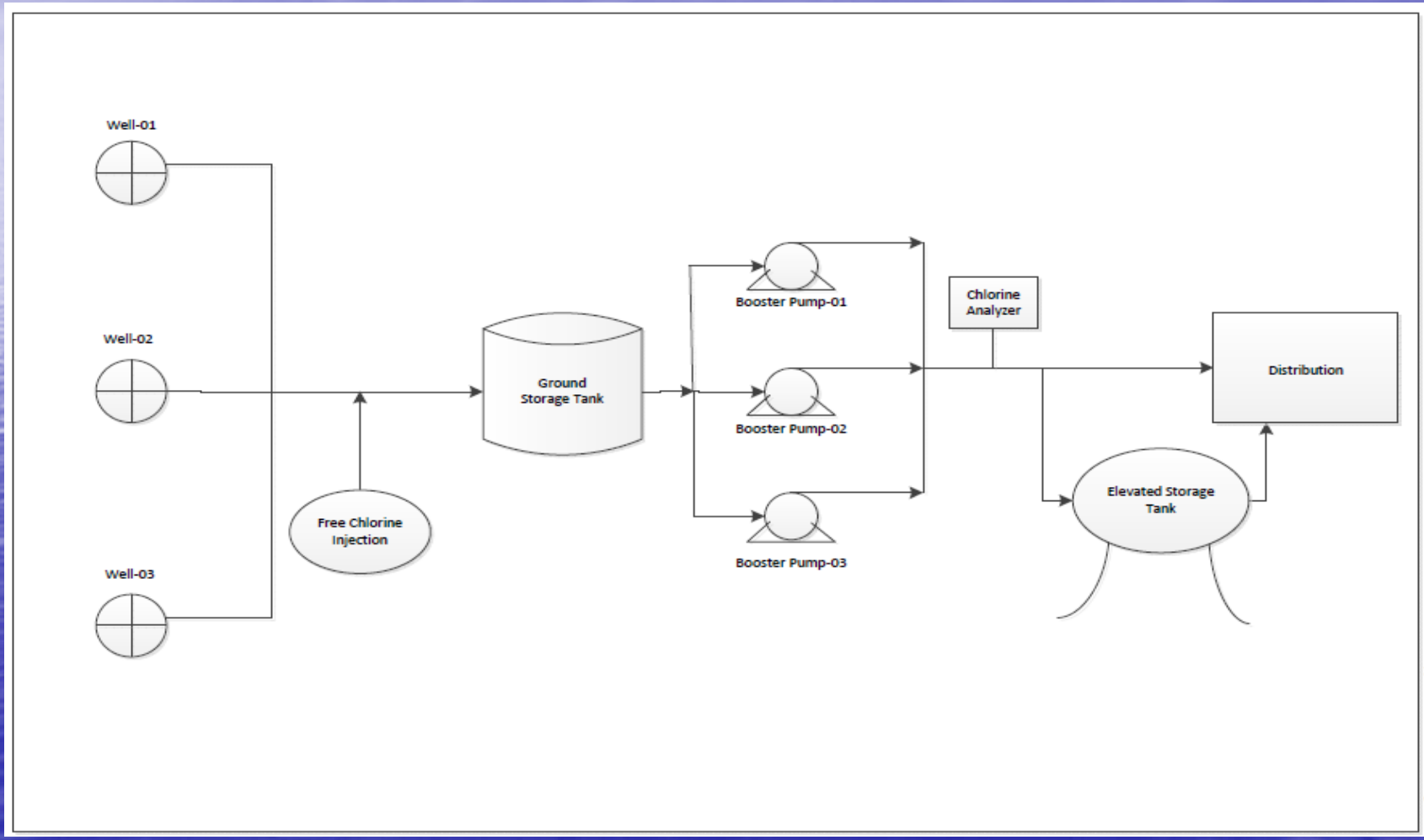




Components of a Municipal Water System

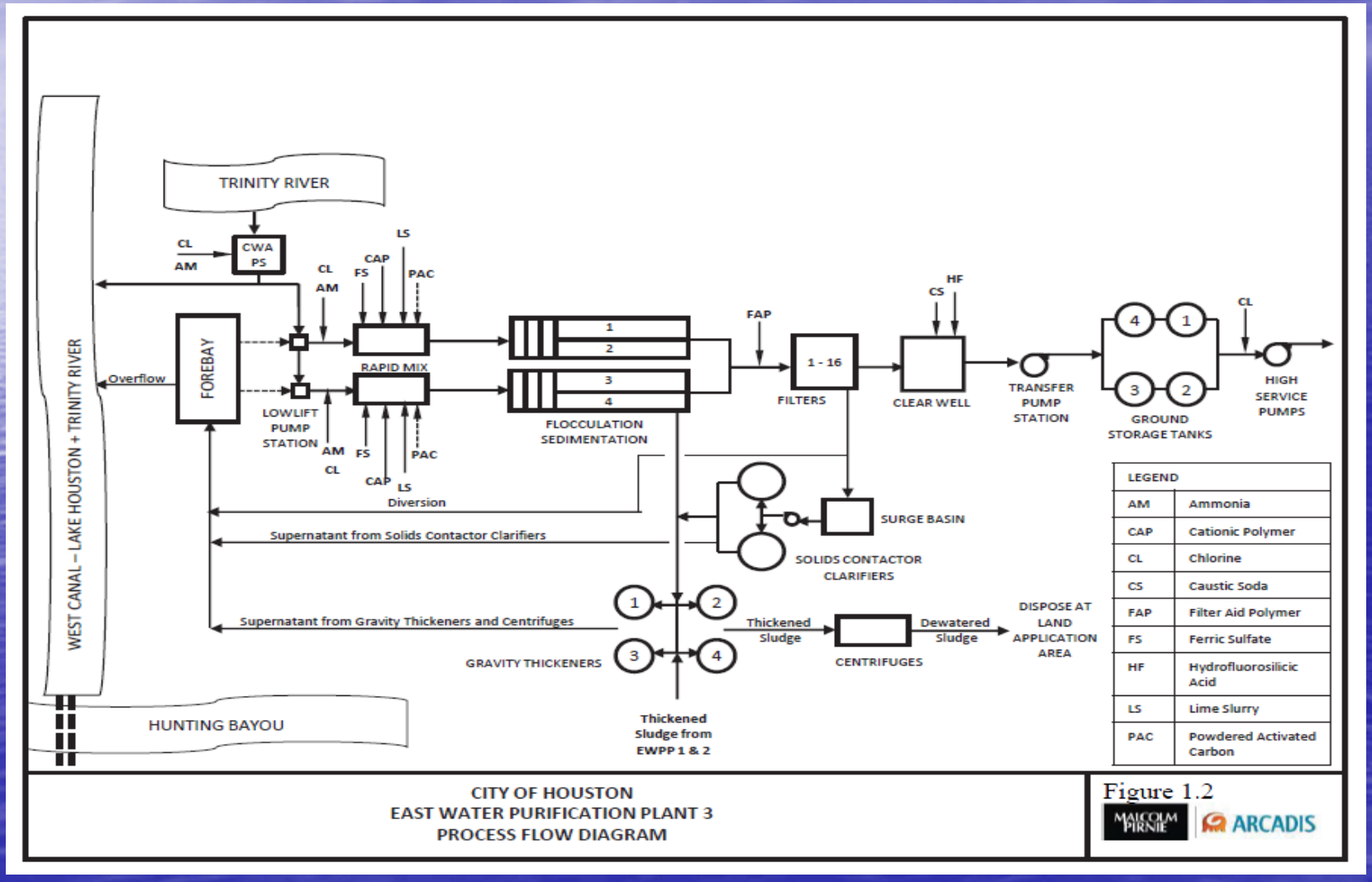
Water Treatment Process

Ground Water



Water Treatment Process

Surface Water

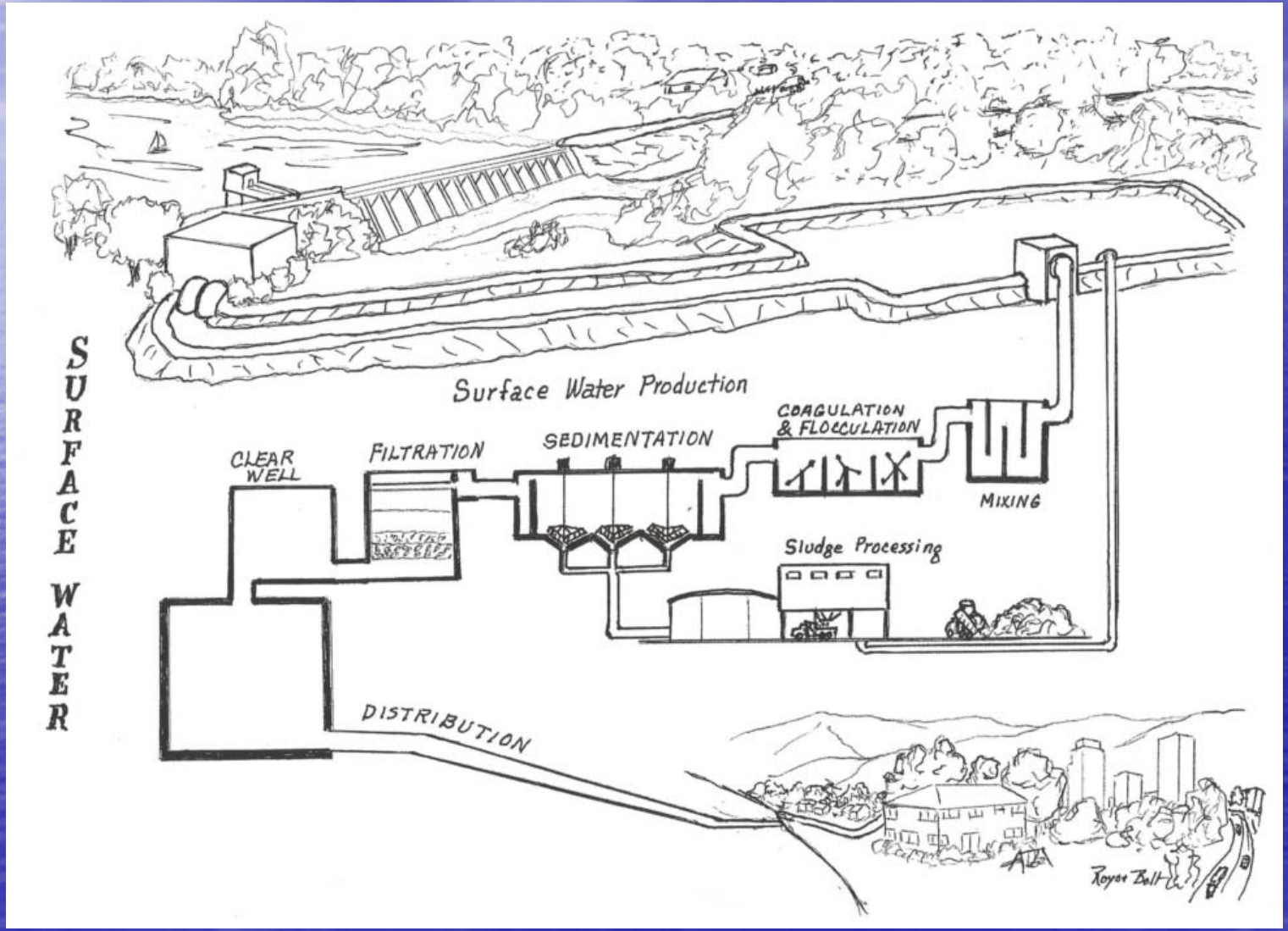


Water Treatment Process

Surface Water

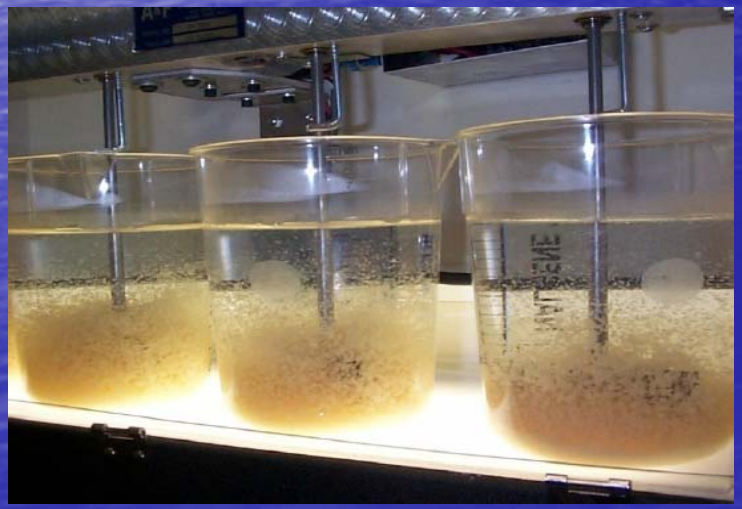
Water Treatment Process

Surface Water



Coagulation Process

