GLOBAL PERSPECTIVE.
LOCAL FOCUS.

Associated Engineering

Cost Effective Treatment of Small Ground Water Systems




Garry Drachenberg, P.Eng.

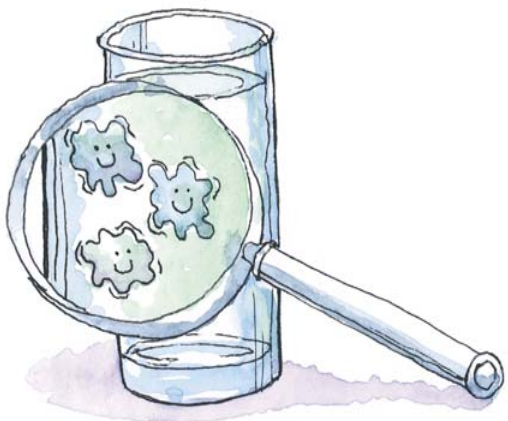
Cost Effective Treatment of Small Ground Water Systems

"The most cost effective treatment is the one that accomplishes treatment objectives at the least cost …… *it doesn't mean it's the least expensive*"

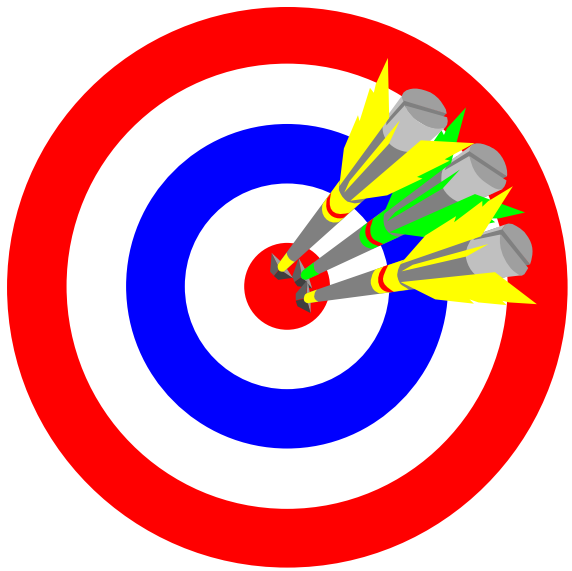
Associated Engineering

Cost Effective Treatment of Small Ground Water Systems

"How we treat it depends on"



"What's in it"

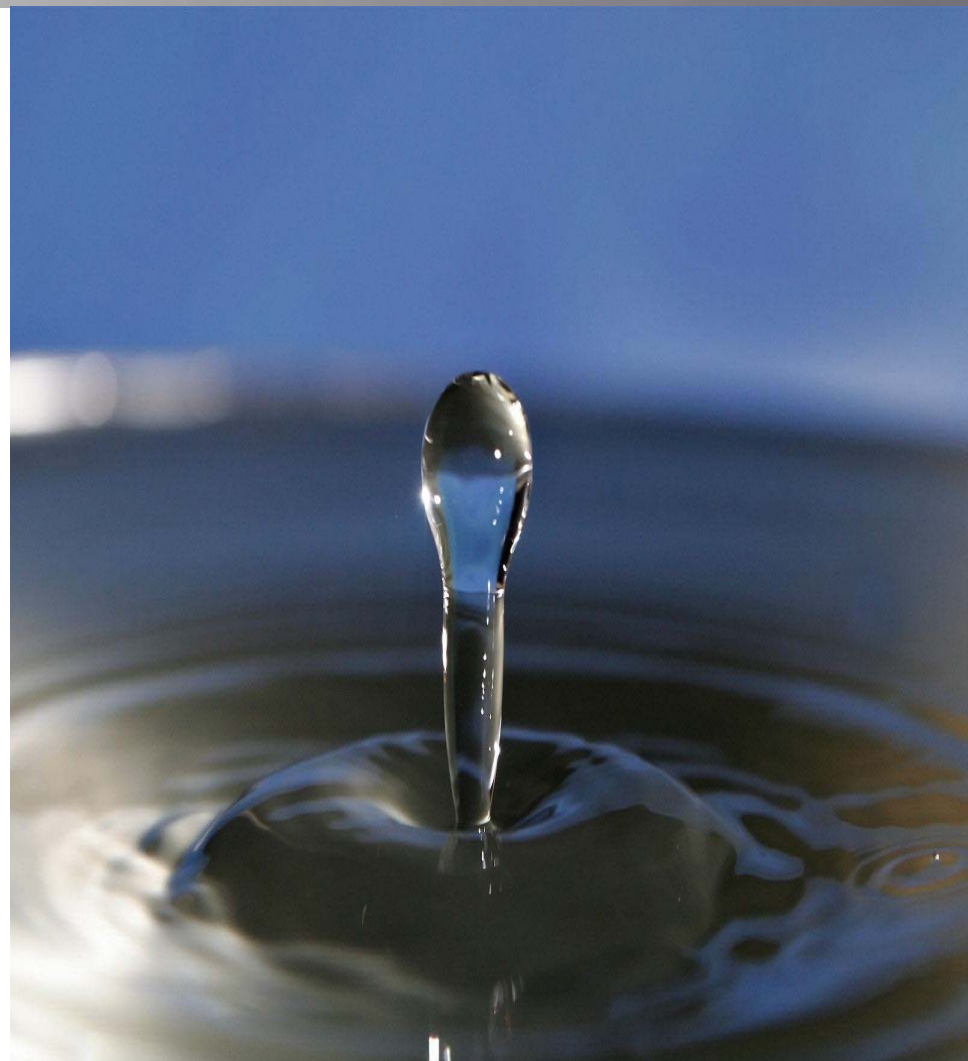


"Treatment Targets"

Associated Engineering

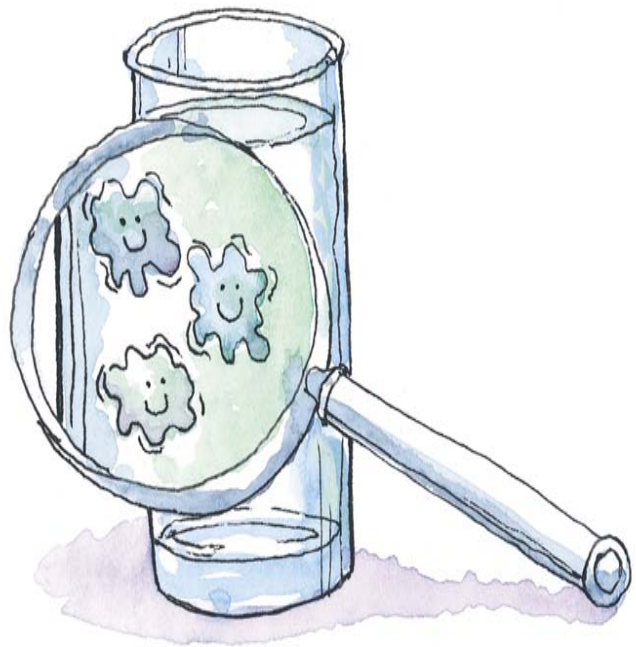
Presentation Overview

- What's in water
- What's in groundwater that needs treatment
- Typical ground water treatments
  - *CT Concept*
- Summary Comments

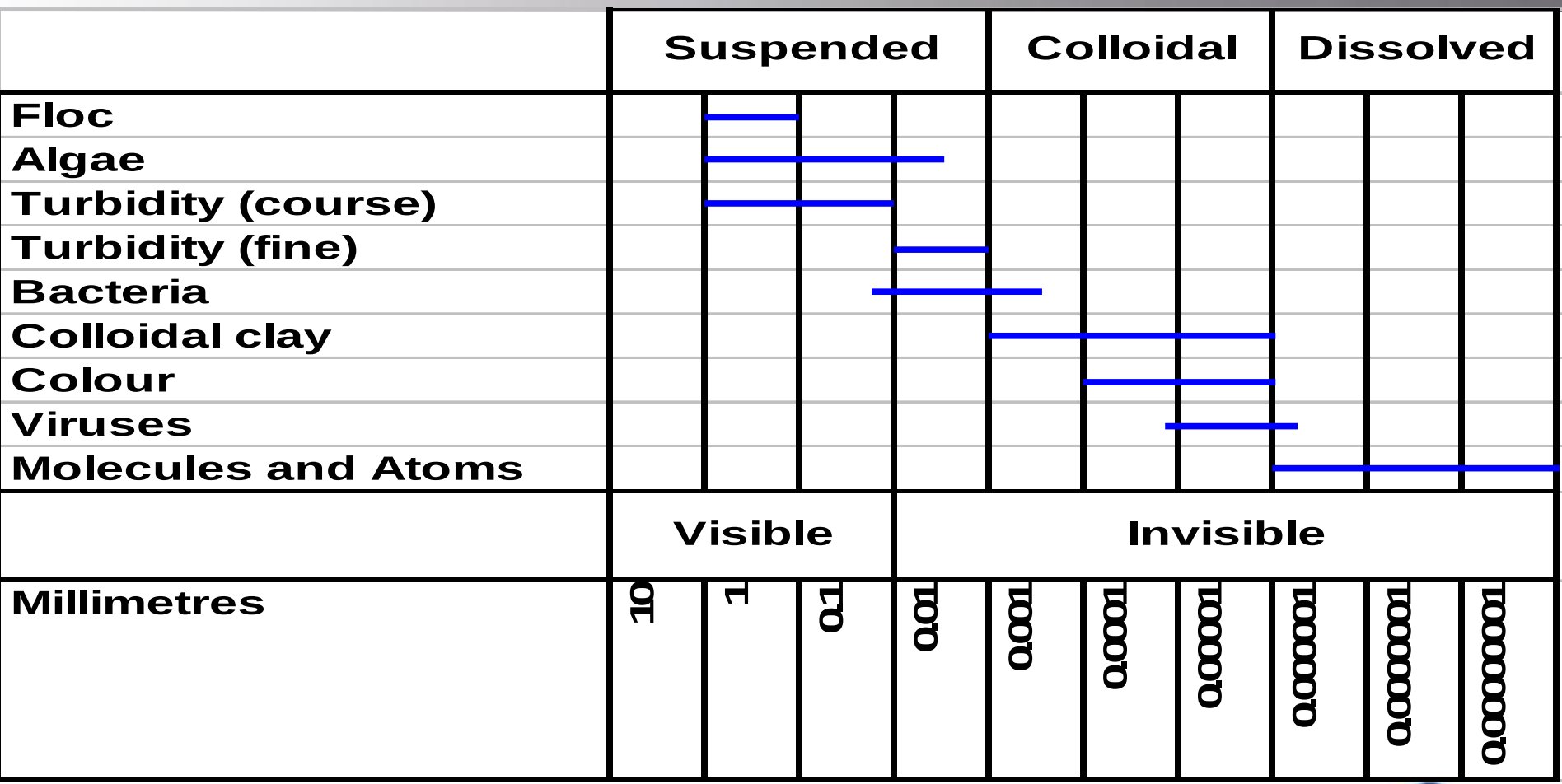


What's In Water

- Small & Big "Stuff"
- Basic Categories
  - Health Rated Parameters
  - Aesthetic / Nuisance Related



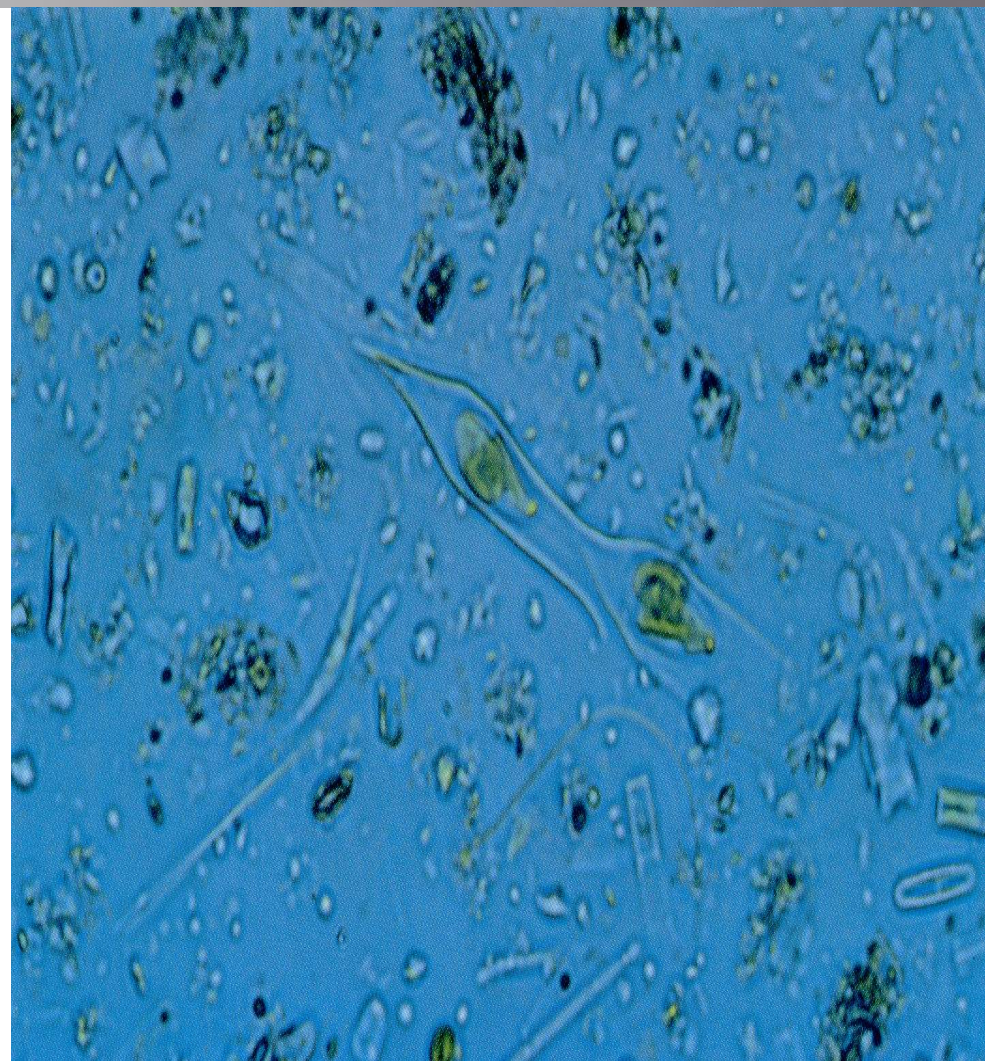
What's In Water



Associated Engineering

What's In Water

- Current "Prime Time" Contenders
- Less Pondered "Critters"
- Rising Stars



Prime Time Contenders

- Viruses
  (e.g., Norwalk virus, rotaviruses)
- Bacteria
  (e.g., *Shigella, E.coli*)
- Parasites, protozoa and cysts
  (e.g., *Giardia lamblia, Cryptosporidium*)

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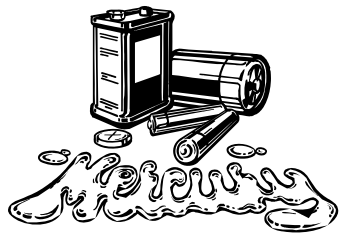
Types of Contaminants Causing Chronic Health Effects

