The background of the slide features a close-up, high-speed photograph of water ripples, creating a dynamic and textured blue surface. The ripples are most prominent in the center and lower half of the image, with the water appearing to flow from the center towards the edges. The colors range from light, airy blues to deep, dark blues, giving a sense of movement and depth.

**Toxic Use Reduction Institute**  
***Water Resource Conservation in Water  
Treatment***

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# What are we going to Discuss

- Review the process of water treatment and water generation.
- Discuss means of reducing water consumption and chemical generation in these systems
- Discuss reclamation of water and waste utilizing these processes.



# RODI Water Systems



# RODI Water

What is RODI Water?

RO = Reverse Osmosis  
DI = De-ionized

Water Quality Standards

ASTM Standards (Types 1-4) (American Society for Testing and Materials)				
Parameter	ASTM 1	ASTM 2	ASTM 3	ASTM 4
Conductivity (mS/cm)	0.056	1.0	0.25	5.0
Resistivity (megohm-cm)	18.0	1.0	4.0	0.2
pH	--	--	--	5.0-8.0
TOC (mg/L)	100	50	200	--
Sodium (mg/L)	1	5	10	50
Chloride (mg/L)	1	5	10	50
Nitrate (ppm)	--	--	--	--
Silica (mg/L)	3	5	500	No limit
Bacteria (cfu/mL)	0.01	0.1	10	--



# RODI Water – Water Quality Standards

CAP Guidelines (Types 1-3)  
(College of American Pathologists)

\*previously known as the National Committee for  
Clinical Laboratory Standards\*

Parameter	CAP/NCCLS 3	CAP/NCCLS 3	CAP/NCCLS 3
Conductivity (mS/cm)	< 0.1	< 0.5	< 10.0
Resistivity (megohm-cm)	> 10	> 2.0	> 1.0
pH	--	--	5.0-8.0
Silica (mg/L)	< 0.5	<0.1	<1.0



# BPE's RODI System Basics

Pretreatment

Reverse Osmosis

Storage Tank

Recirculation Pumps

Ion Exchange (DI)

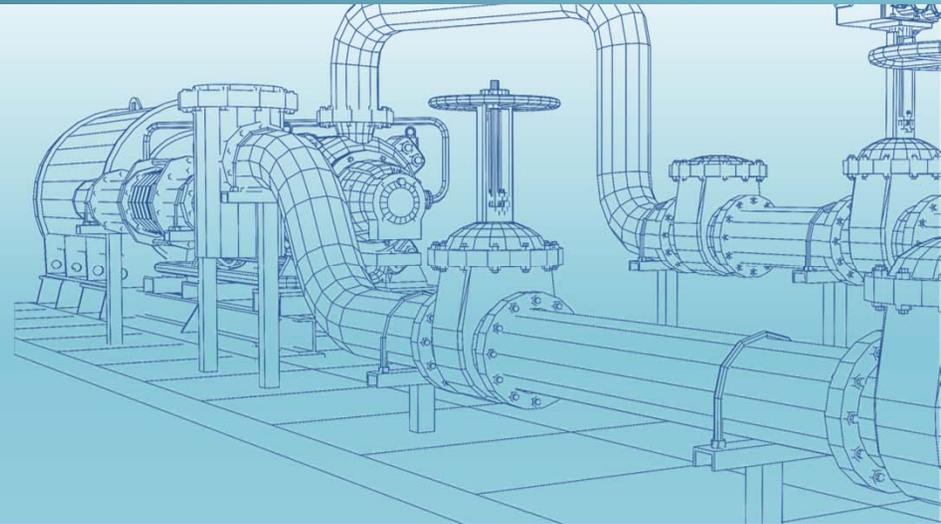
UV (Ultraviolet lamps)