- **Purpose: Removal of Particulate Matter**
  - **By changing a larger number of small particles to a smaller number of large particles.**
- **Common Coagulants**
  - **Aluminum sulfate [$Al_2(SO_4)_3$] – Alum**
  - **Ferric sulfate [$Fe_2(SO_4)_3$] - Ferric**



Coagulation

Stable Particle

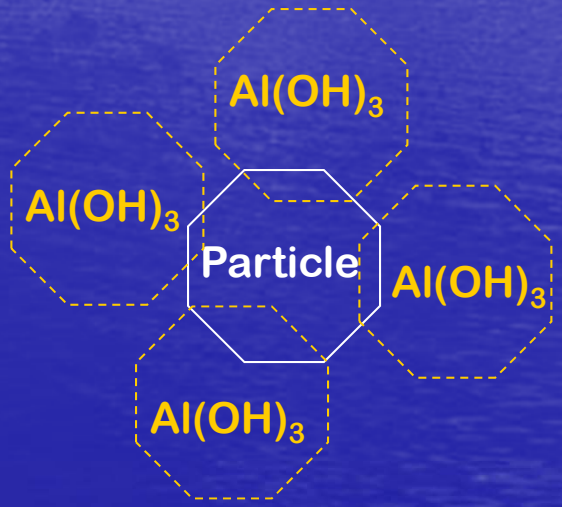
Charge
Neutralization

Al(OH)

Al(OH)

Al(OH)