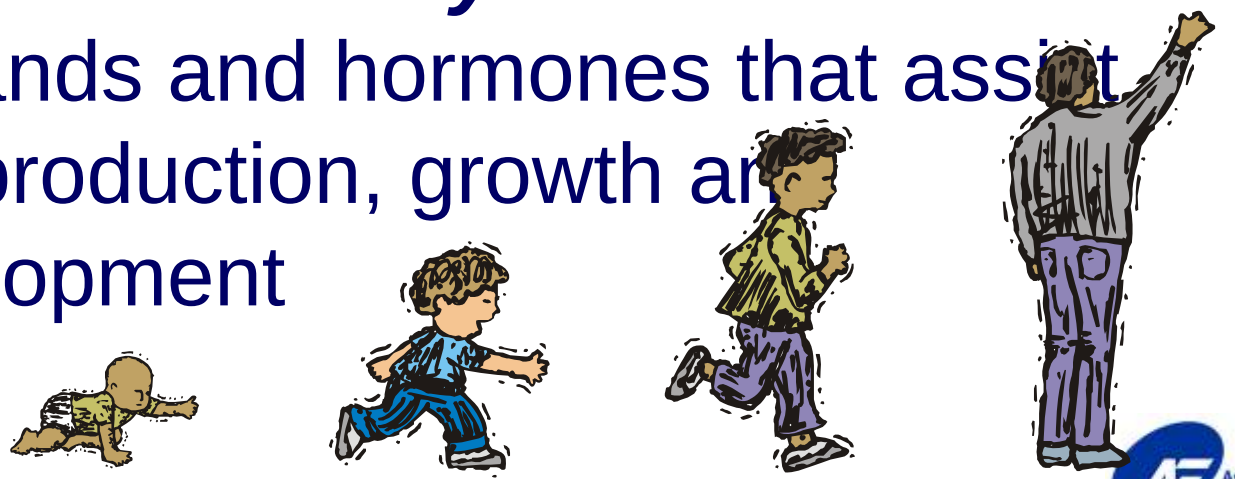
- Volatile organic chemicals (VOCs)
- Inorganic chemicals (IOCs)
- Synthetic organic chemicals (SOCs)
- Radionuclides



Associated Engineering

Rising Stars

- ***EDCs***: compounds that block, mimic, stimulate or inhibit the endocrine system
- ***The endocrine system***: combination of glands and hormones that assist in reproduction, growth and development



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Helicobacter pylori

- First discovered in 1982 in Australia
- Lives in the stomach!!
- 30-40% carry the organism in U.S.
  - Infection related to age and socioeconomic status

Associated Engineering

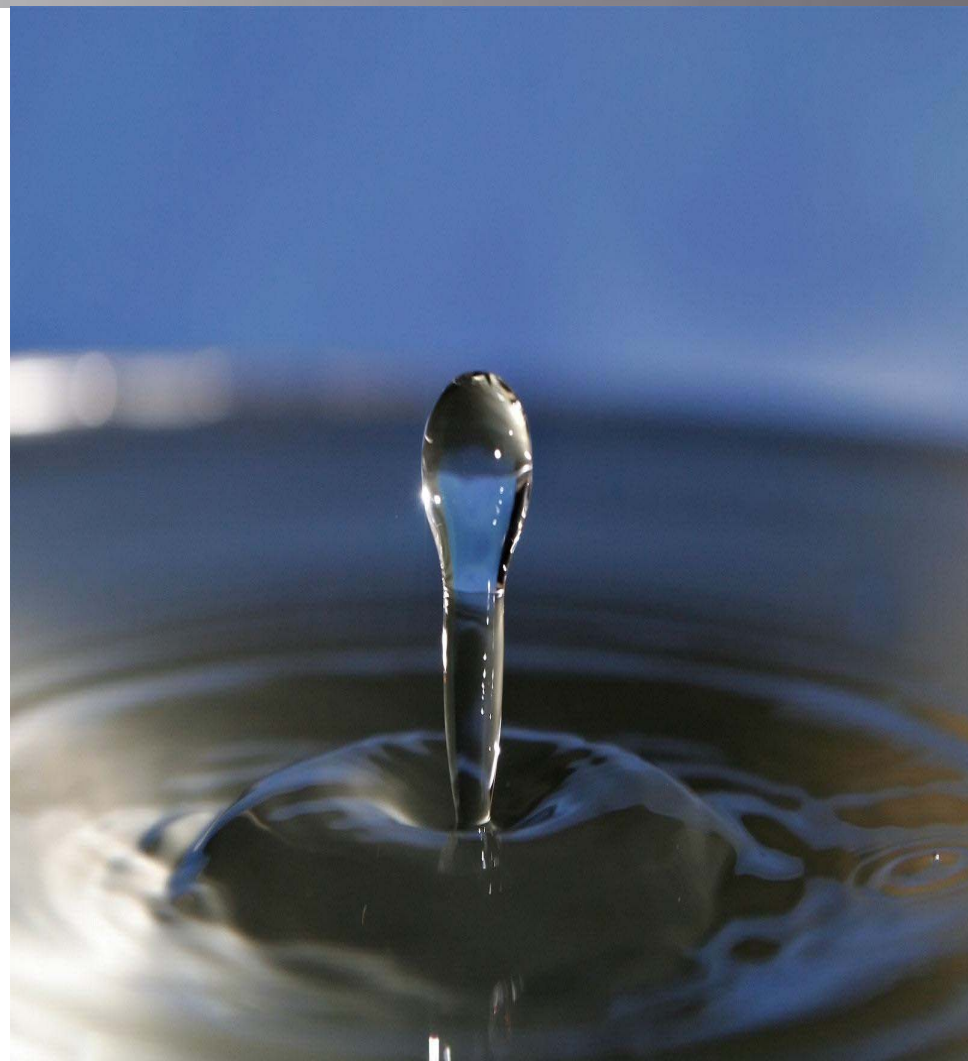
H. Pylori in Water?

- Reservoirs and transmission outside humans unclear
- Water transmission appears to be a major source
- Has been found even in wells with no total coliform bacteria!!!

Associated Engineering

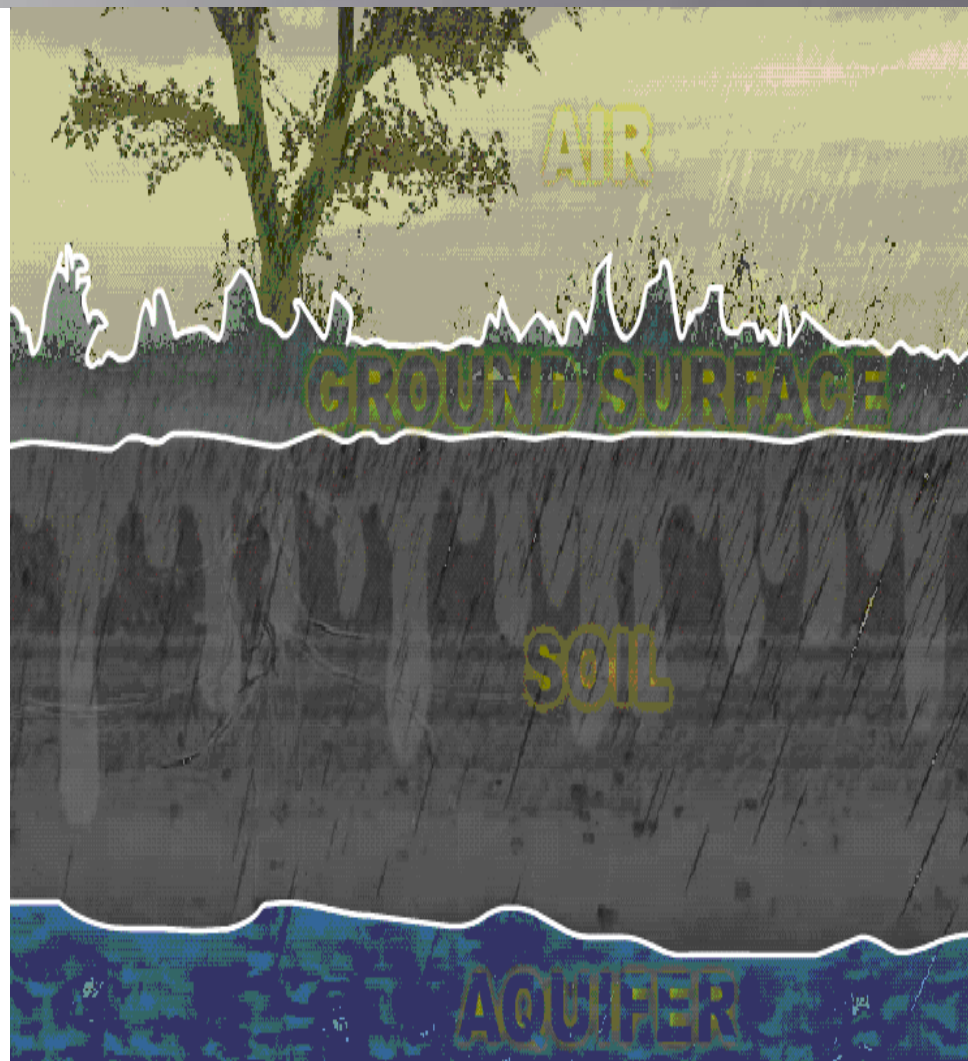
Presentation Overview

- What's in water
- What's in groundwater that needs treatment



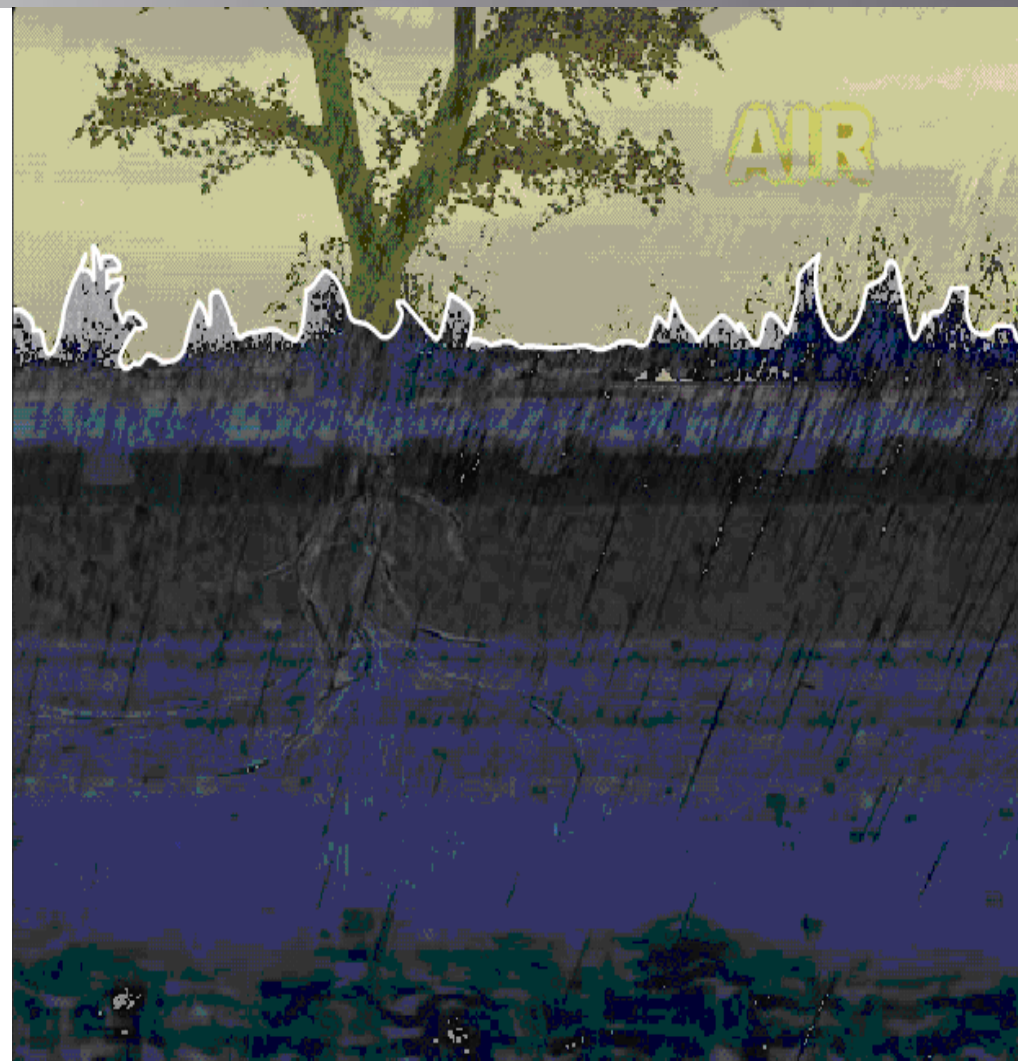
Groundwater Quality Determinants

- Groundwater quality is influenced by four factors:
  - air quality,
  - the surface of the ground,
  - subsurface soils,
  - characteristics of the aquifer