Final Filter

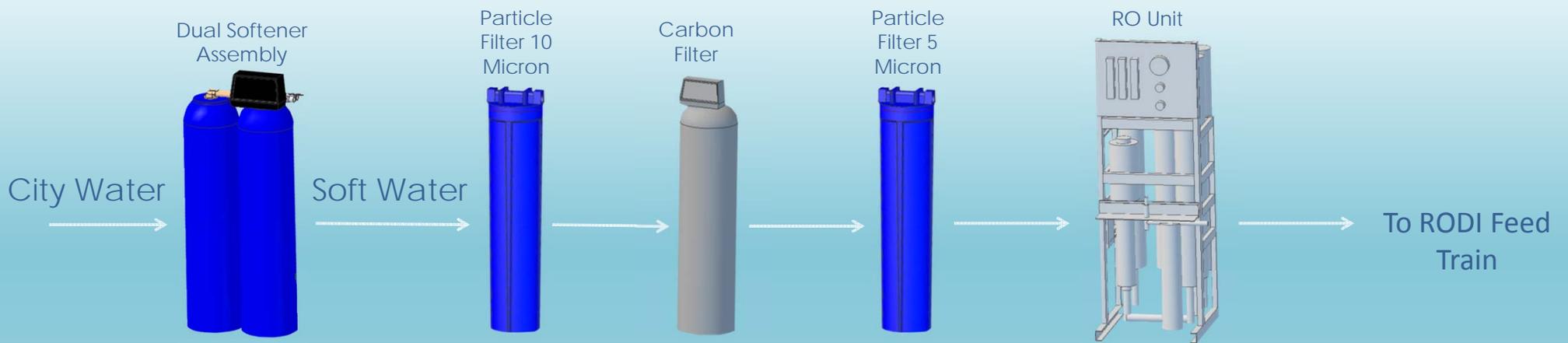
Instrumentation

The Loop (plumbing)

EDI



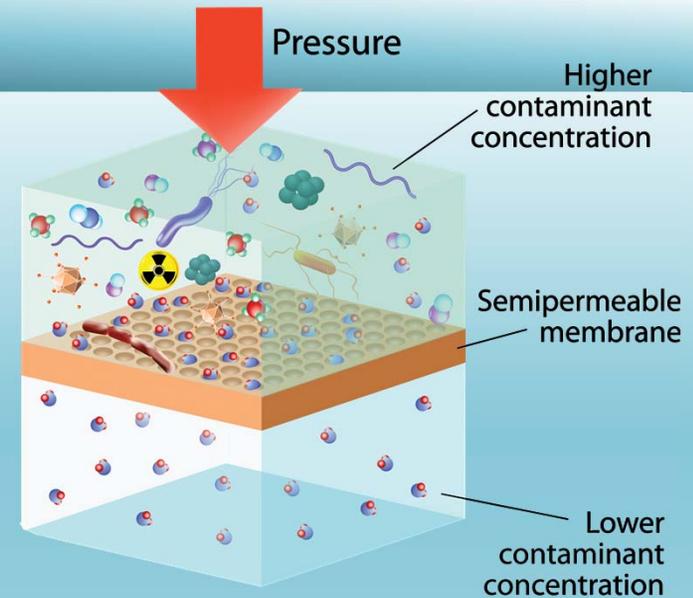
# Pretreatment Train



# Reverse Osmosis (RO)

The Reverse Osmosis process uses a semi-permeable membrane to separate and remove dissolved solids, organics, pyrogens, submicron colloidal matter, viruses, and bacteria from matter.

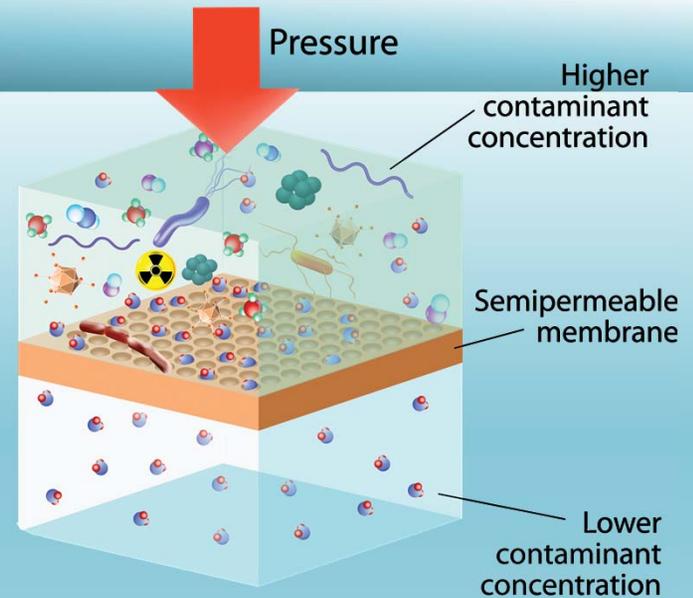
The process is called "reverse" osmosis since it requires pressure to force pure water across a membrane, leaving impurities behind. Reverse osmosis is capable of removing 95-99% of the total dissolved solids (TDS) and 99% of all bacteria.



# Reverse Osmosis (RO)

The typical RO unit includes a high pressure pump (approx. 150-300 psig), RO membranes, and associated pressure gauges and plumbing.