Sweep
Floc

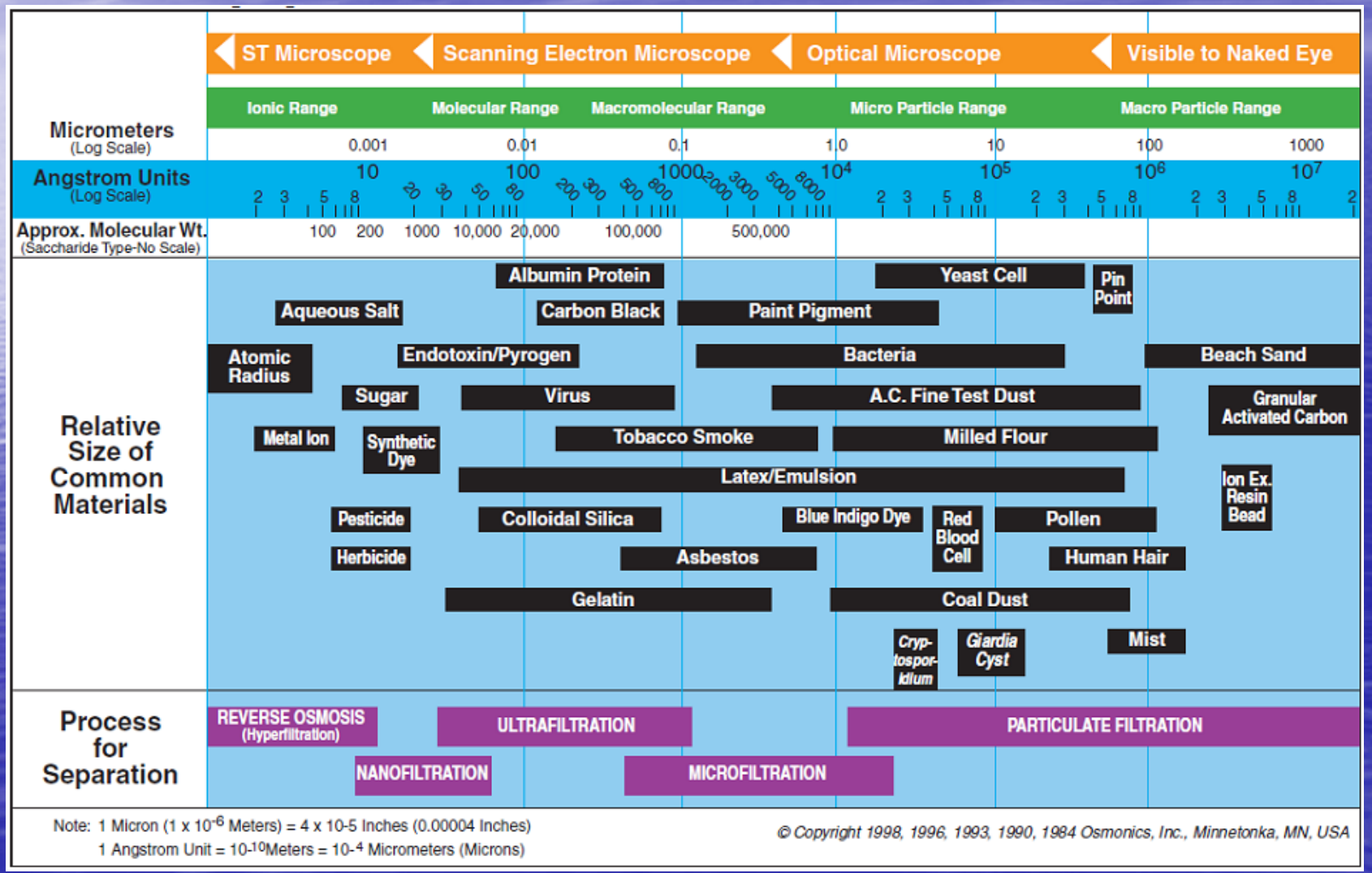


Destabilized Particle

Particle Enmeshed in Floc

Filtration

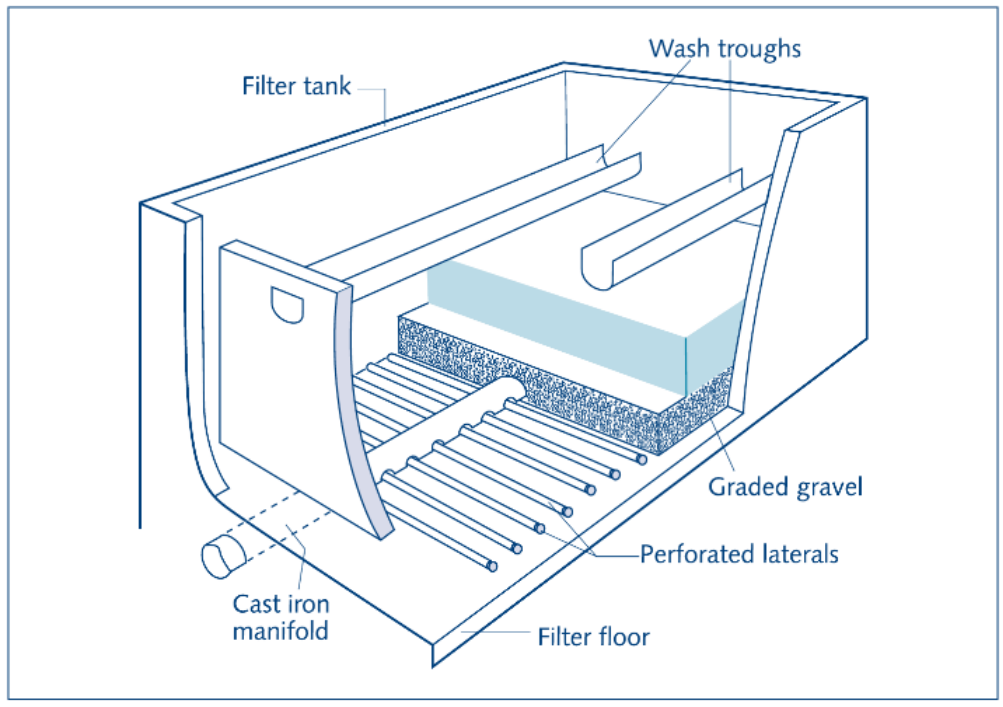
Filtration Ranges

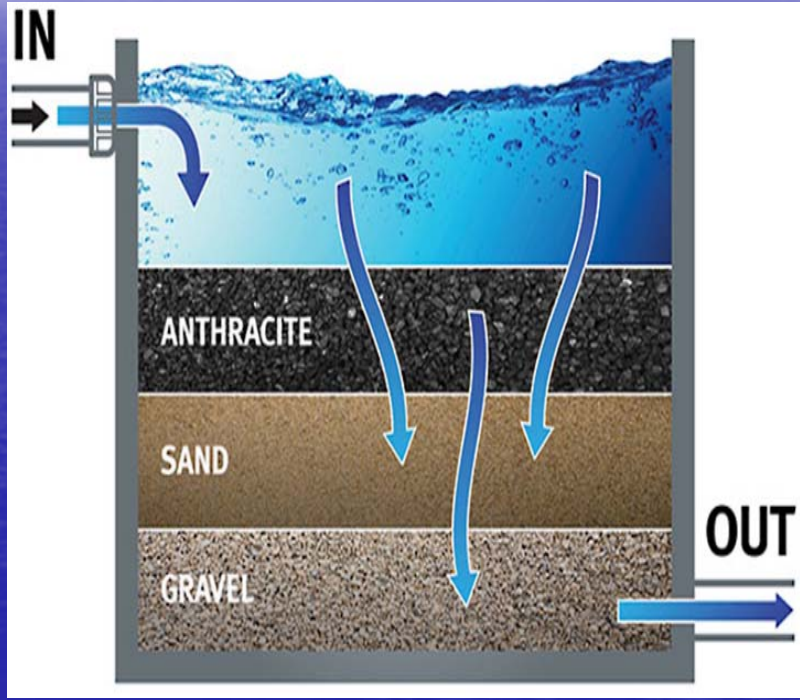