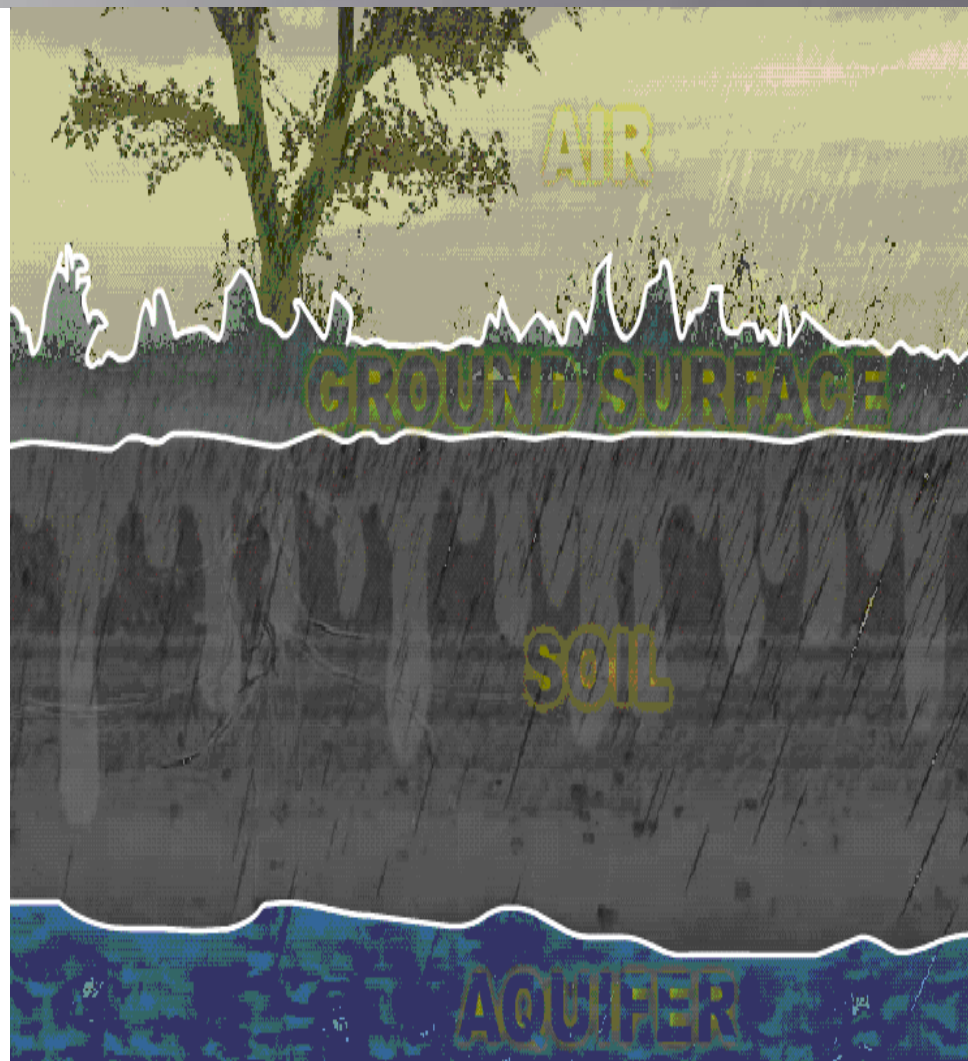
Groundwater Quality Determinants

- *Air Quality*: Can influence pH of rainwater



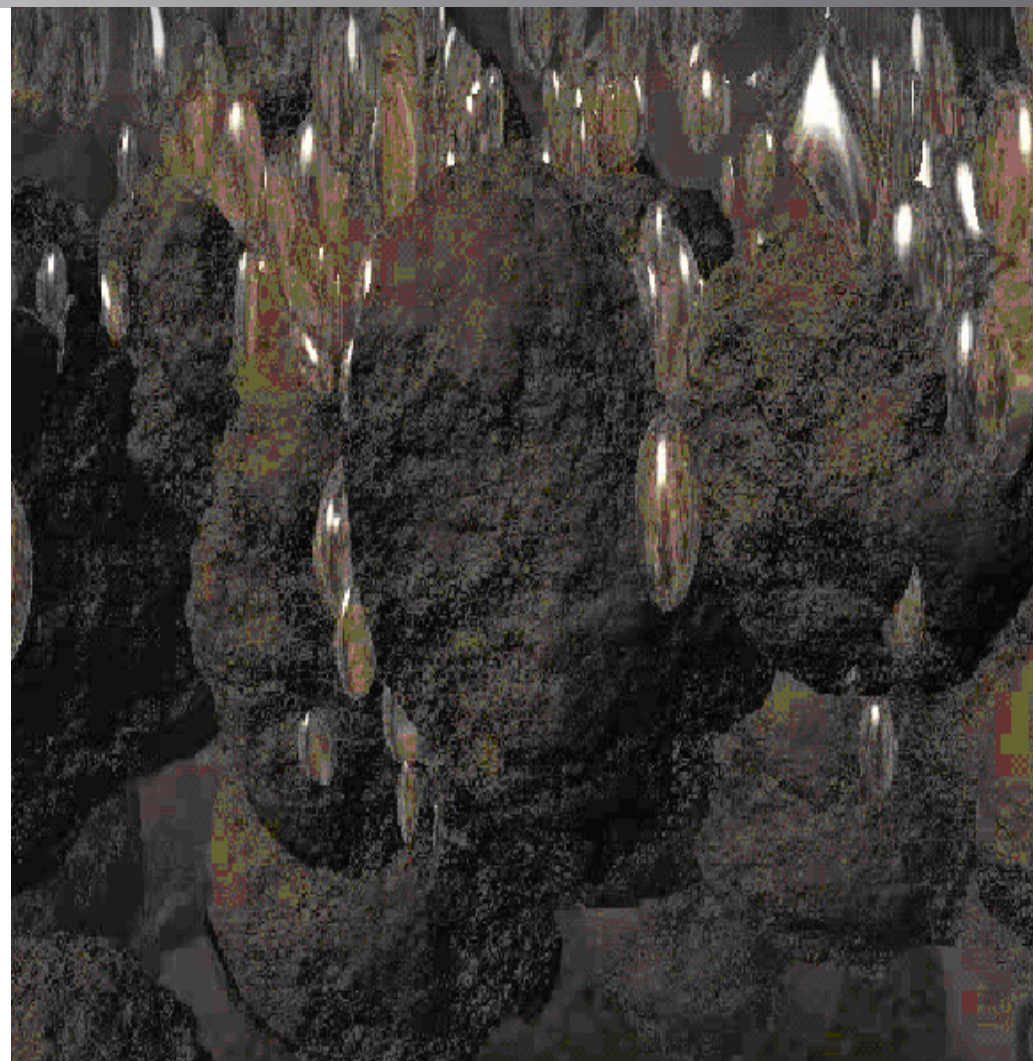
Groundwater Quality Determinants

- *Surface:* carbonic and tannic are released which depress the pH



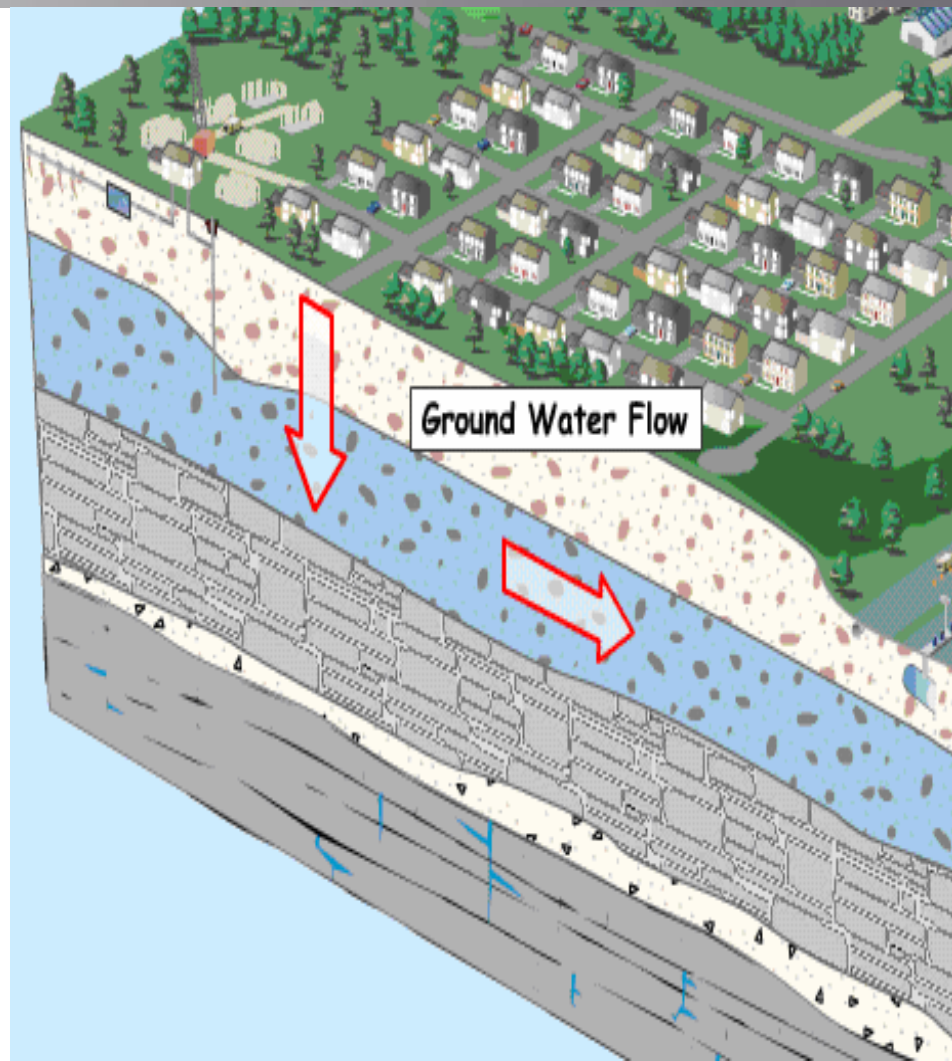
Groundwater Quality Determinants

- *Subsurface:* Iron, manganese, sodium, calcium & more are dissolved into passing water making its way to the aquifer

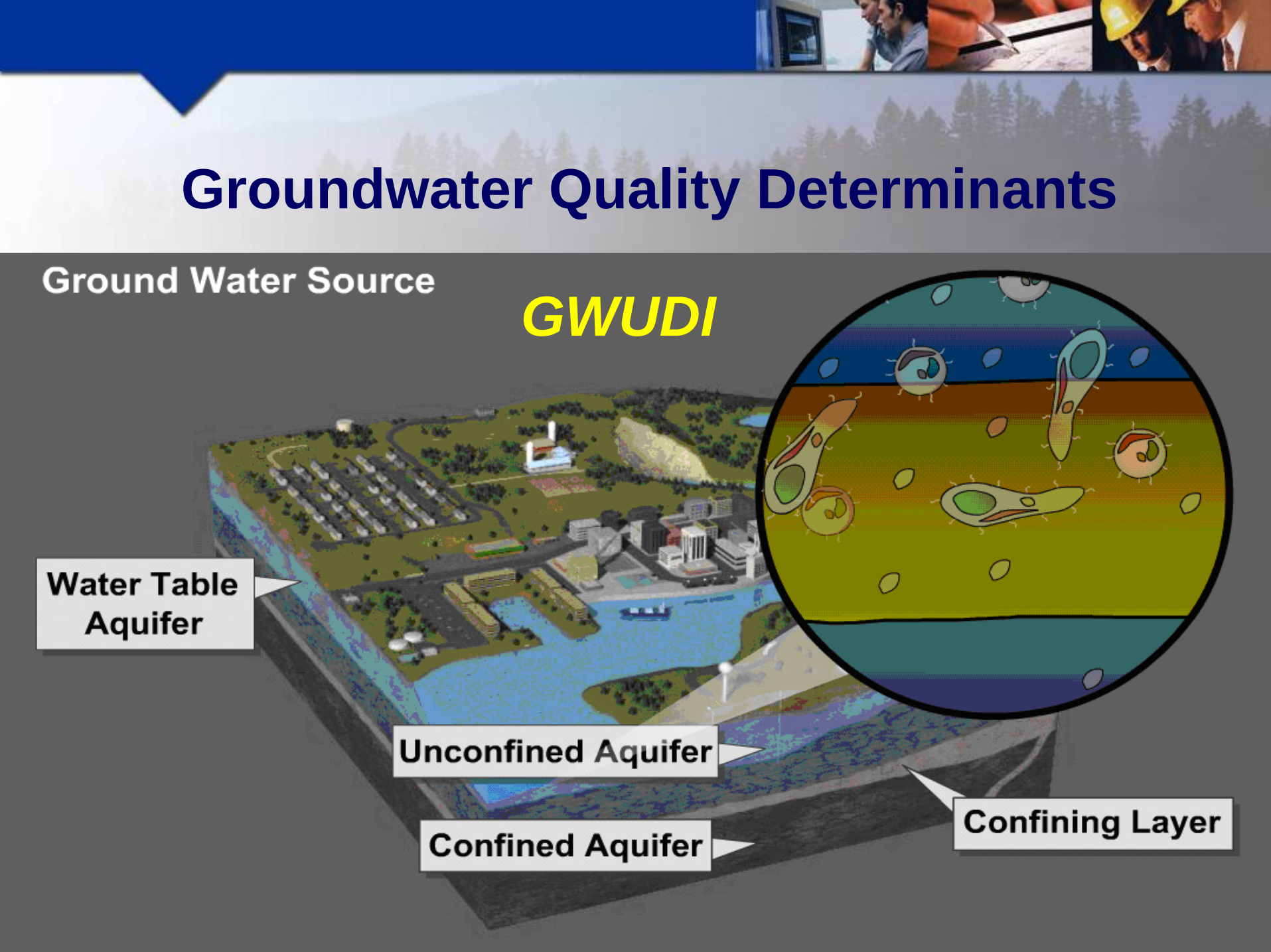


Groundwater Quality Determinants

- *Within Aquifer:* The geology and residence time within the aquifer are primary effectors of quality within the aquifer



Groundwater Quality Determinants



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- What's in water
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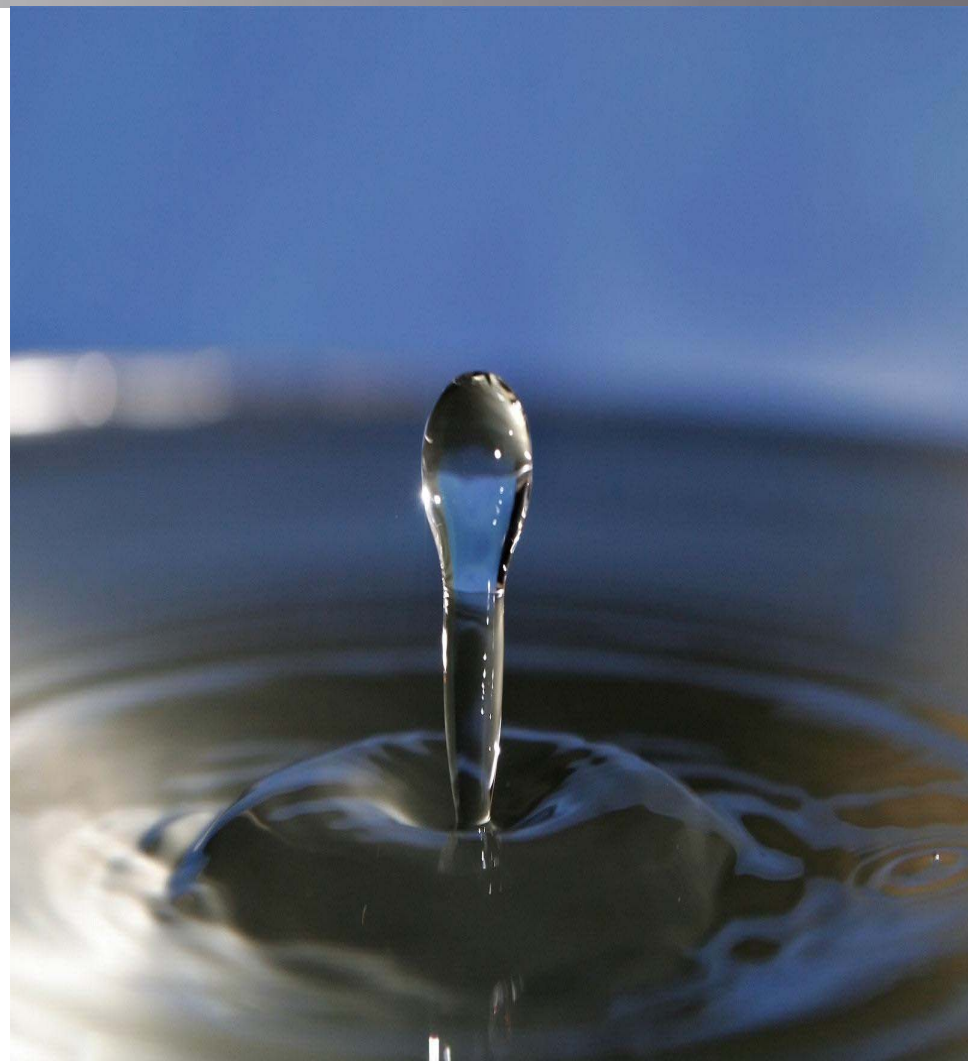
- Typical ground water treatments



Ground Water Treatment

Identify Key Constituents of Concern

("What type of stuff we want out of the water")