The purified water that is produced is known as the permeate, while the water concentrated with the impurities is known as the concentrate or reject. A portion of the reject water can be recycled back to the pump inlet to minimize wastewater generation.



# Reverse Osmosis (RO)

**A good rule of thumb:** For every one gallon of permeate produced, 2 gallons of incoming, pretreated water are required.

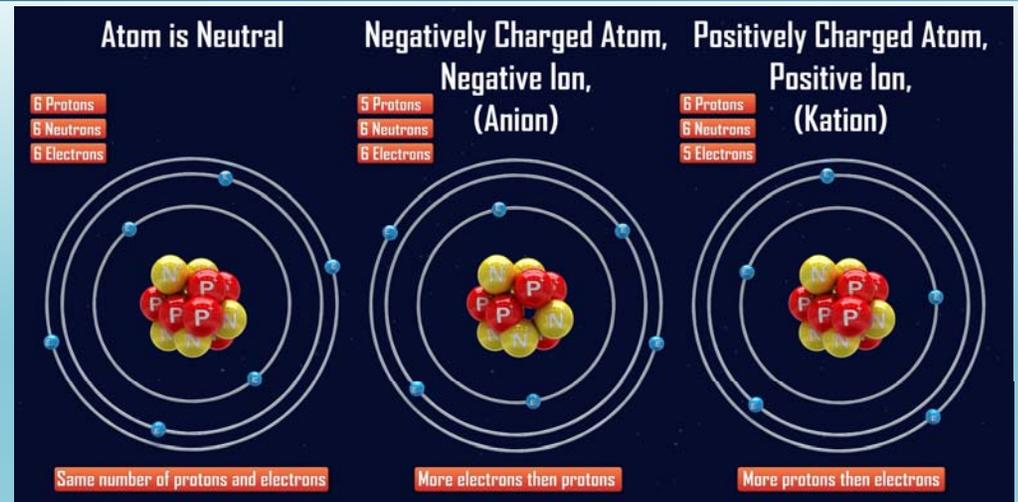
A two probe conductivity meter (one on the inlet to the RO and one on the permeate outlet) is used to measure the efficiency of the RO unit.



# Ion Exchange - deionization

In the context of water purification, ion-exchange is a rapid and reversible process in which impurity ions present in the water are replaced by ions released by an ion-exchange resin.

The impurity ions are taken up by the resin, which must be periodically regenerated to restore it to the original ionic form.

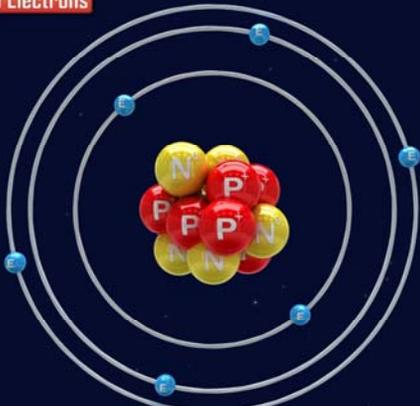
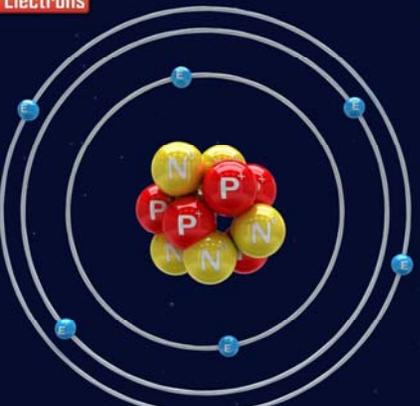
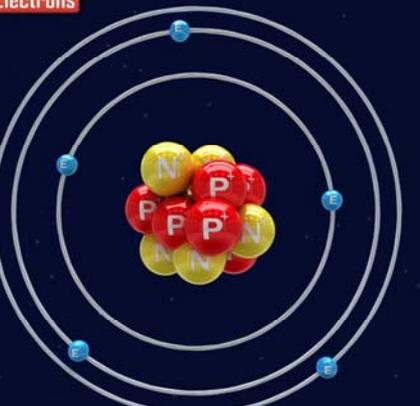


# Ions

An ion is an atom or group of atoms with an electric charge.

Positively-charged ions are called cations and are usually metals; negatively-charged ions are called anions and are usually non-metals.