Note: 1 Micron (1 x 10^{-6} Meters) = 4 x 10-5 Inches (0.00004 Inches)
1 Angstrom Unit = 10^{-10}Meters = 10^{-4} Micrometers (Microns)

Filtration

- **Gravity Filter (Anthracite Sand)**

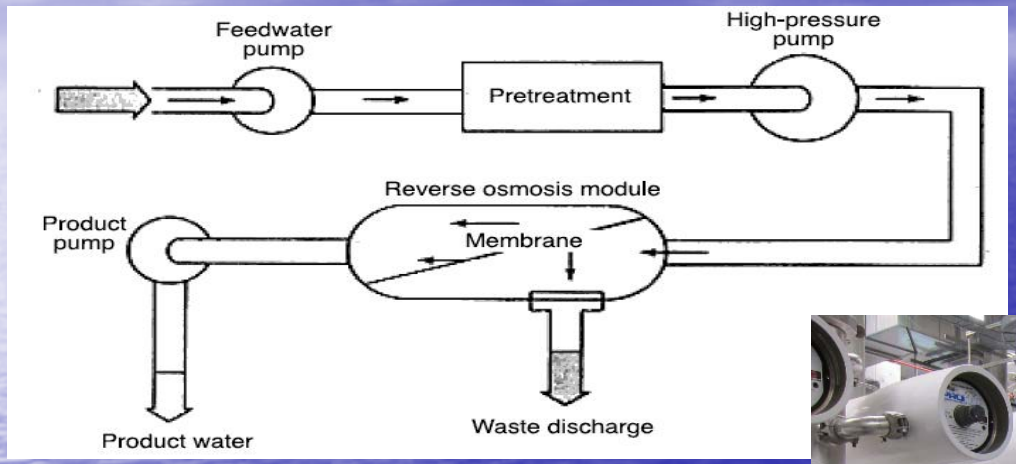




(Turbidity 0.1 NTU at end of process)