Focus

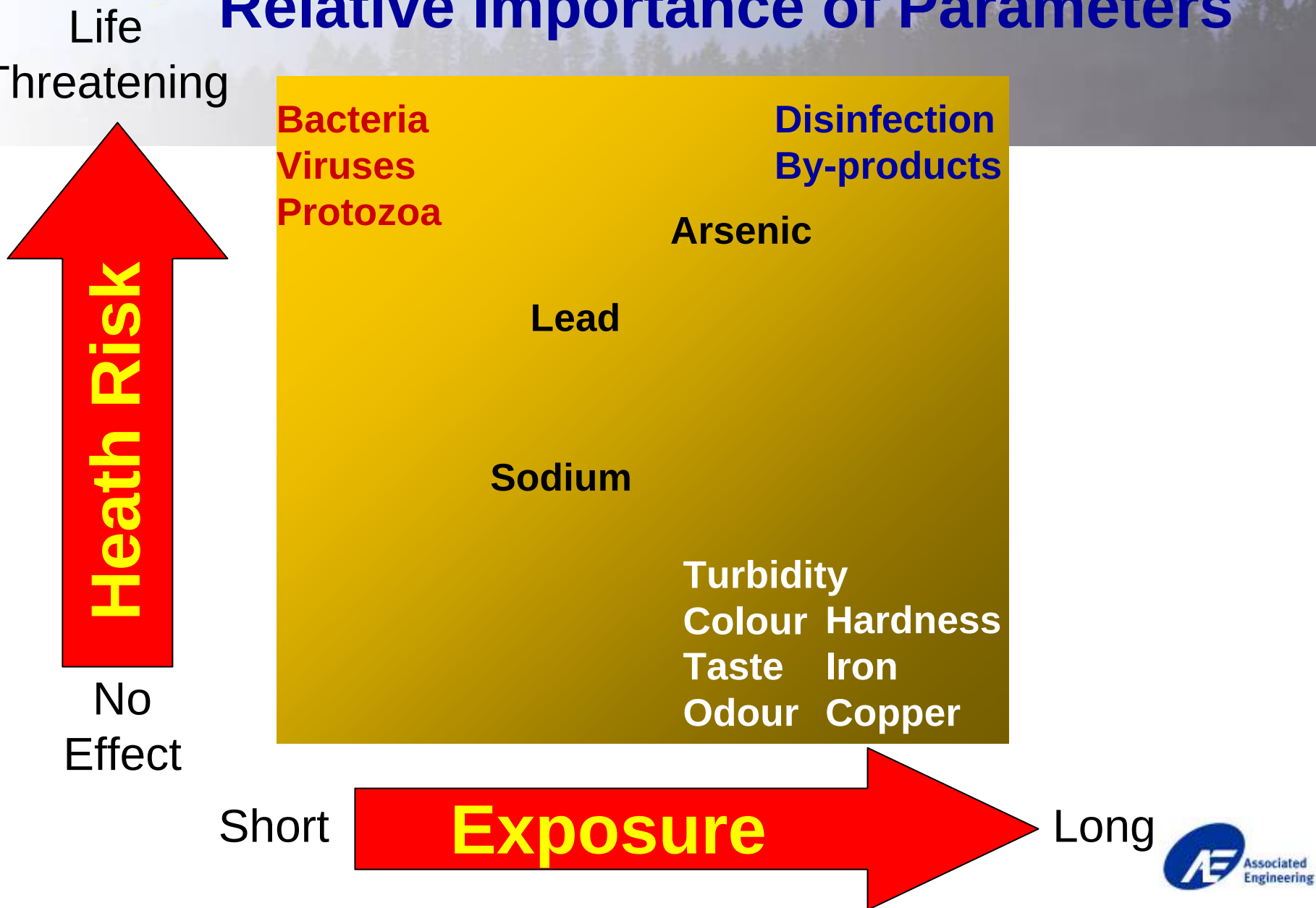
Health Based Parameters

Aesthetic Based Parameters

Treatment Aggravators

Associated Engineering

Relative Importance of Parameters

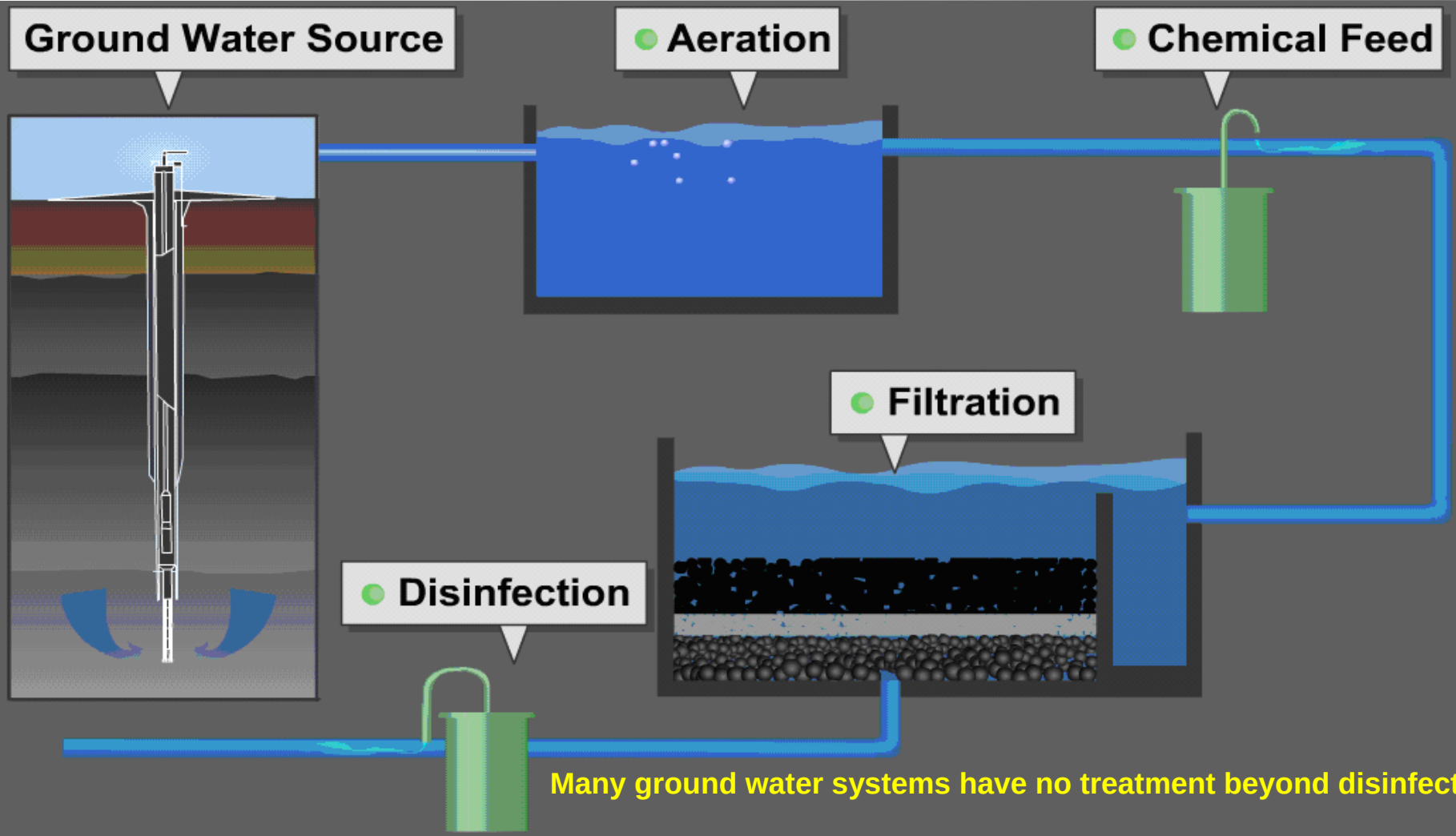


Ground Water or Surface Water Treatment

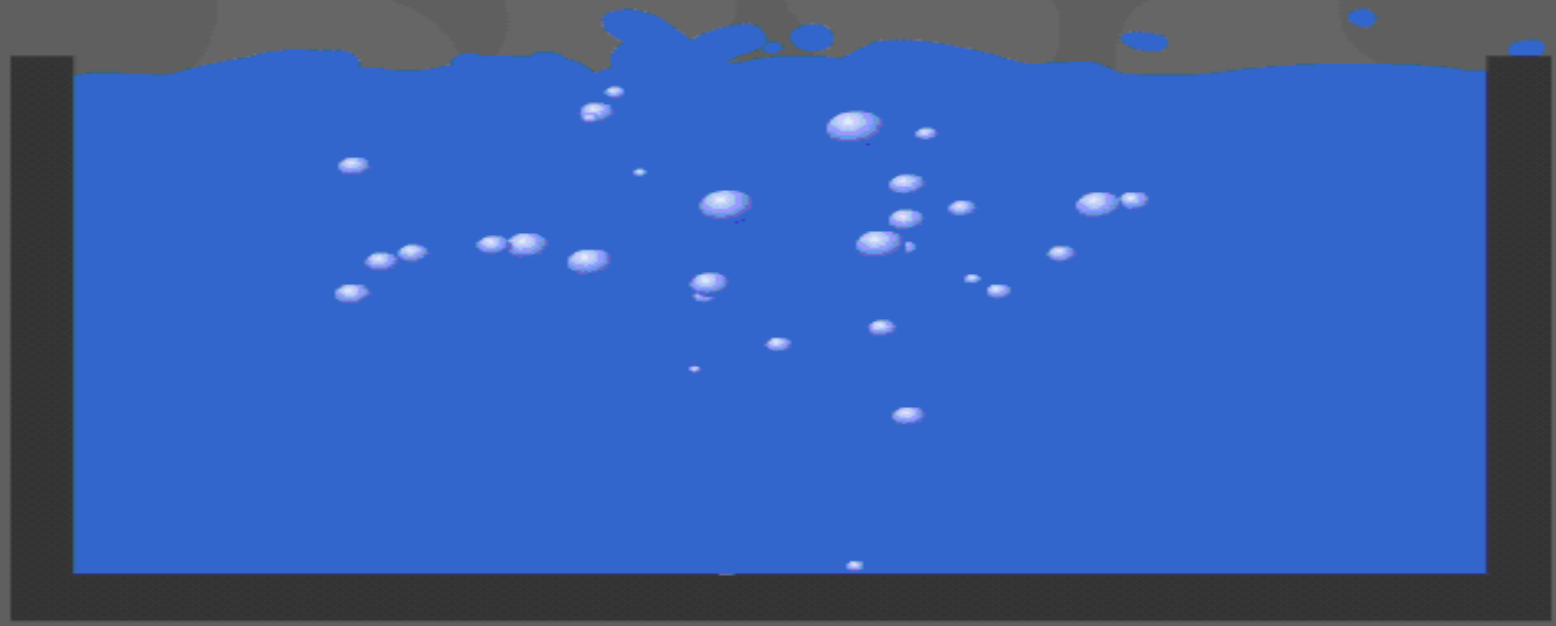
- *"Conditioning"* Stuff
- *"Trapping"* Stuff
- *"Zapping"* Stuff
- *"Manipulating Time Travel"* of Stuff