Atom is Neutral	Negatively Charged Atom, Negative Ion, (Anion)	Positively Charged Atom, Positive Ion, (Kation)
6 Protons 6 Neutrons 6 Electrons	5 Protons 6 Neutrons 6 Electrons	6 Protons 6 Neutrons 5 Electrons
		
Same number of protons and electrons	More electrons than protons	More protons than electrons

# Ion Exchange - ions removed

The following are widely found in raw water streams:

Calcium ( $\text{Ca}^{2+}$ )

Magnesium ( $\text{Mg}^{2+}$ )

Sodium ( $\text{Na}^+$ )

Potassium ( $\text{K}^+$ )

Iron ( $\text{Fe}^{2+}$ )

**Cations**

Chloride ( $\text{Cl}^-$ )

Bicarbonate ( $\text{HCO}_3^-$ )

Nitrate ( $\text{NO}_3^-$ )

Carbonate ( $\text{CO}_3^{2-}$ )

Sulfate ( $\text{SO}_4^{2-}$ )

**Anions**

# Ion Exchange - bottles

Resin tanks/bottles are available in many different sizes.

Standard size is a 14" diam. x 47" tall FRP bottle with a 3.5 cuft resin capacity.

Each of these bottles can treat a maximum flow of 10 gpm.

- These bottles can also be placed in parallel (to achieve higher flow rates),
- In series (to achieve more polishing),
- Or a combination of both.



# Ion Exchange - bottles

## Resin Trap

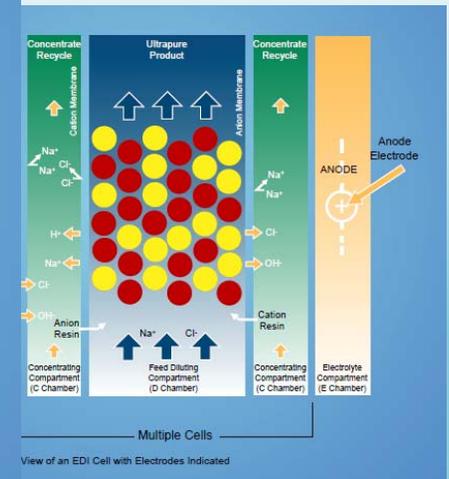
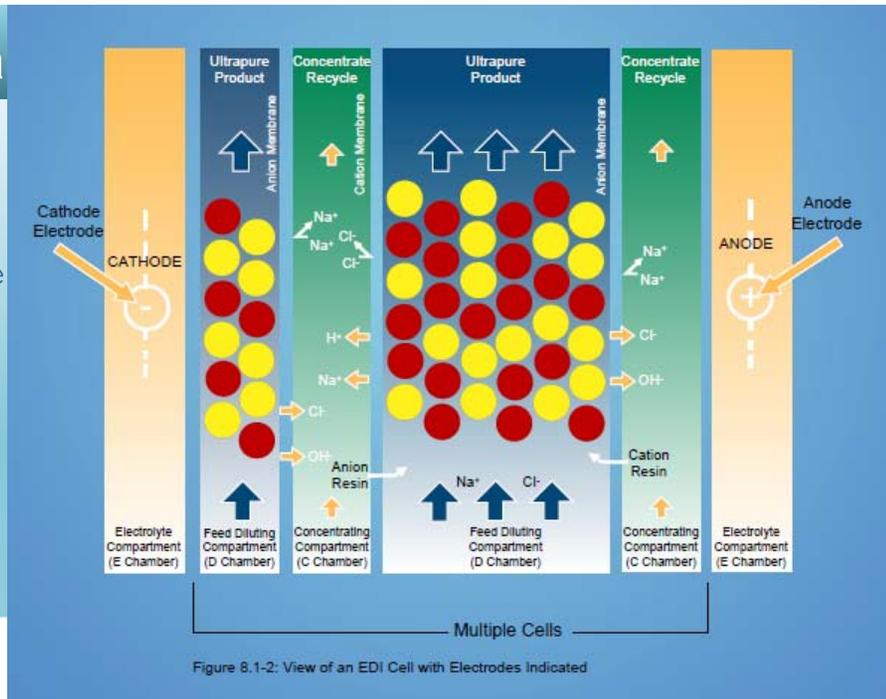
A particle filter is required after the ion exchange bottles to capture any resin fines from entering the loop. This is known as a resin trap.

When the resin's exchange capability has been depleted it needs to be either replaced (as is the case in some ultra pure situations) or regenerated. In the case of regeneration, the entire bottle can be removed and replaced with a new bottle complete with resin. The old bottle is then taken off site for regeneration).