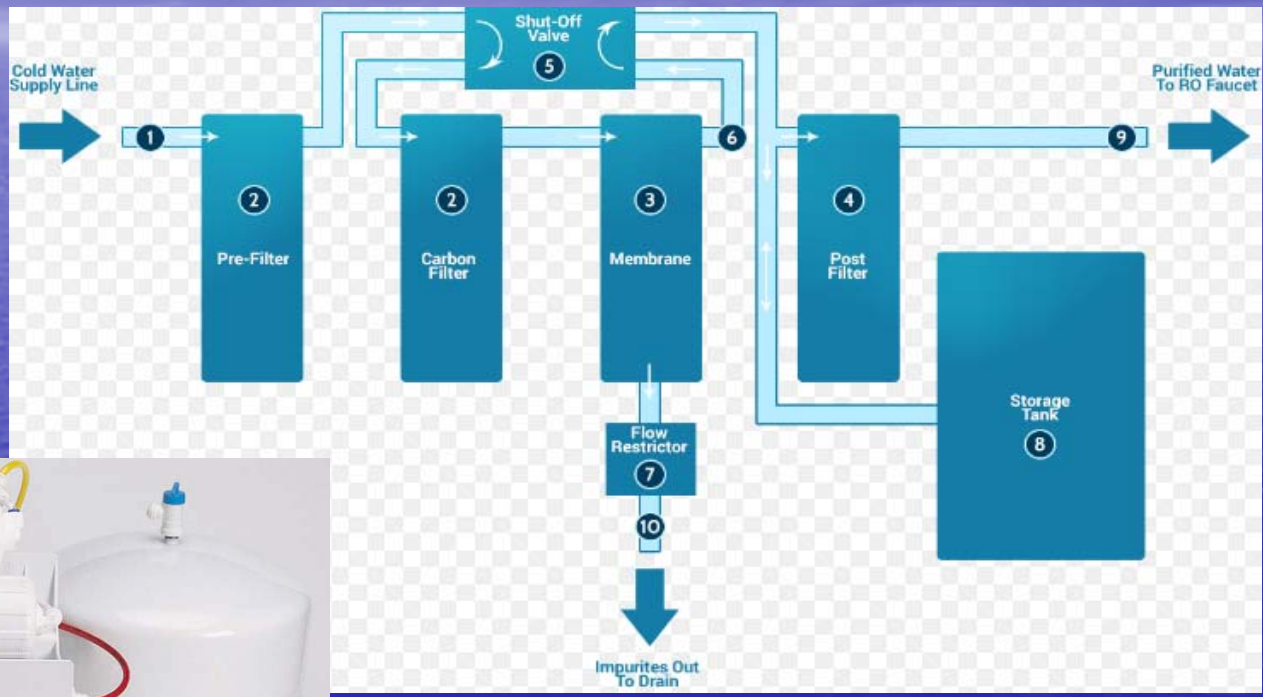
Filtration

- **Reverse-Osmosis (Plant Production)**



Filtration

- **Reverse-Osmosis (On-site)**



Filtration

- **In-Line Filter (On-site)**

Hardness Removal

- **What is Hardness?**

  - Water hardness is defined as the amount of divalent metallic cations in the water and is expressed in mg/L as $CaCO_3$.

  - The major divalent metallic cations that contribute to water hardness are calcium (Ca^{2+}) and magnesium (Mg^{2+}).

  - Mainly a concern with well water

Hardness Removal

➢ Hardness Concerns

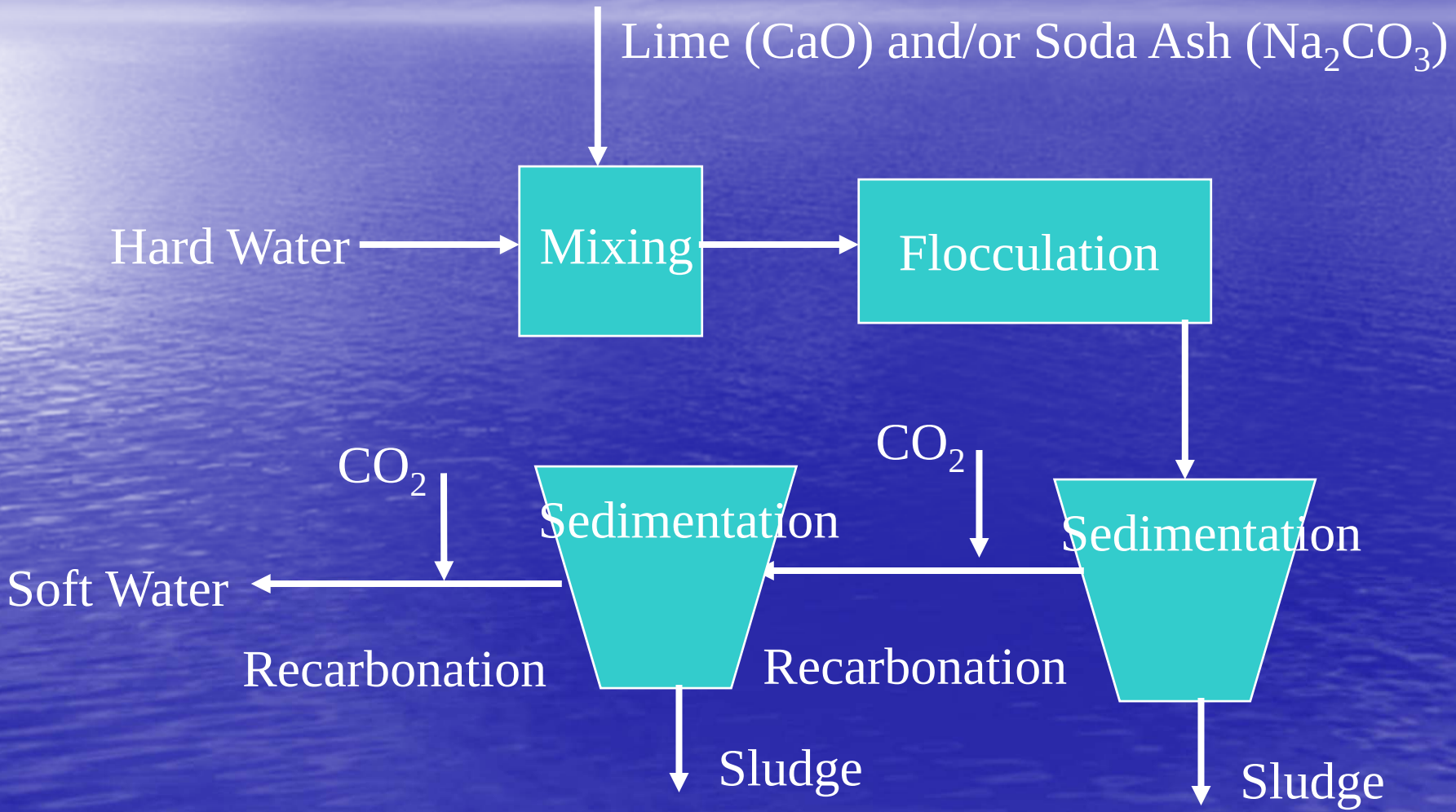
- Scale formation in a distribution system, hot water piping and fixtures.