Associated Engineering

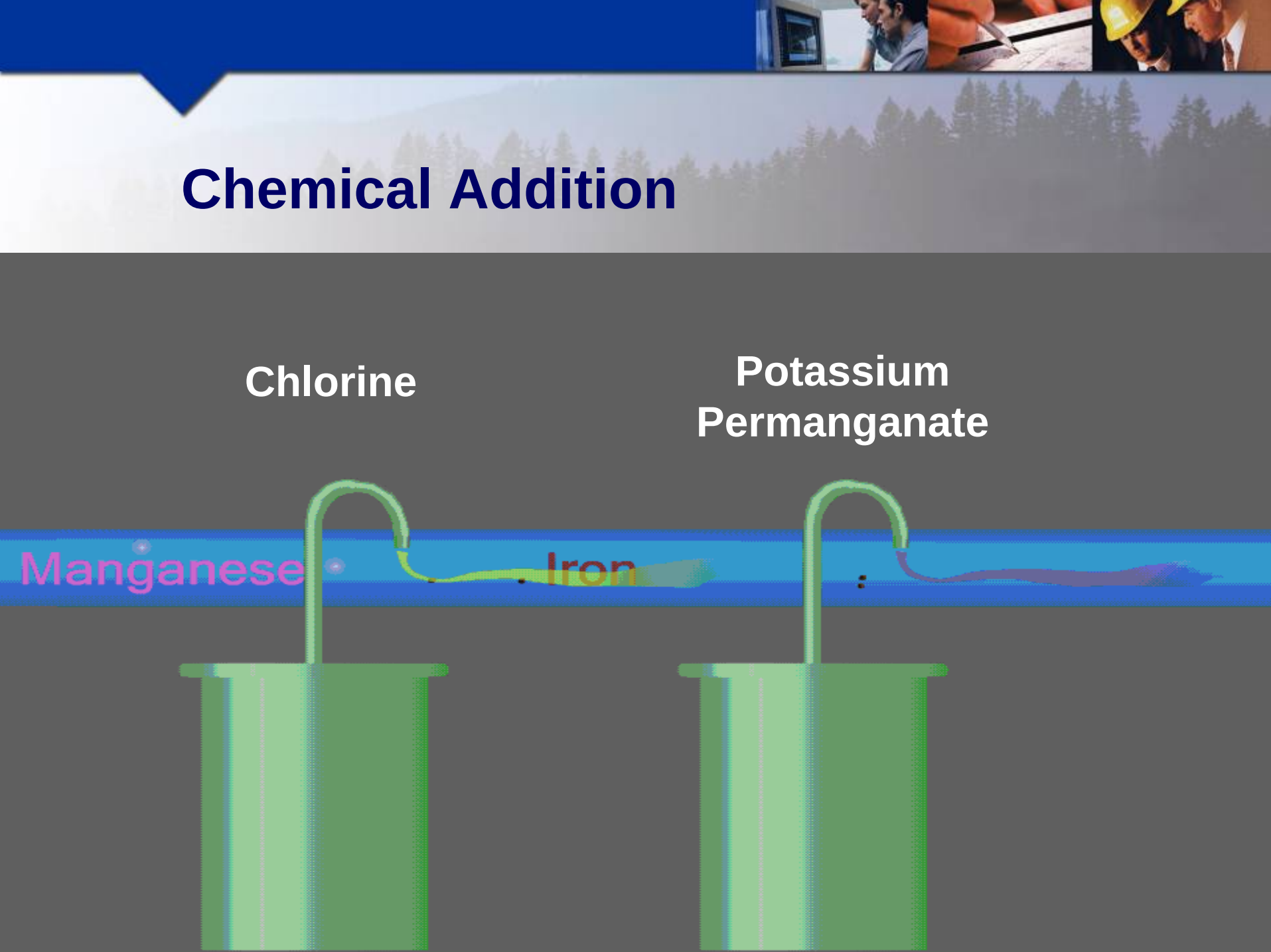
Ground Water Treatment



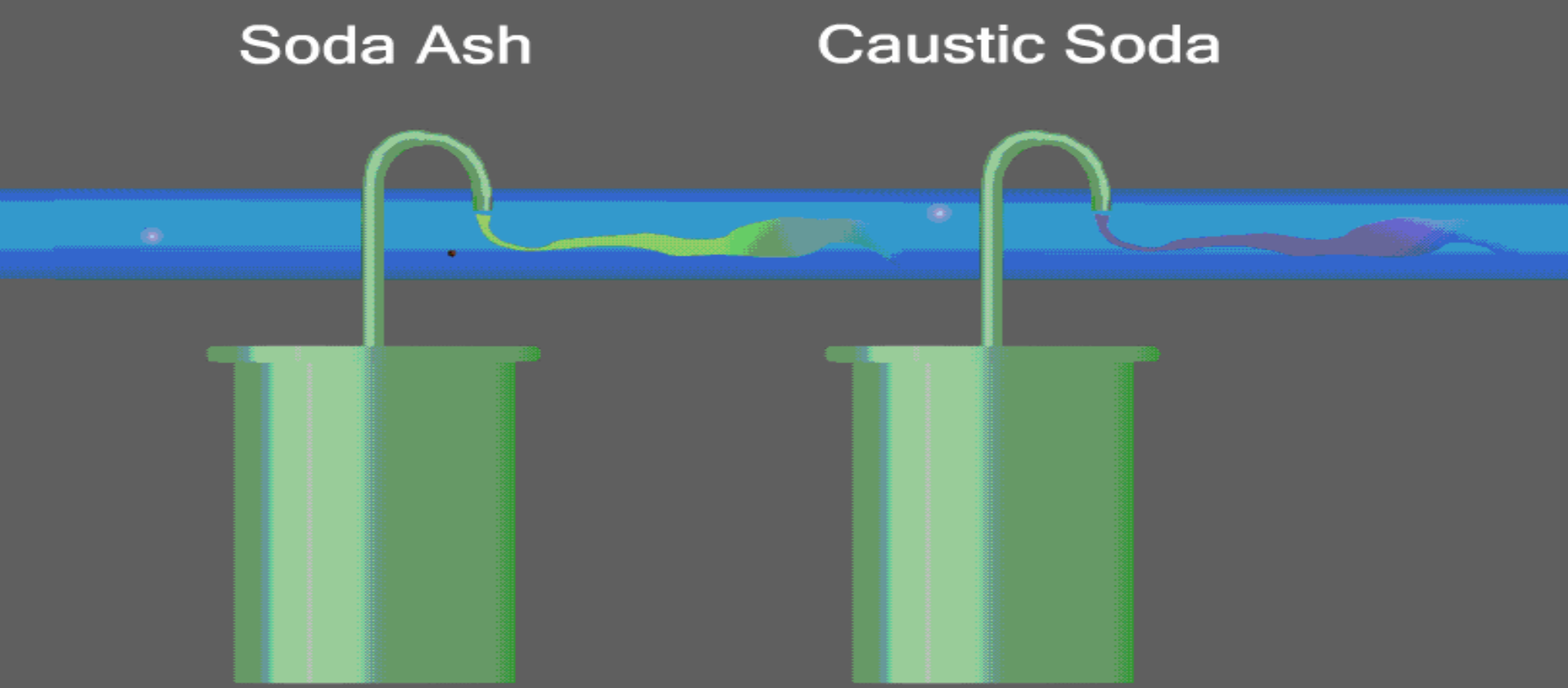
Aeration



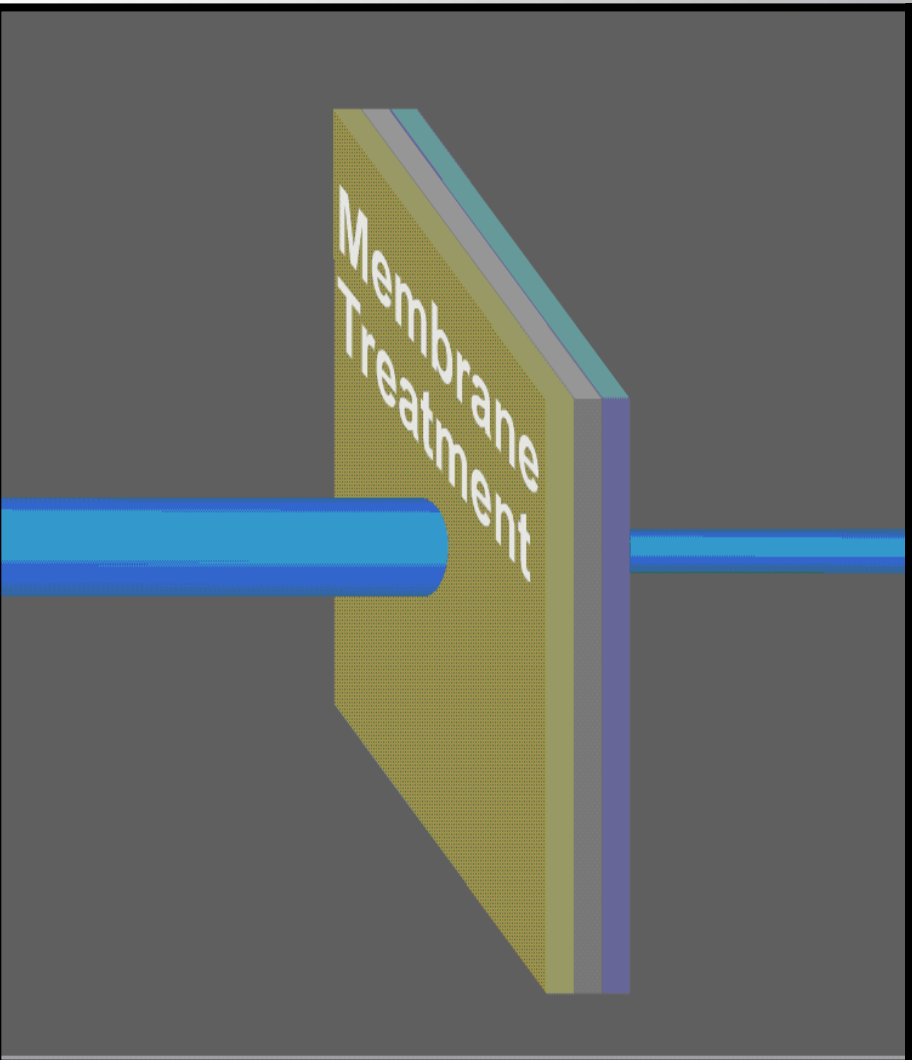
Chemical Addition

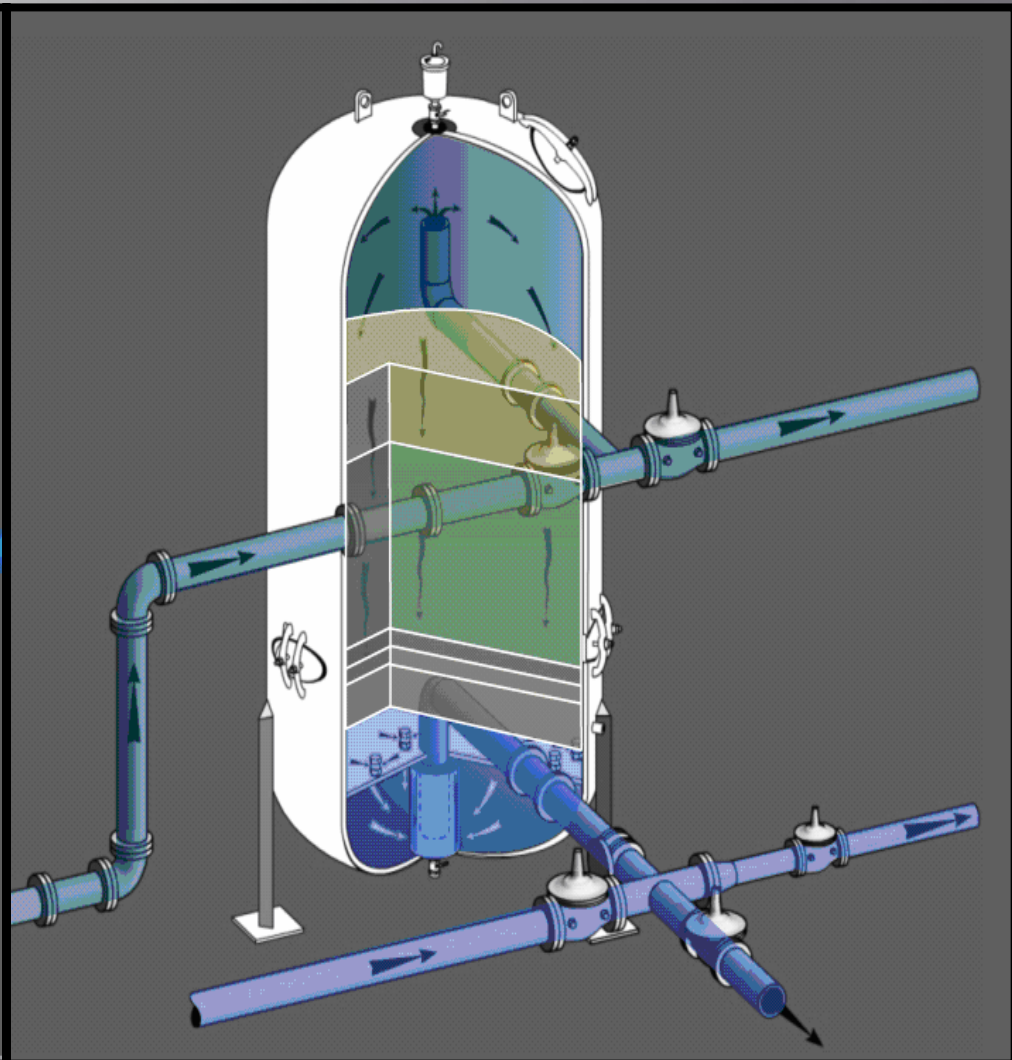


pH Adjustment

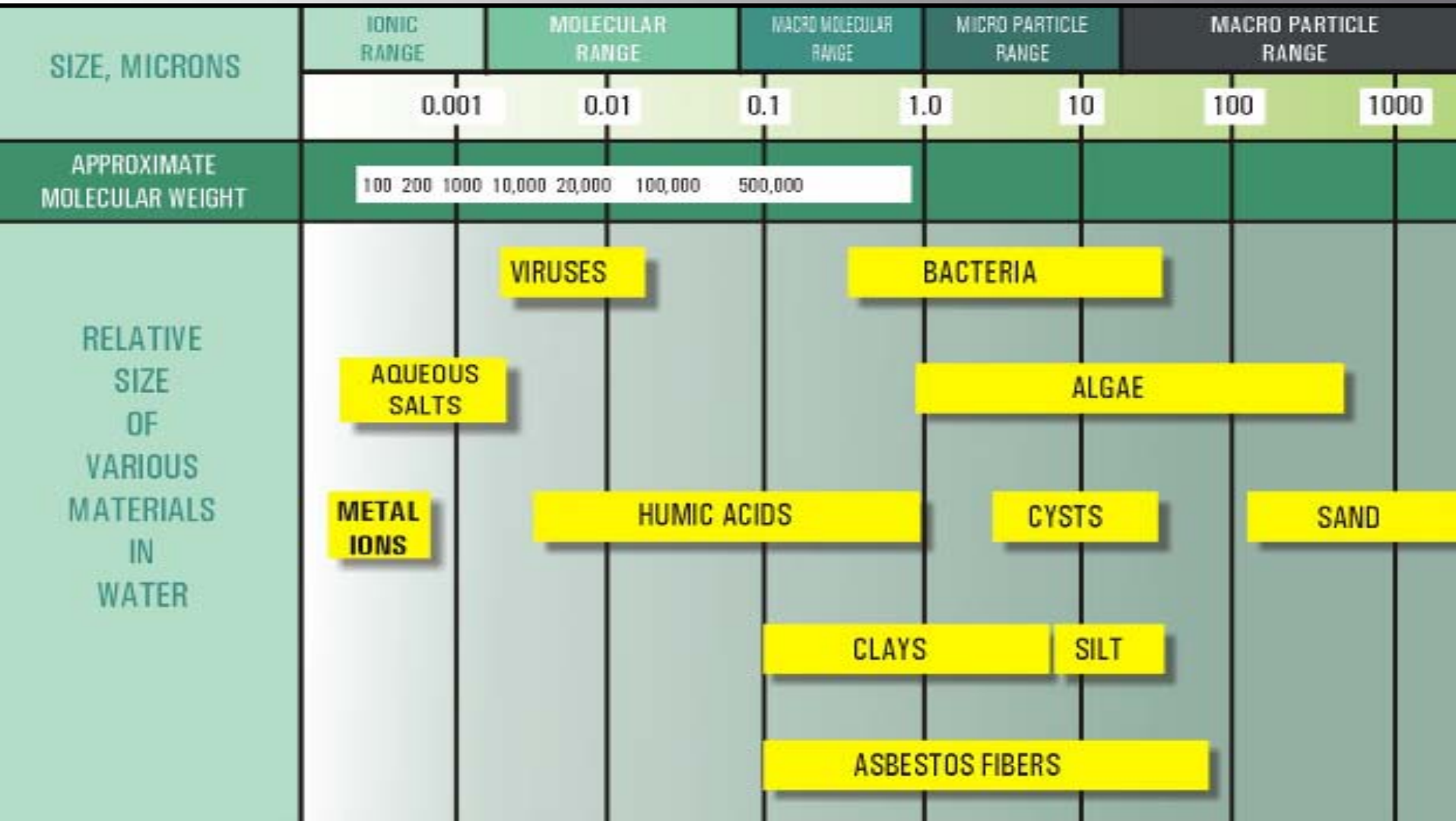


Filtration

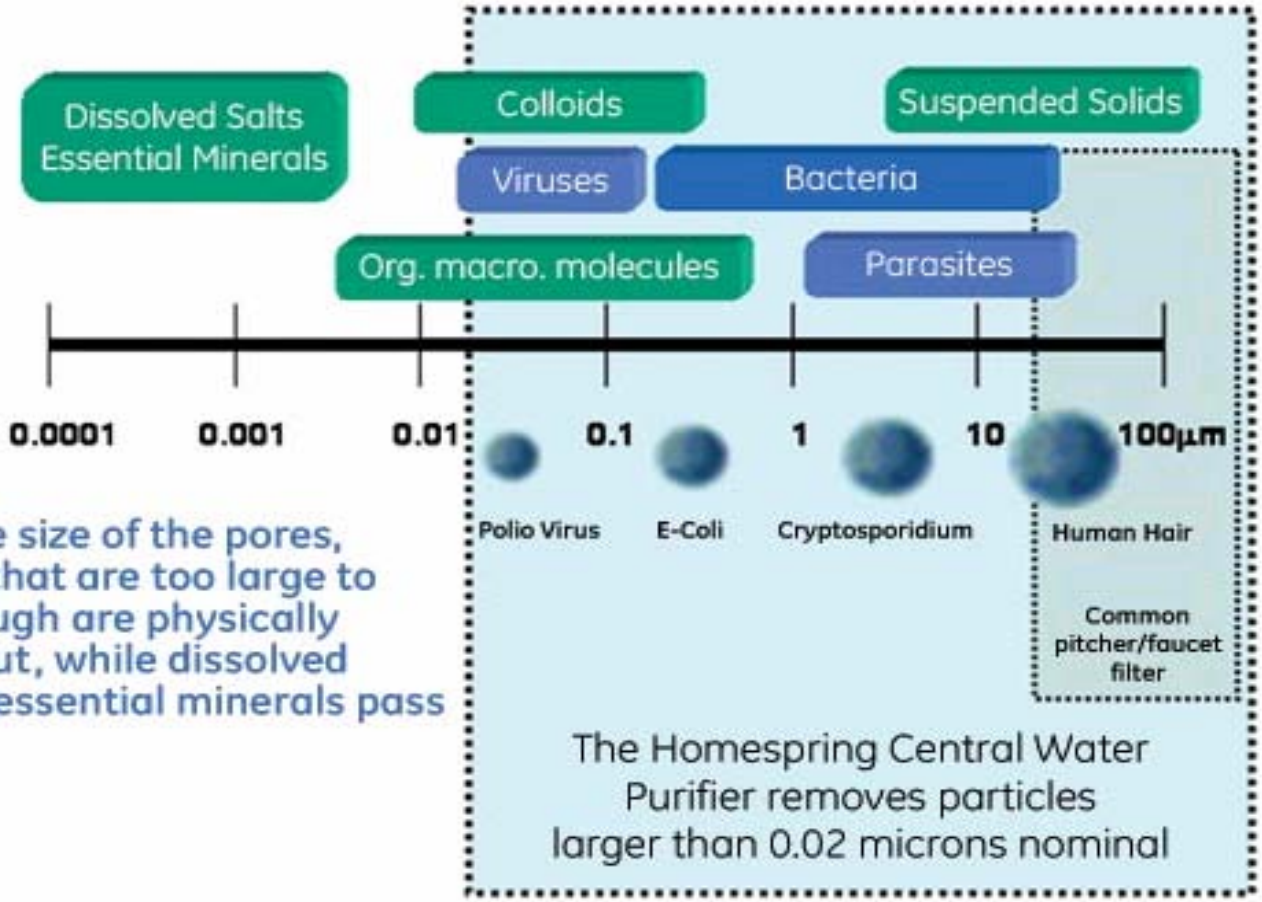




Particle Removal Spectrum



Filtration (Membrane)



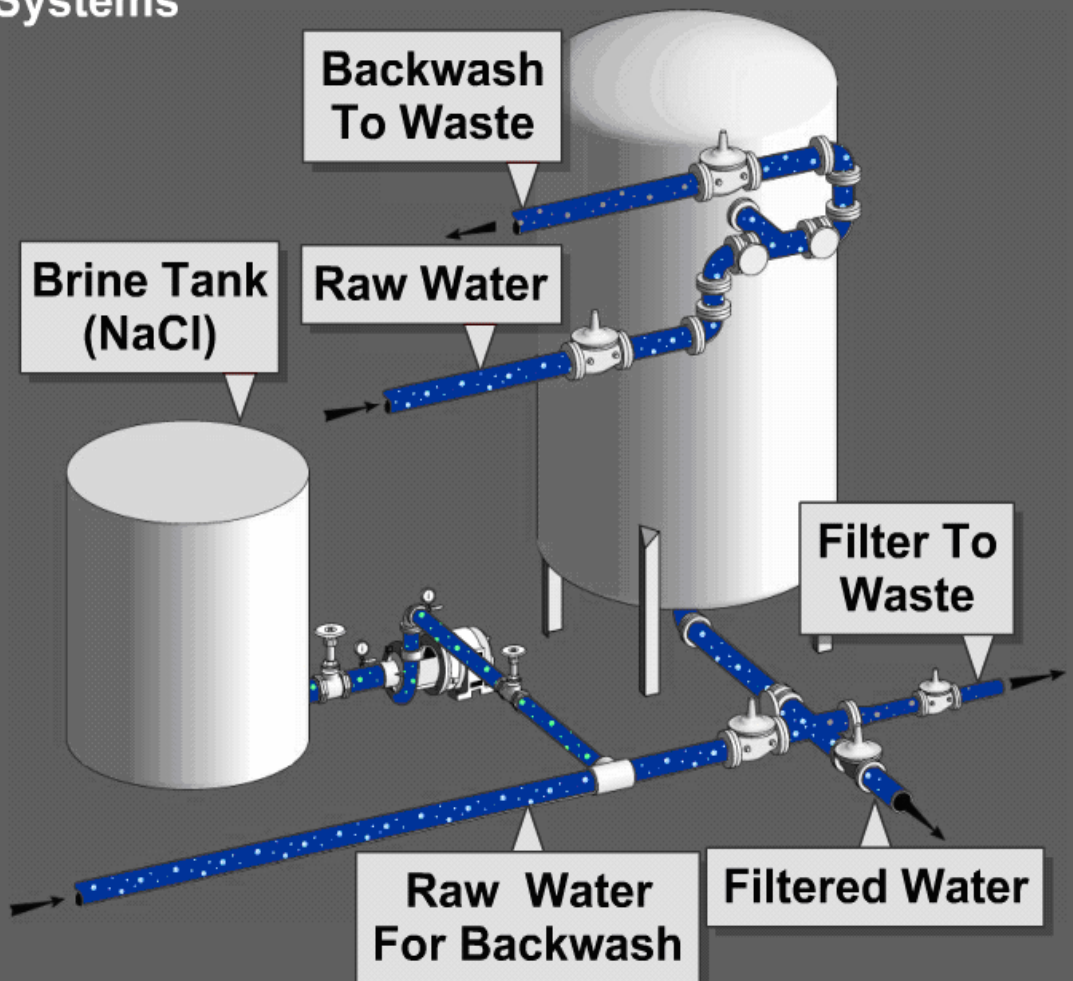
Due to the size of the pores, particles that are too large to pass through are physically blocked out, while dissolved salts and essential minerals pass through