# EDI – electro deioniza

Electro deionization or EDI is a water treatment technology that separates dissolved ions from water by ionizing the water and creating a charge potential that pulls charged impurities out of the water.



## UV- ultraviolet lamps

Ultraviolet light provides a physical process for the disinfection of water and wastewater without the disadvantages associated with chemical disinfection.

254nm UV

UV either kills microorganisms or inactivates their reproductive capability - effectively disinfecting wastewater effluent. In the process of disinfecting with UV, wastewater flows past specially engineered light bulbs, which emit ultraviolet light energy. This form of treatment reduces free chlorine levels required up to 99%.

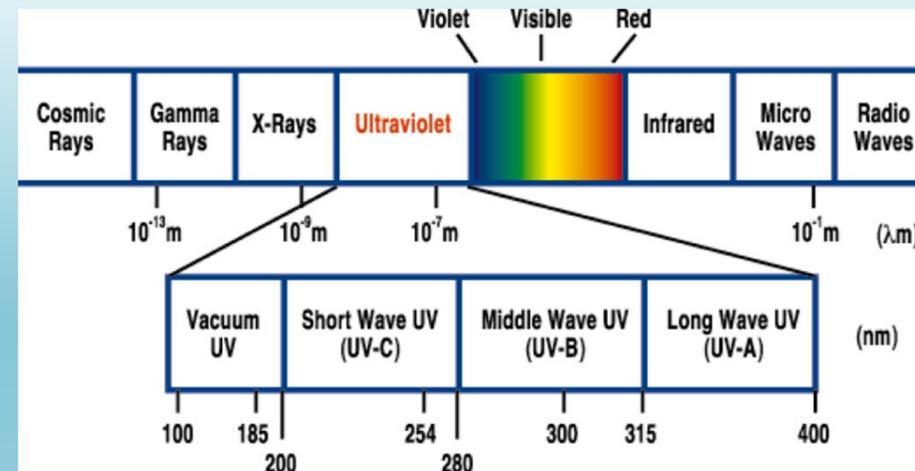


# UV- wavelengths

UV units are supplied in two standard wavelengths:

- 185 nm for TOC reduction
- 254 nm for disinfection (prevents bacteria from reproducing) and for ozone destruct.

\*Ozone is sometimes used for loop disinfection. It is very aggressive however to most filter elements and ion exchange resin. For this reason, 254 nm UV units are used to break down the ozone after sanitization.



## Final Filter

The final filter is the last part of the high purity generation system before connecting to the distribution loop. It is designed to catch any last particles (specifically endotoxins) from entering the system.



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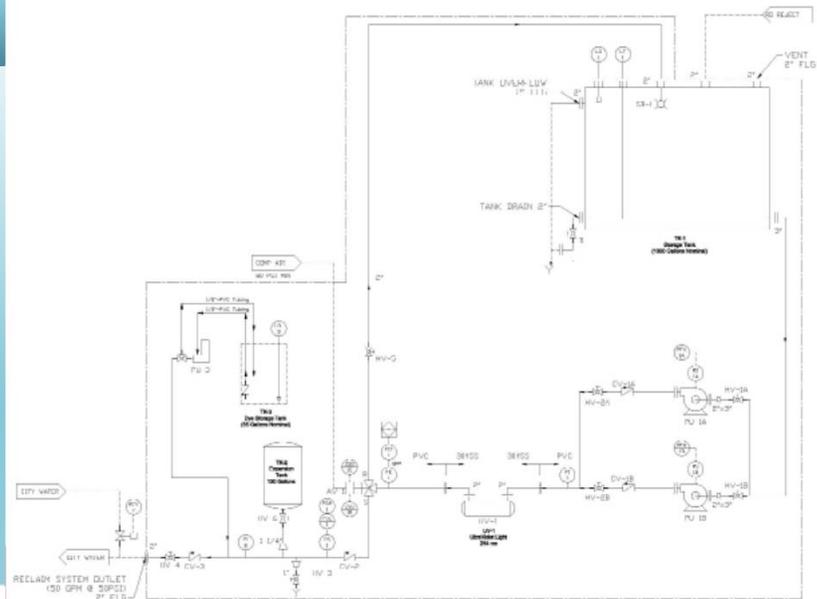
## Final Filter

Filter elements are absolute rated, generally 0.5 micron or better. These elements can be supplied in ozone resistant materials (so they do not need to be removed for ozonation), but are very expensive.



# RO Reclaim

Reclaim system technology has been widely applied to use in RODI system reject system recovery and reuse.