- Soap “Demand”: making lather or suds for washing is difficult.

Water Hardness Scale		
Grains/Gal	**mg/L & ppm**	**Classification**
Less than 1	Less than 17.1	**Soft**
1 – 3.5	17.1 - 60	**Slightly Hard**
3.5 - 7	60 - 120	**Moderately Hard**
7 - 10	120 - 180	**Hard**
Over 10	Over 180	**Very Hard**

Hardness Removal

- **Two-Stage Lime Softening**



Hardness Removal

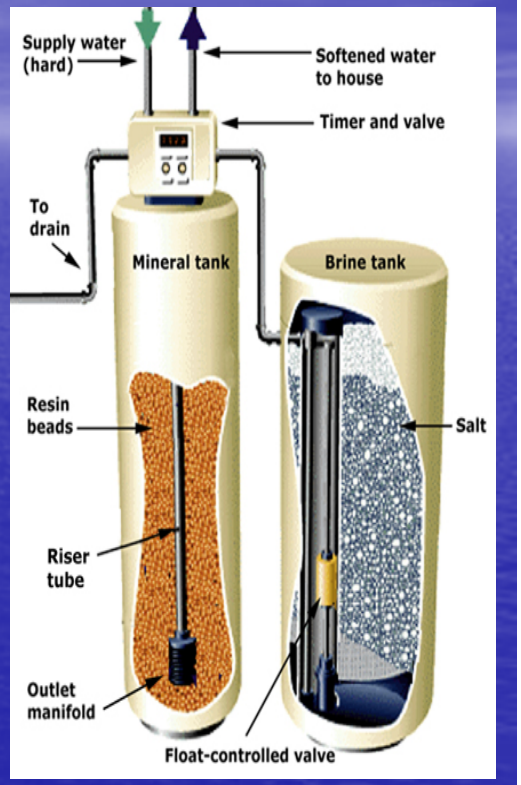
➢Ion Exchange Softening

- Softening reaction:

$$Na_2R + \left.\begin{matrix} Ca^{2+} \\ Mg^{2+} \end{matrix}\right\} \leftrightarrow \left.\begin{matrix} Ca \\ Mg \end{matrix}\right\} R + 2\,Na^{+}$$

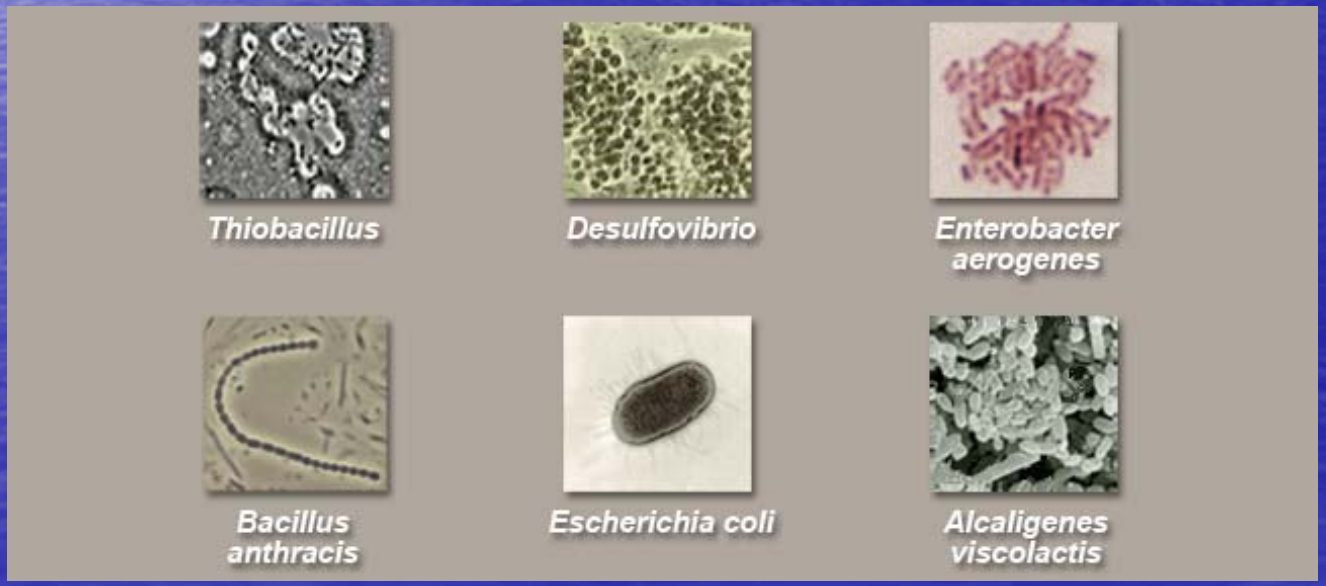
- Regeneration reaction:

$$\left.\begin{matrix} Ca \\ Mg \end{matrix}\right\} R + 2\,NaCl \leftrightarrow Na_2R + \left.\begin{matrix} Ca \\ Mg \end{matrix}\right\} Cl_2$$



Disinfection Process

- **Disinfection Goals**
  - Inactivate pathogenic organisms
  - Provide disinfectant residual to protect distribution system from contamination