Filtration (Membrane)

Associated Engineering

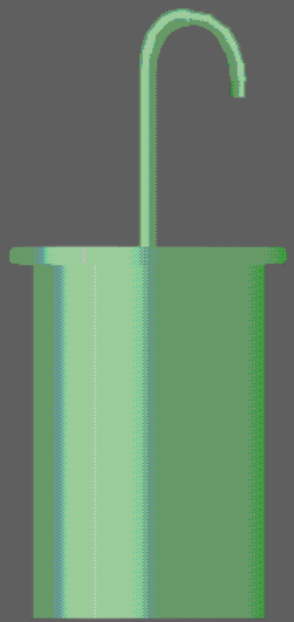
Water Softening

Softening Systems

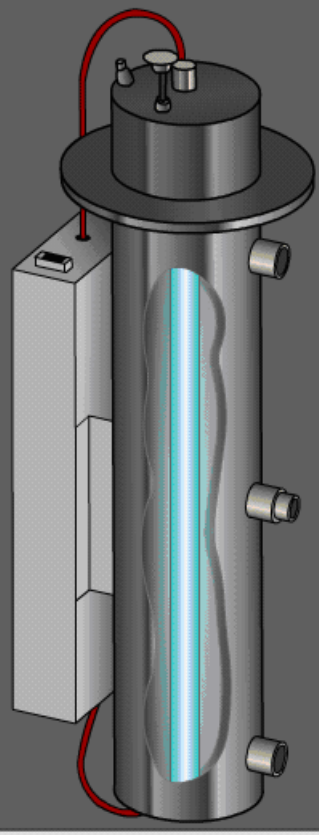


Simplest Disinfection Techniques

Disinfection



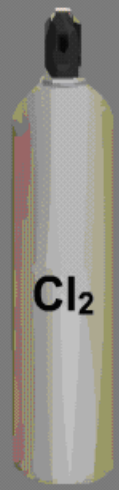
Chemical Disinfection



UV Disinfection

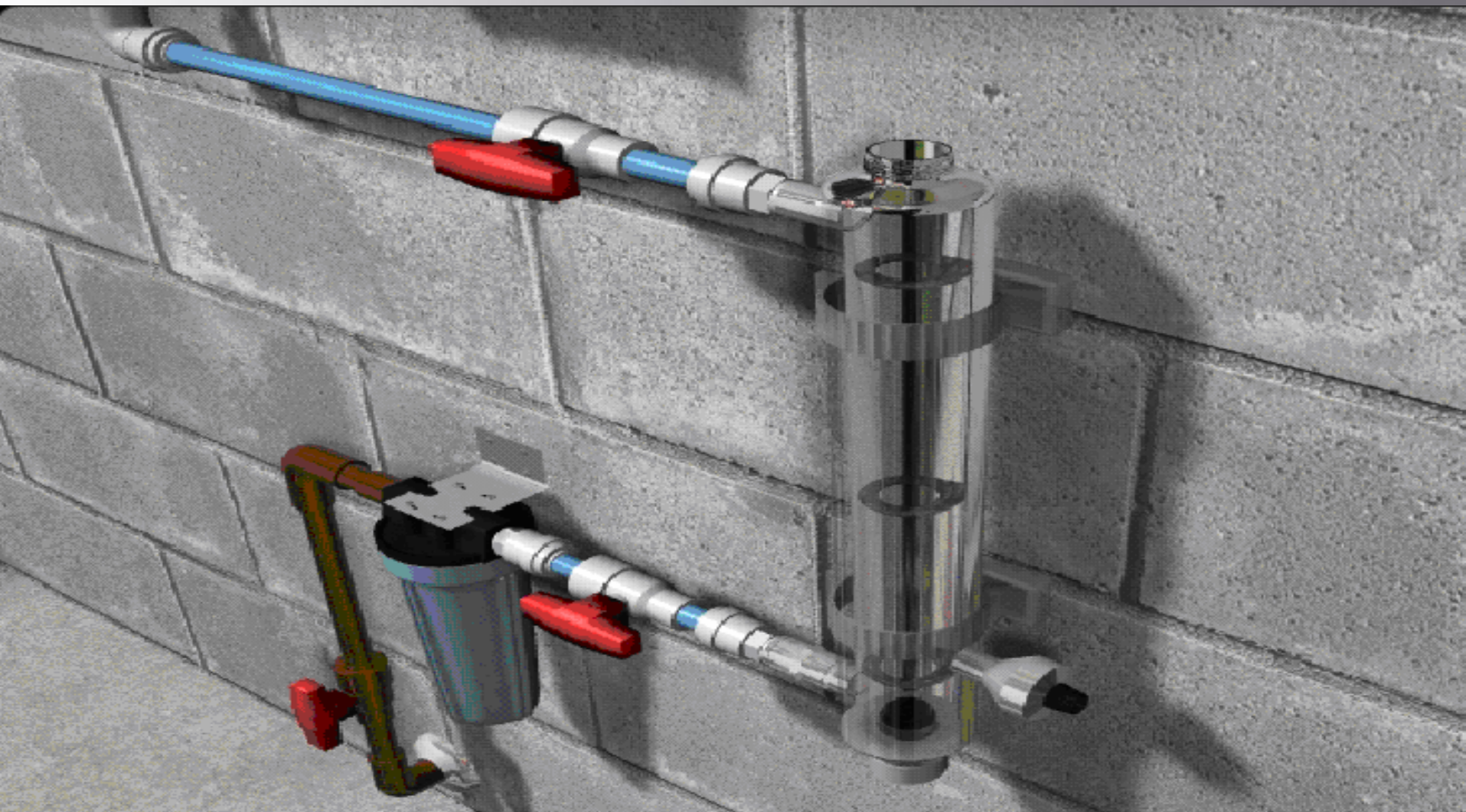
Common Chlorine Disinfectants

Hazard Level

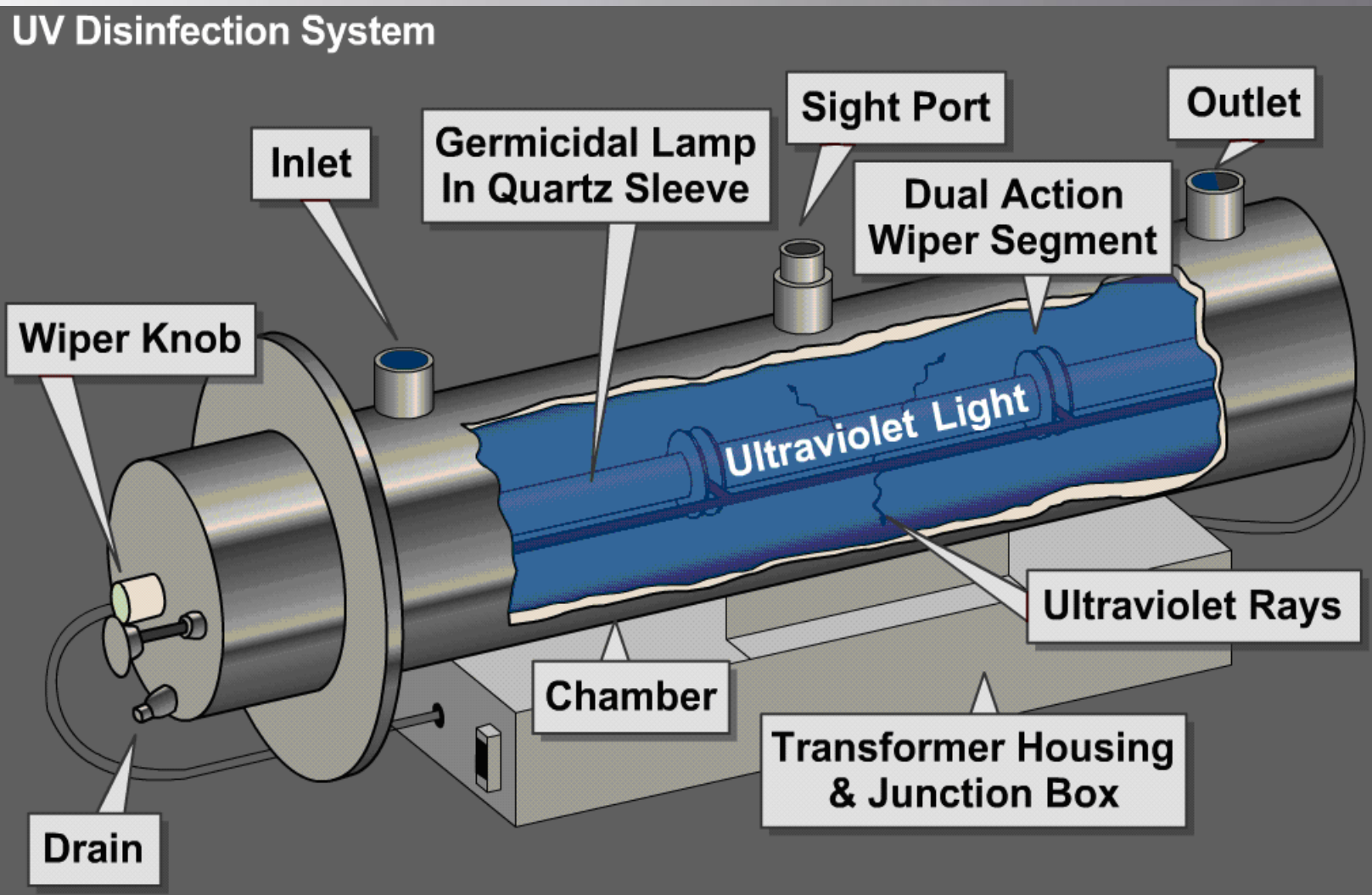
Sodium Hypochlorite	Calcium Hypochlorite	Chlorine Gas
		
5 - 15%	65%	100%
Liquid	Solid	Gas

Hazard Level

UV Disinfection

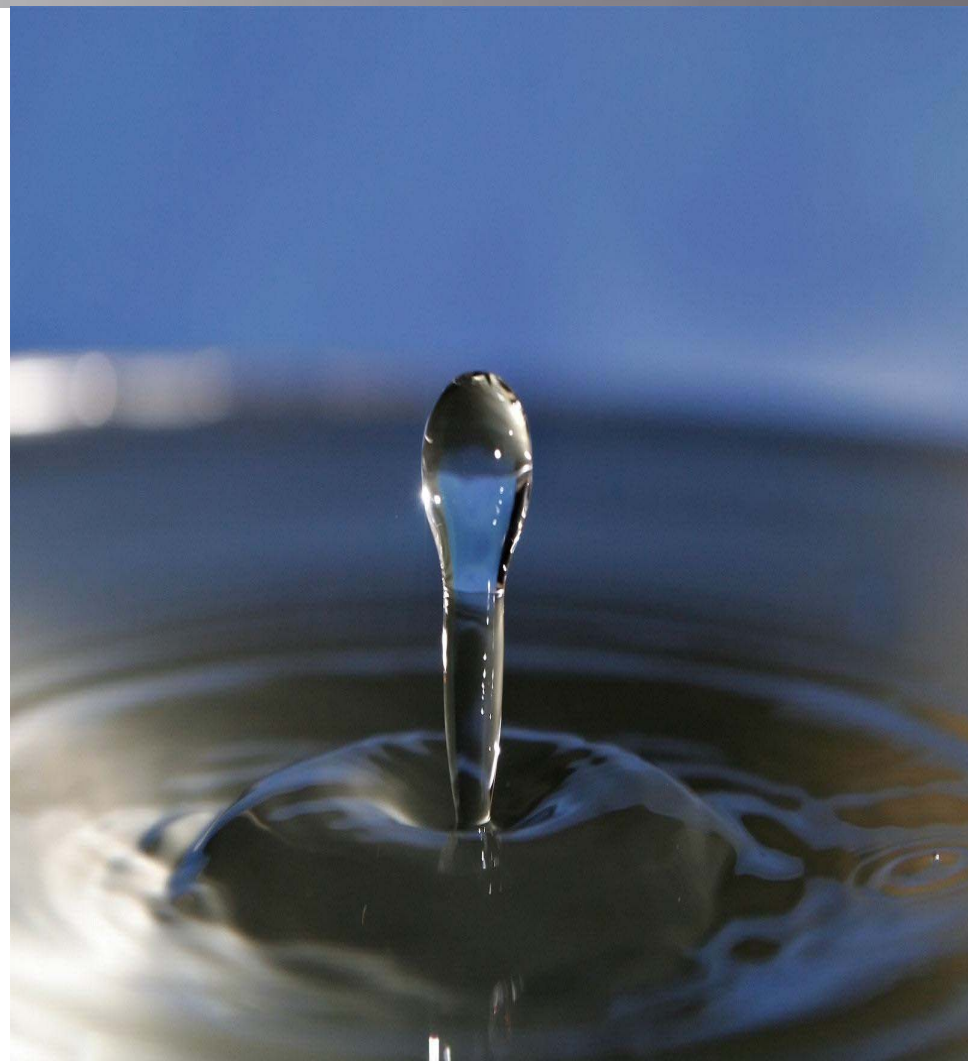


UV Disinfection



Presentation Overview

- What's in water
- What's in groundwater that needs treatment
- Typical ground water treatments
  - ***CT Concept***