# RODI High Purity Water System

Lab University High Purity Water Case Study



# RO Water System

Reclaim Water Case Study



# Waste Water Treatment Systems

## Active Neutralization System and Recovery



## Got Waste?

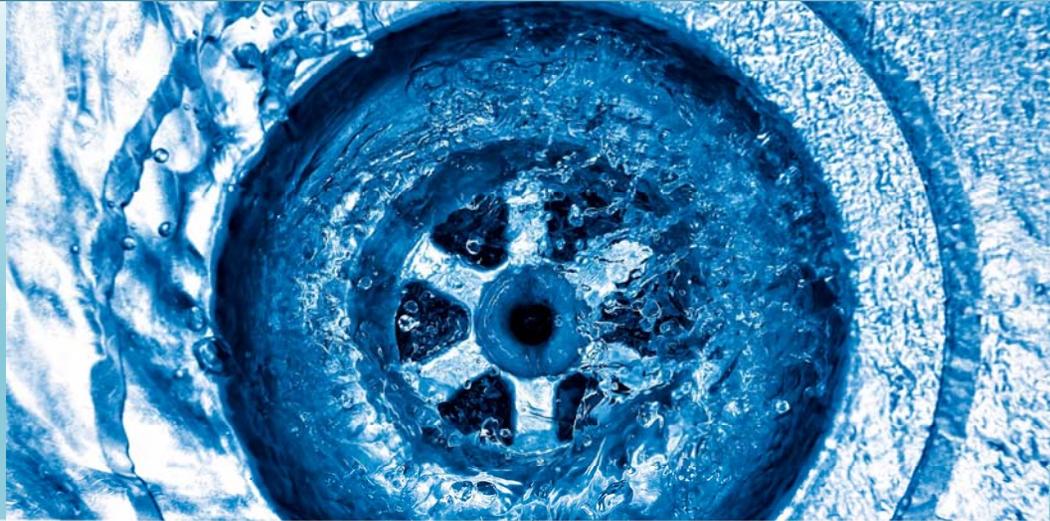
### The 5 Truths of Active pH Treatment Systems

1. Know Thine Enemy... Wastewater.
2. Knowing Is Half the Battle
3. Size Matters!
4. Composition Is Everything... Almost.
5. Waste Treatment Systems Are Big! Plan For Them Early In Your Project Or ...



# Wastewater

Truth # 1  
Know Thine Enemy...  
Wastewater.



# Wastewater

Wastewater is any water which has been adversely affected by anthropogenic sources.



# Wastewater Producing Industries

Where does the wastewater come from?



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**EQUIPMENT**

# Understanding Wastewater

## Why do we need to understand wastewater?

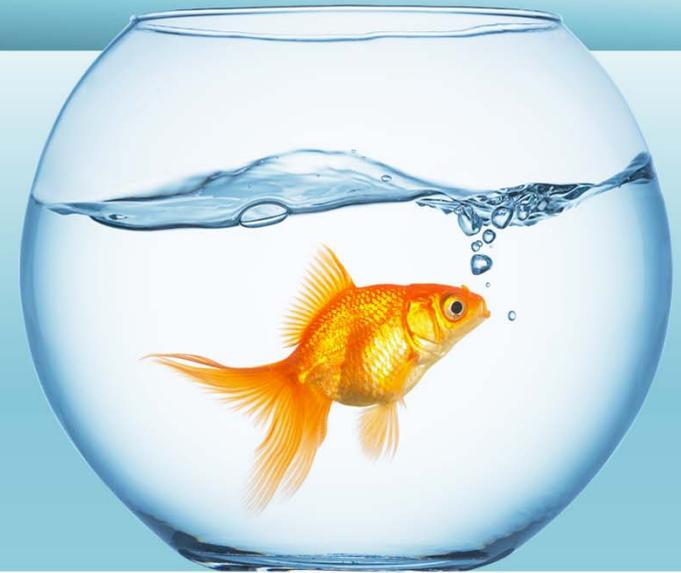
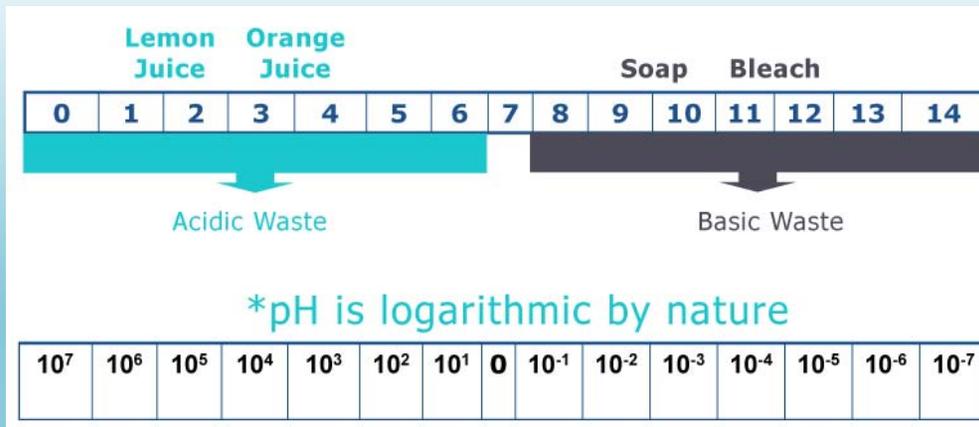
Local municipalities and federal guidelines regulate discharge limits. These include:

- pH Discharge
- Temperature
- Metals
- Organic Species
- Biochemical Oxidization Demand (BOD)
- Chemical Oxidation Demand (COD)
- Volatile Organics
- Solvents

Discharge limits vary by region.



# pH Scale



# Treatment Systems

Truth # 2  
Knowing Is Half the Battle:  
Wastewater Treatment  
System



# Active VS. Passive Systems

## Passive Systems

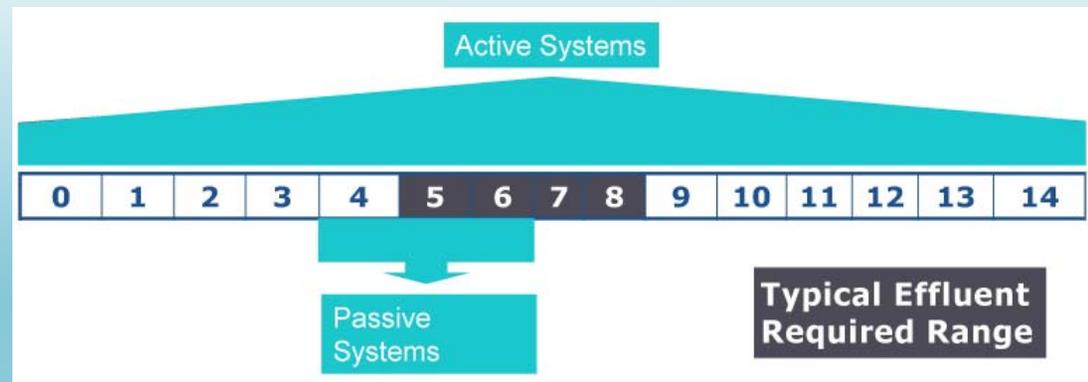
Single direction Treatment

Unable to treat strong waste streams

## Active Systems

Can treat in both directions

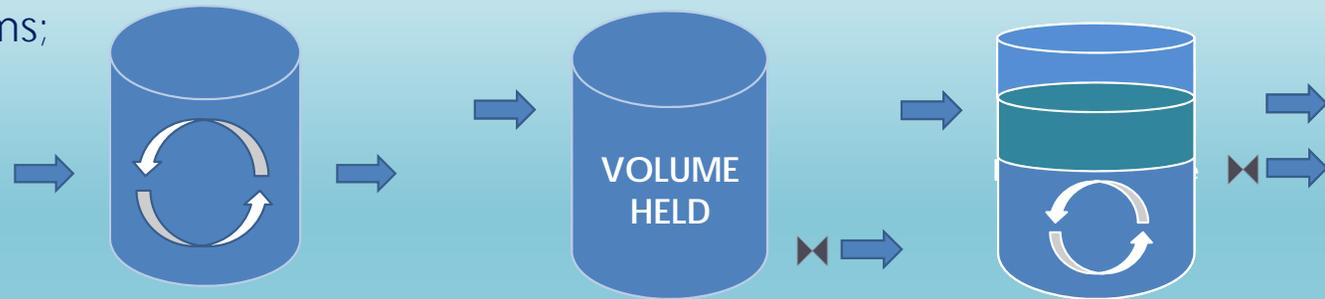
Can treat waste of any strength



# System Designs

There are three main styles of pH/wastewater treatment systems;

- Flow Through Systems
- Batch Treatments Systems
- Hybrid Flow/Batch Systems



# Flow Through Systems

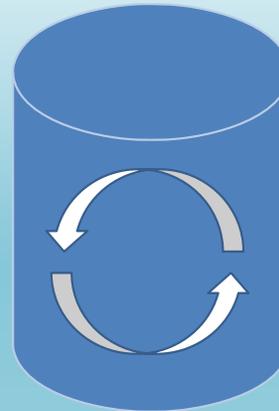
## Flow Pattern:

Determines residence time

Flow through systems are designed to treat the waste on a continuous basis over a number of stages.