Disinfection Process

- **Disinfectants**

  - Chlorine
  - Chloramines
  - Chlorine Dioxide
  - Ozone
  - Ultra-violet light (UV)

Disinfection Process

- **Chlorination (Free Chlorine)**

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Chlorine Water Hypochlorous Acid Hydrochloric Acid

  - Disinfection residual 0.2 to 4.0 mg/L
  - Faster inactivation of pathogens
  - Short distribution system residual
  - DBP formation

Disinfection Process

- **Chloramination (Combined Chlorine)**

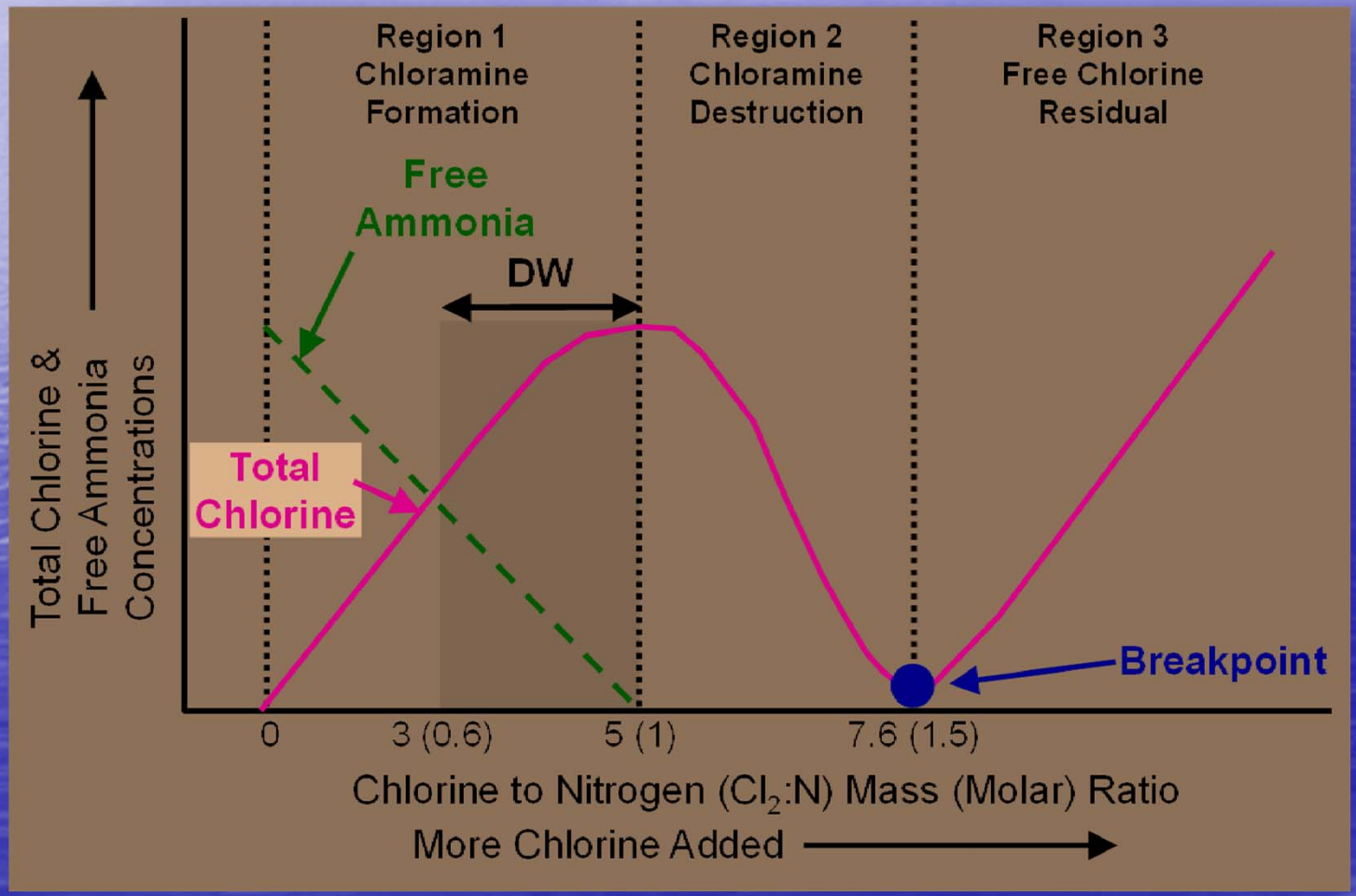
$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$

Ammonia Hypochlorous Acid Chloramine Water

  - Disinfection residual 0.5 to 4.0 mg/L
  - Longer lasting residual than free chlorine
  - Low DBP formation