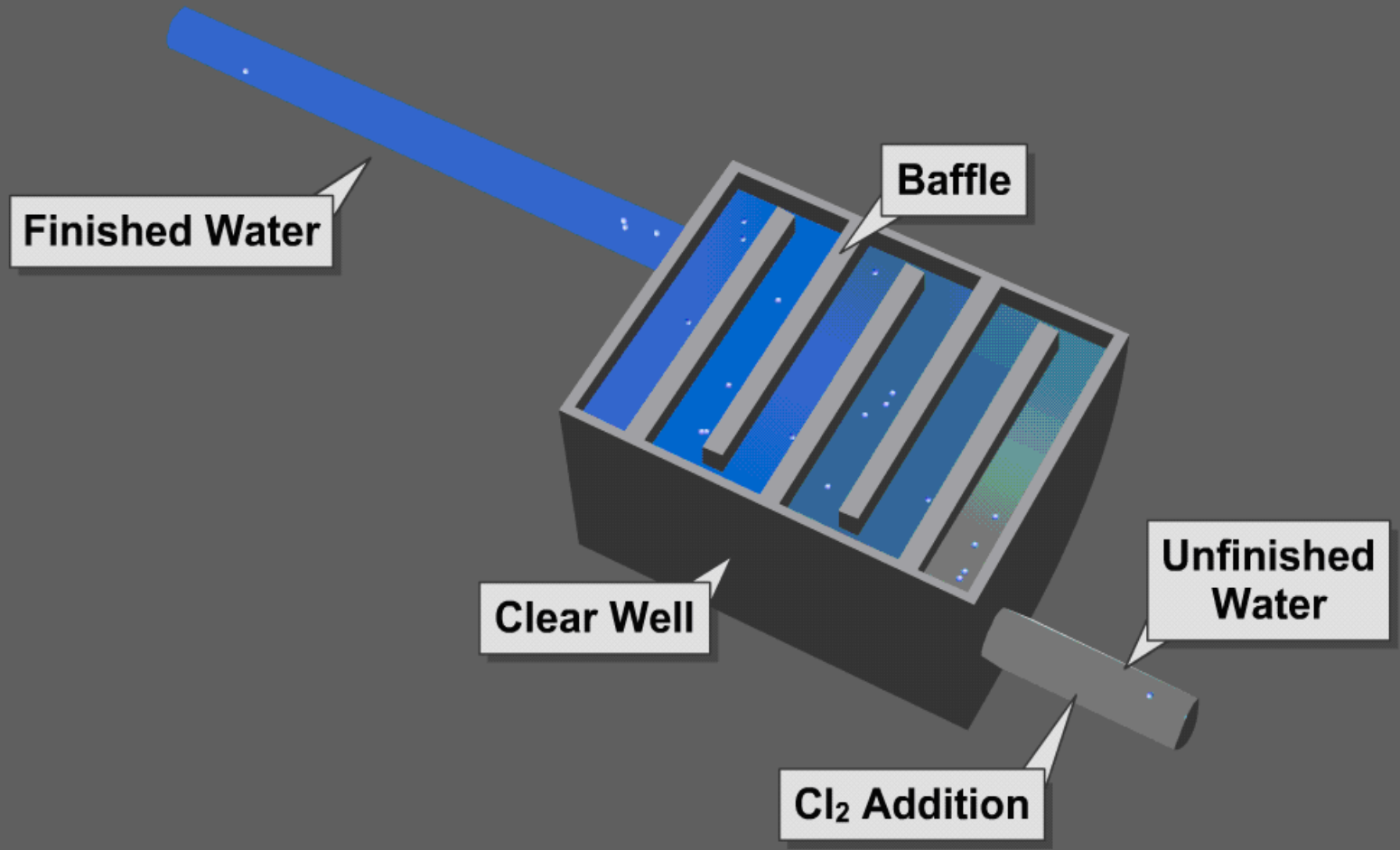
Disinfection Considerations

- Type of Disinfectant
- Dose (C in mg/L)
- Contact Time (T in minutes)
- Microorganism Type and Concentration
- Water Quality (e.g., turbidity and organics)

Associated Engineering

Key Disinfection Concepts (CT)

Disinfection



Key Disinfection Concepts (CT)

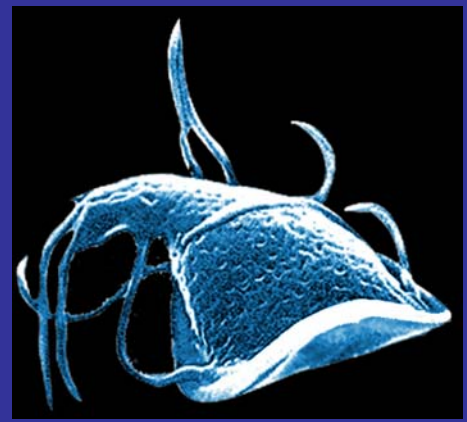
	Amount / Unit of Measure		Time
Water disinfectants	mg/L	x	minutes
CT =	Concentration	x	Time
10 =	1	x	10
10 =	10	x	1
10 =	5	x	2

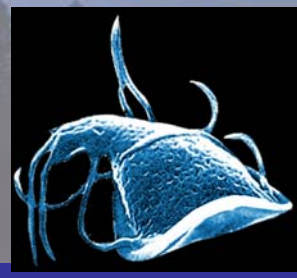
Note: The amount of disinfectant needed is highly pH and temperature dependent

Key Disinfection Concepts (CT)

Affects of pH and Temperature on Chlorine Disinfection
(CT needed to inactivate Giardia)

pH	CT @ 20°C	CT @ 5°C
≤ 6	39	105
7	56	124
8	81	216
9	117	312





Key Disinfection Concepts (CT)

Comparison of Chlorine and Chloramine Disinfection at 20°C (CT needed to inactivate Giardia)

pH	Chlorine CT	Chloramine CT
6	39	1100
7	56	1100
8	81	1100
9	117	1100

UV Dose Calculation

UV DOSE

UV Dose

UV Intensity

Contact Time

UV Fluence Calculation

UV Fluence

UV Dose $\mu Ws/cm^2$ = UV Intensity $\mu W/cm^2$ x Contact Time (Seconds) x % Transmittance

40,000 $\mu Ws/cm^2$

40 mWs/cm^2

40 mj/cm^2

Associated Engineering

Dose Examples

Dose required to kill 90% of a given population of a known organism.

i.e. - A one log reduction

e.g - E coli

5.4 mJ cm^{-2} = 90% kill

10.8 mJ cm^{-2} = 99%

etc...

Associated Engineering

Dose Examples

E. coli	5.4
Listeria monocytogenes	3.4
Legionella pneumophila	2.0
Pseudomonas aeruginosa	5.5
Hepatitus B Virus	11.0
Bacillus subtilus (Spores)	12.0
Penicillium expansum	13.0
Saccharomyces sp.	8.0
Infectious Pancreatic Necrosis	60.0

Associated Engineering

Factors Affecting UV

- Total Suspended Solids
- Transmittance

Associated Engineering

Factors Affecting UV

Total Suspended Solids

- As suspended solids increase in the water bacteria becomes occluded, or shadowed, from exposure to the UV light.

- Filtration is needed to decrease the amount of suspended solids, thus increasing the chance of disinfecting the water efficiently

Associated Engineering

Factors Affecting UV

Transmittance

- The ability of light, at a wavelength 254 nm, to transmit through the water.

- Transmittance is not equivalent to NTU values.

- Iron salts and organic matter have the most effect on transmittance

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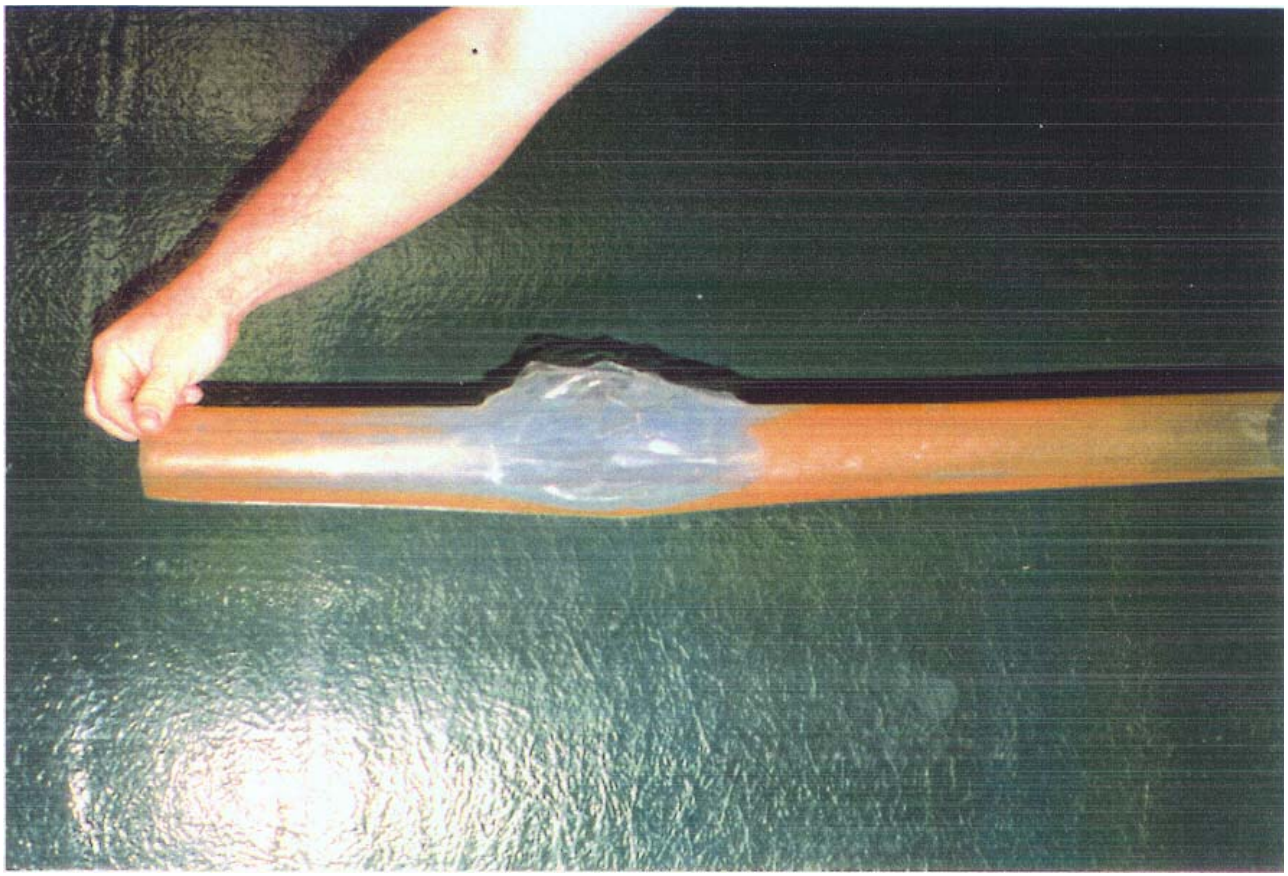
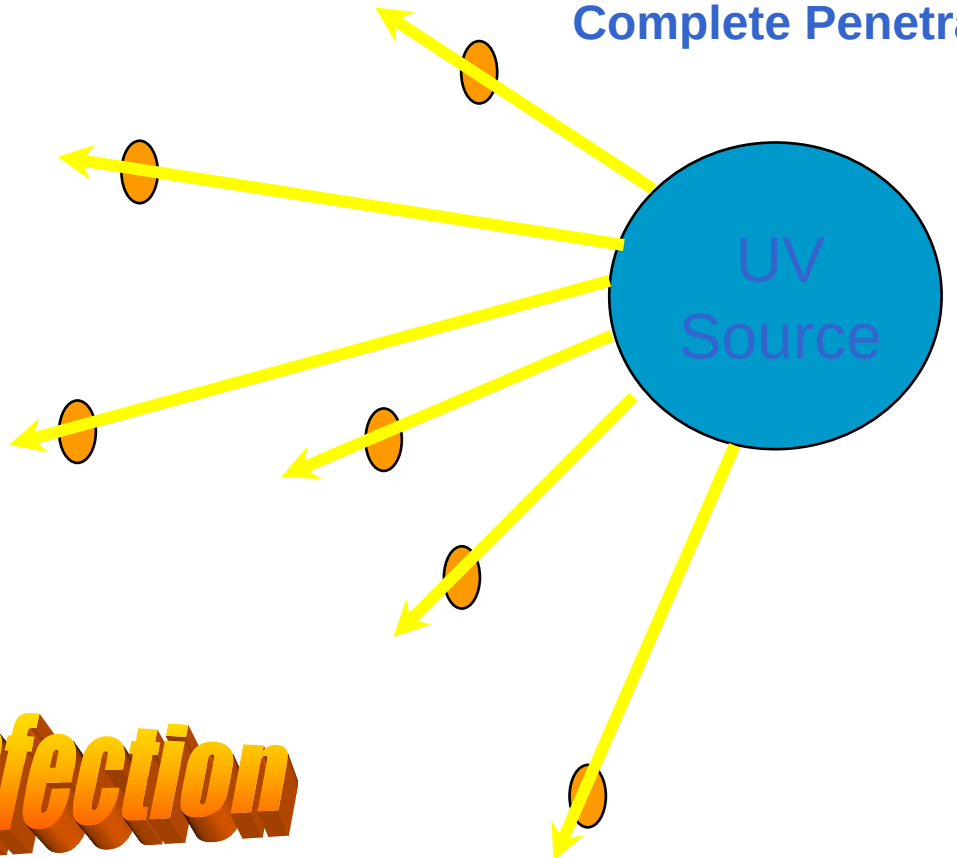
Factors Affecting UV



Lamp Technology - Fouling

“Cornerstone of Effective Disinfection”

Particle Free Water is “Ideal” (Shielding is of concern)

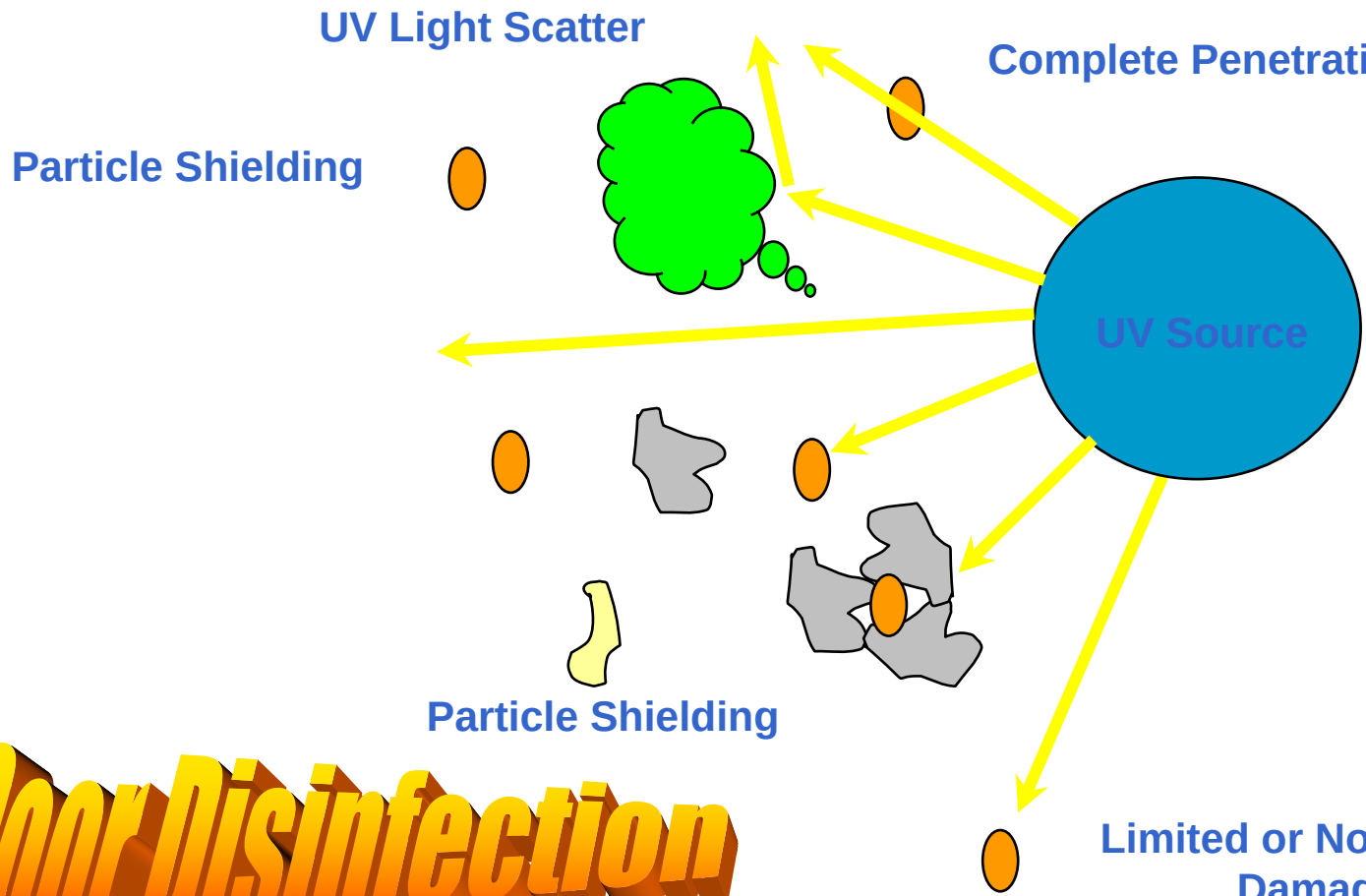


Effective Disinfection

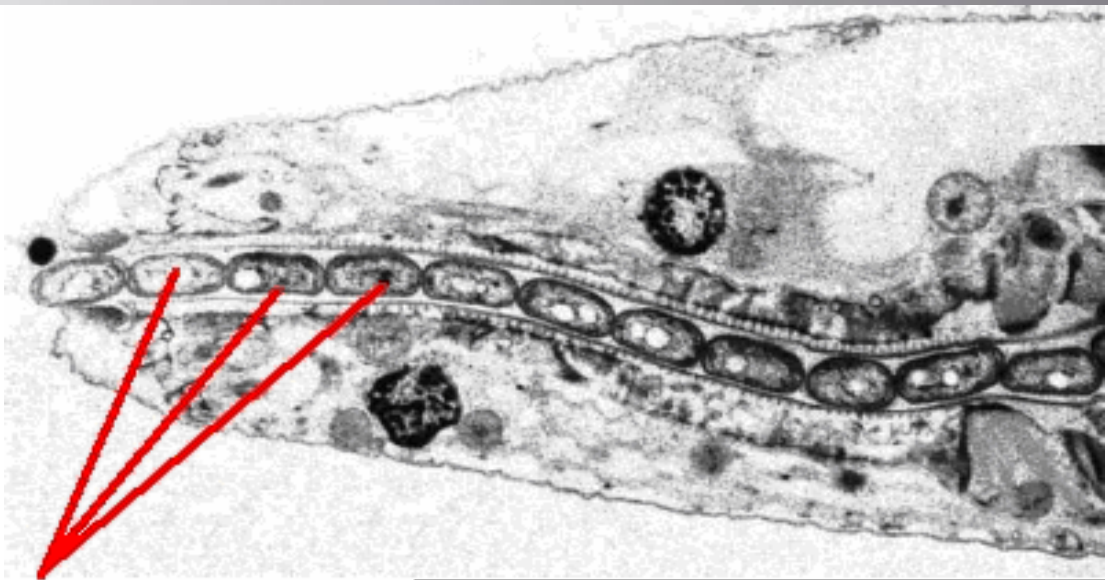
Associated Engineering

“Cornerstone of Effective Disinfection”