Disinfection Process

- **Chlorine Demand or Breakpoint Chlorination**

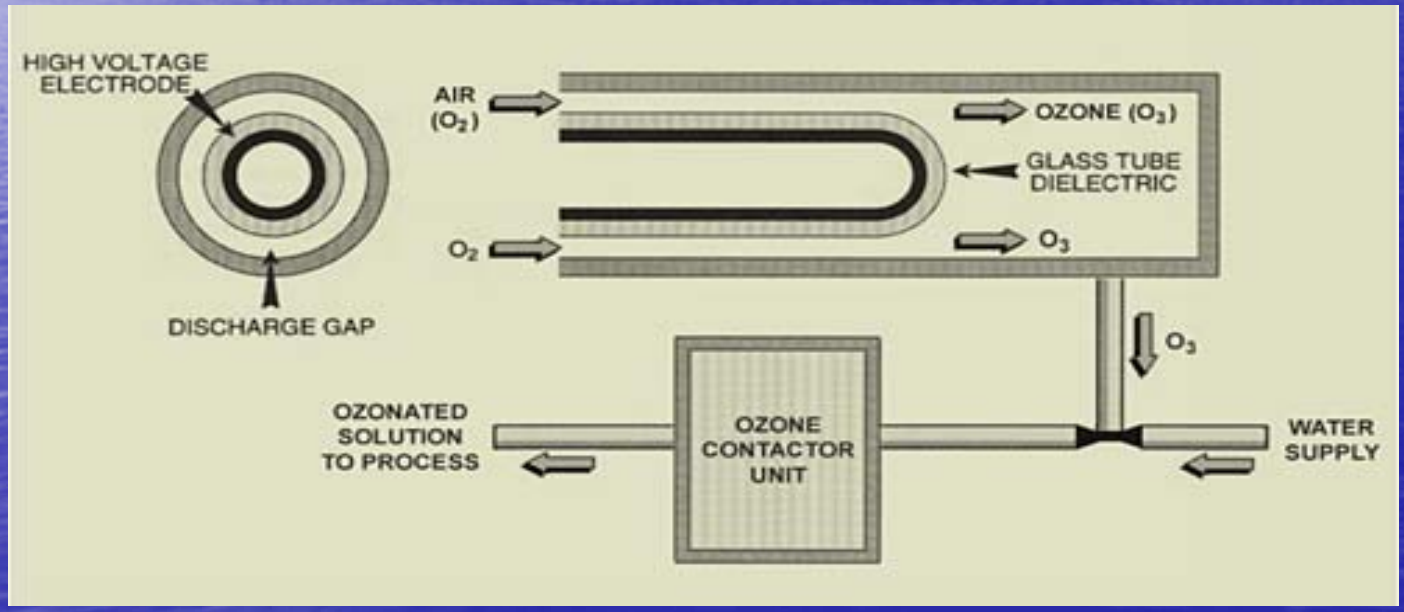


Disinfection Process

- **Ozonation**

$$O_3 \rightarrow O_2 + [O]$$

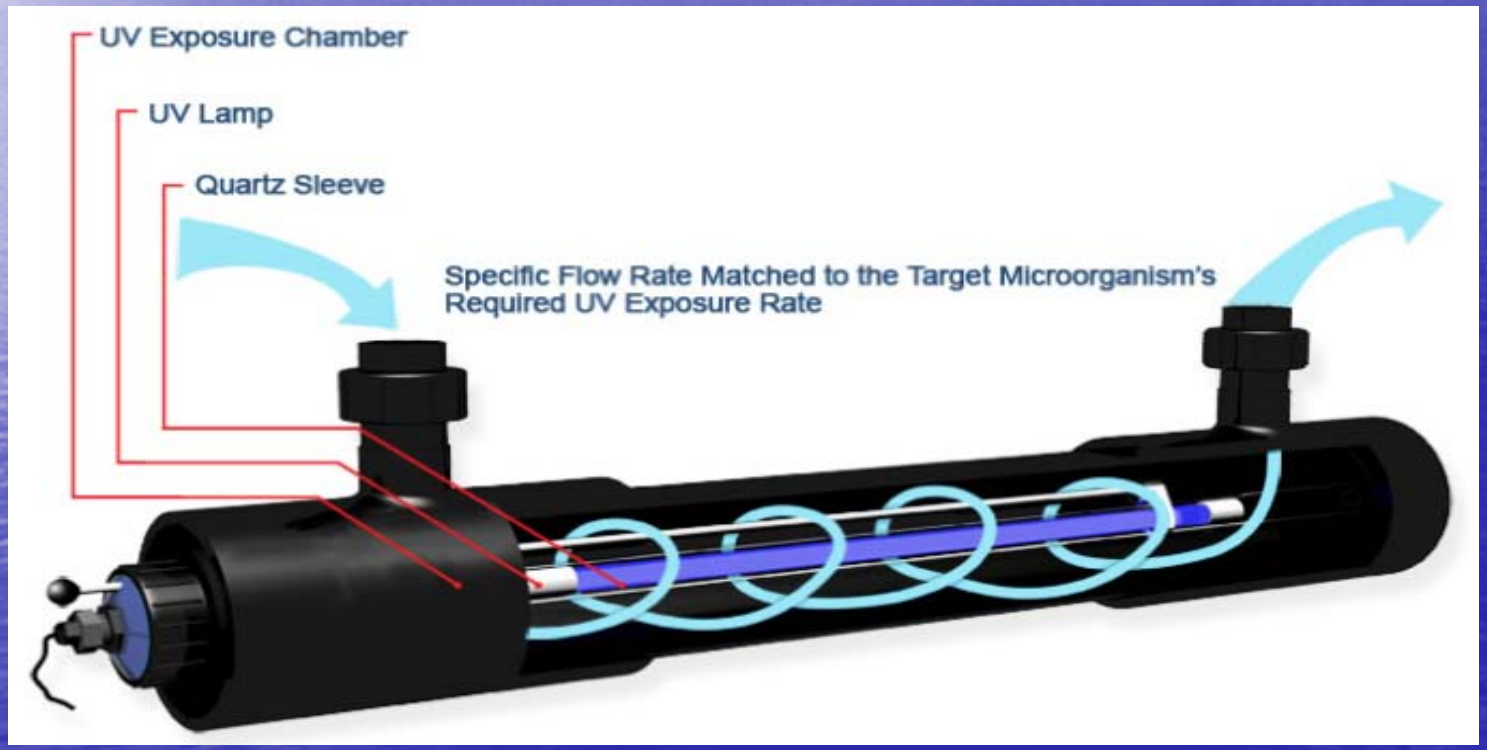
Ozone — Oxygen — Oxygen Atom (powerful oxidant and disinfectant)



Chlorination is used for residual disinfectant

Disinfection Process

- **UV Radiation**



Chlorination is used to provide a residual disinfectant

Disinfection Process

Comparison of Disinfectant Inactivation Efficiency

Disinfectant	Contact Time (min)	
	99% Giardia Inactivation	99% Virus Inactivation
Free Chlorine	18	1
Chlorine Dioxide	3.7	1.4
Chloramines	250	214
Ozone	0.16	0.15
UV Irradiation	0.15	0.5

Distribution Treatment

- **Disinfectant Residual in system maintained by flushing. (Chloramine residual 0.5 mg/L - 4.0 mg/L, average is 2.0)**
- **Corrosion Control by pH adjustment during treatment (7.6 to 8.6) and addition of inhibitors (e.g. phosphate).**

PURE WATER IS THE WORLD'S FIRST AND FOREMOST MEDICINE.

Proverb

Fabian Heaney
City of Houston
Public Works and Engineering
Drinking Water Operations Lab