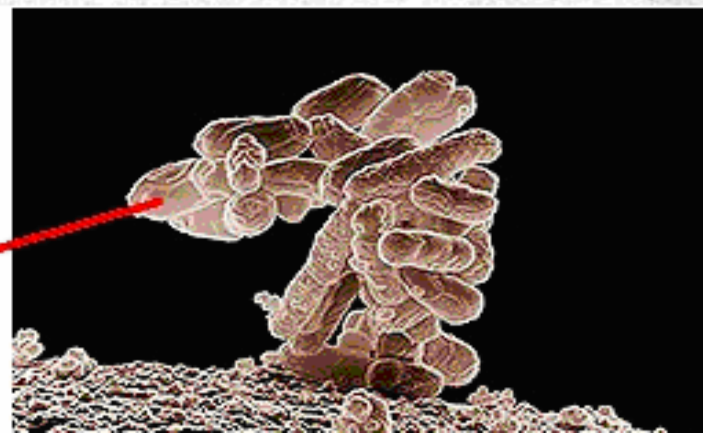
Particle Free Water is “Ideal” (Shielding is of concern)



Associated Engineering



Bacteria ingested by a nematode are protected from disinfection.



Clusters of bacteria are also protected from disinfection.

Associated Engineering

Treatment of Microbes

- Two methods…
  - Filtration
    or
    Disinfection

- In other words…
  - "Trap-em"
    or
    "Zap-em"

Proper Pretreatment is Critical!

Associated Engineering

Cost Effective Treatment of Small Ground Water Systems

"The most cost effective treatment is the one that accomplishes treatment objectives at the least cost …… *it doesn't mean it's the least expensive*"

Associated Engineering

Treat Technologies Summary for Small Systems

Associated Engineering

Cost Comparison

Technology	Some Contaminants Removed	Initial Cost	Operating Cost	Operating & Maintenance Skills
Chlorine	Microbial	$	$	$
UV, Ozone	Microbial	$$	$	$$
Cartridge Filter	Protozoa Bacteria	$	$ to $$	$
Reverse Osmosis	Microbial ,Inorganic Chemicals and Metals Radium, Minerals, Some Organic Chemicals	$$	$$$	$$$
Distillation	Microbial, Inorganic Chemicals and Metals, Minerals, Some organic Chemicals, Radium, Uranium	$$	$$	$
Activated Carbon	Organic Chemicals, Radon, Odors (solid block can filter protozoa and some bacteria)	$$	$$ to $$$	$
Packed Tower Aeration	Radon, Volatile Organic Chemicals, Tastes, Odors	$$	$	$$$
Ion Exchange	Inorganic Chemicals, Radium, Nitrate	$$	$$ to $$$	$$
Activated Alumina	Arsenic, Selenium, Fluoride	$$$	$$$	$$$

Table 1: Summary of POE/POU Systems and Costs (NSF, 1999)

$ Low $$ Moderate $$$ High

Associated Engineering

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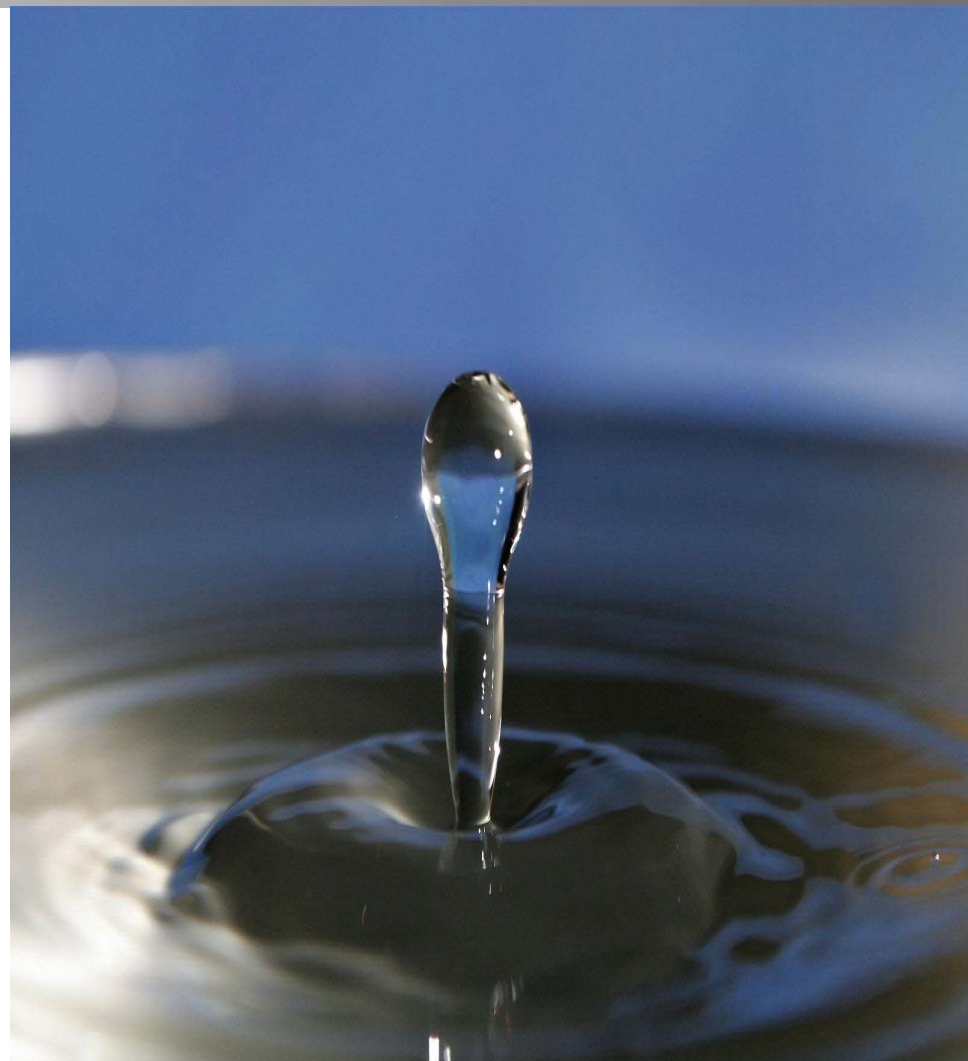
- What's in water
- What's in groundwater that needs treatment
- Typical ground water treatments
  - *CT Concept*
- Summary Comments



Rant #1:

An all too common path that is taken

Meet the standards

Standards Not Met

Associated Engineering

Rant #1:

An all too common path that is taken

Meet the standards

Lab Analysis

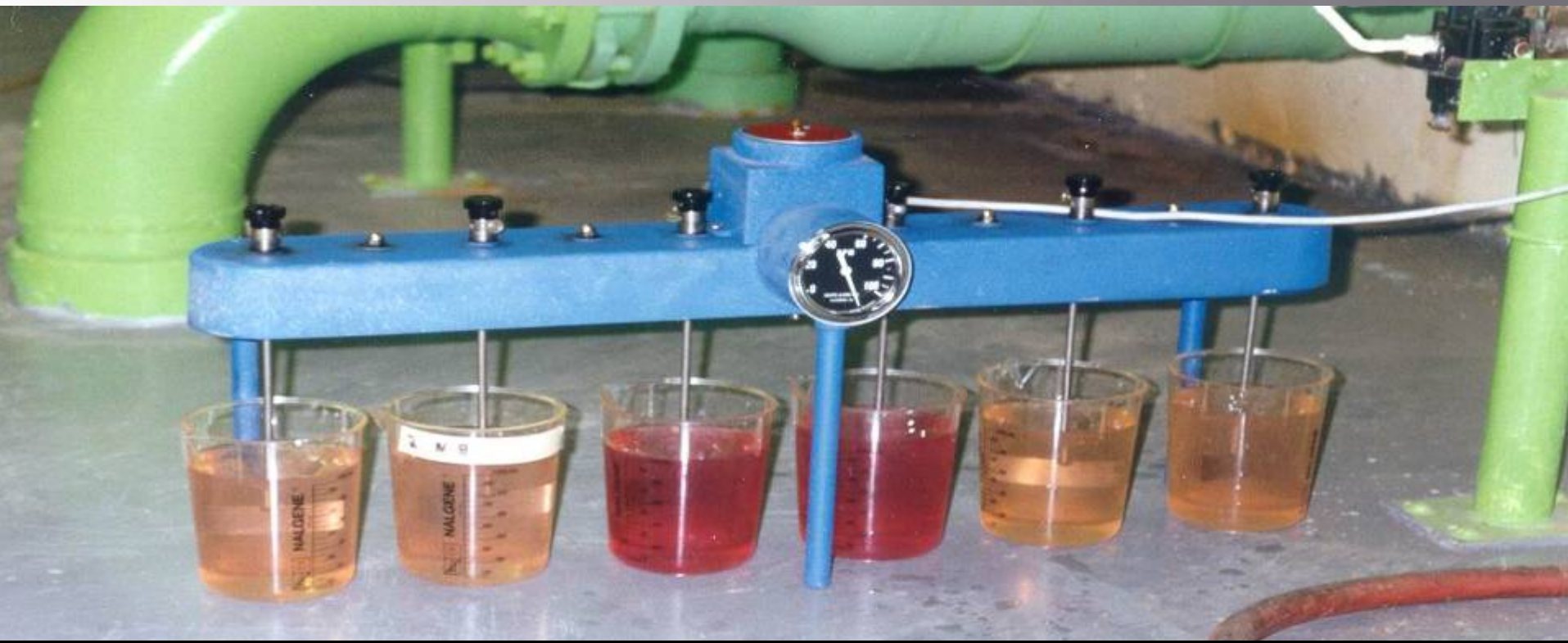
Standards Not Met

Associated Engineering

Rant #1:

An all too common path that is taken

Iron & Manganese Example

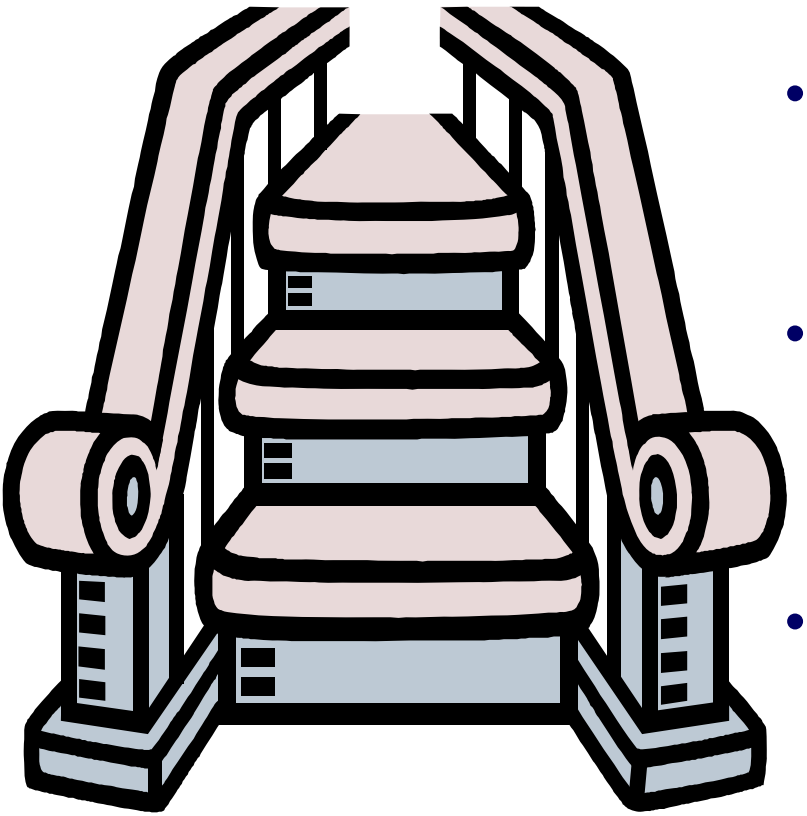


A simple lab analysis, on paper, doesn't tell you the personality of the iron: … ***Is it organically complexed …How readily is it oxidized … Does only a portion of it get oxidized over time … if so how much?***

Iron & Manganese Example

What about the resulting precipitate ….. *Does it form quick …. Is it big … Does it settle well … Is it robust or fragile …. Is it filterable?*

What's the most cost effective treatment to use?



Need To Determine:

- What type of "Stuff is in the water

  (Fingerprint Water Quality)

- Type of "Stuff" we want out of the water

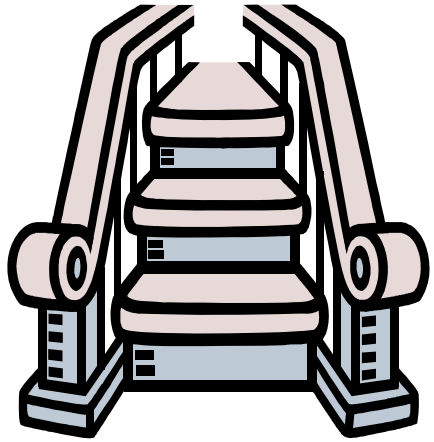
  (Identify Key Constituents of Concern)

- How to get the "Stuff out of the water or sedate its problematic tendancy

  (Fingerprint Treatment Response)

Associated Engineering

Important to do your homework



- What type of “Stuff is in the water
- Type of “Stuff” we want out of the water
- How to get the “Stuff out of the water

Associated Engineering

Prescription / Recipe for Success!

Humility & courage is sometimes needed to get the job done.

Sometimes this means bravely going where others fear to tread……

Associated Engineering

Disinfection Summary

Disinfectant	Bacteria	Viruses	Giardia	Crypto	By-products	Taste & Odour	Residual	Capital Cost	O & M Costs
Chlorine	5	5	3	1	2	3	4	5	4
Chlorine Dioxide	5	5	4	3	3	2	5	3	3
Choramine	4	3	2	1	4	4	5	4	4
Ultraviolet	5	4	5	5	5	4	1	3	3
Ozone	5	5	5	4	3	5	1	1	1

Associated Engineering

Process Integration

- Processes must be brought together for each treatment situation
  - which filtration type ?
  - what pre-treatment ?
  - which disinfectant(s) and where ?
  - other treatment needs
    - e.g.: colour, taste & odour, pH, iron, hardness

Associated Engineering

Questions