They are designed based on the residence time determined for the given flow rate and influent pH and other waste constituents.

Single Stage



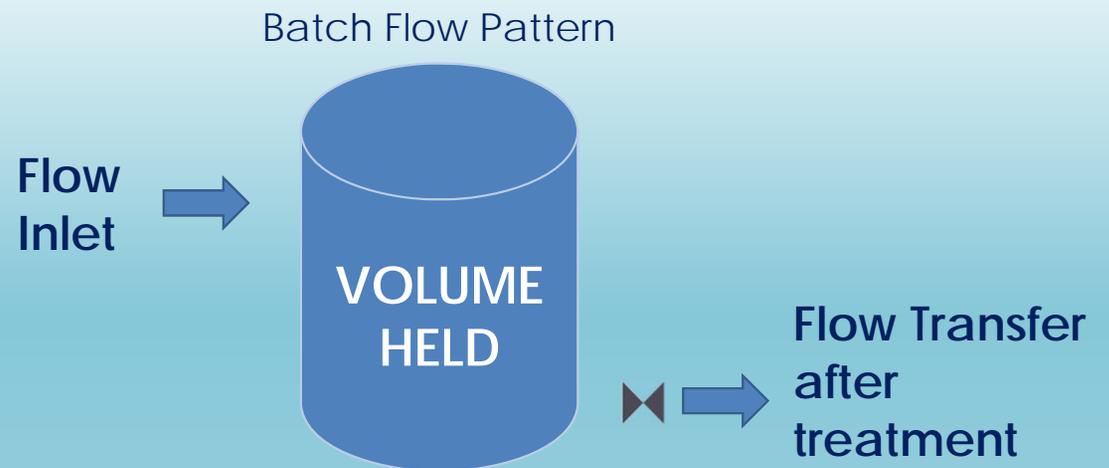
## Note:

Influent flow does not need to be continuous in a flow through system.

# Batch Systems

Batch systems are designed to treat a volume of waste until neutralized, at which point the current batch is discharged and another batch volume is added to the system.

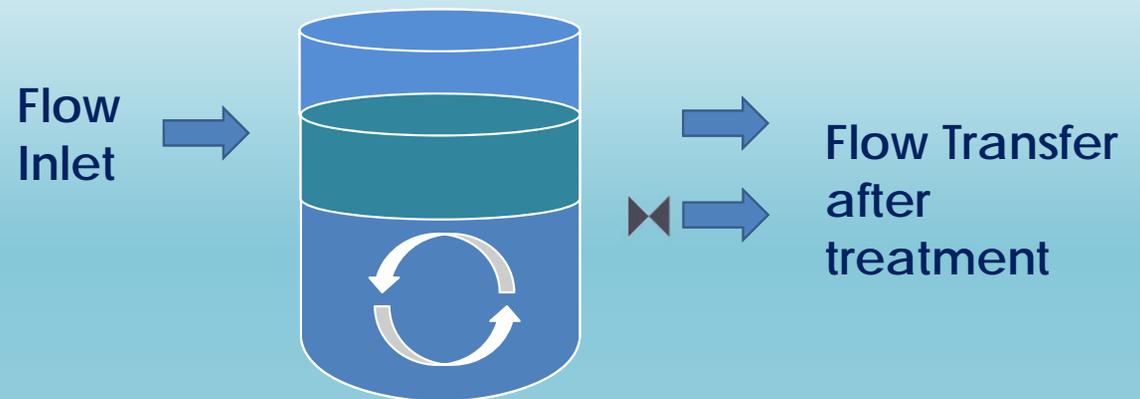
Residence time is not a factor as the batch system treats the waste for as long as necessary.



# Hybrid Systems

Hybrid systems employ the throughput capability of the flow through systems with the additional residence time and compliance control of batch systems.

Batch Flow Pattern



# Major System Components – Treatment Tanks

The treatment tanks in a pH adjustment system are designed as **continuously stirred-tank reactors (CSTR)**.

They are sized and agitated to create ideal mixing so the pH in the tank is equivalent to the pH leaving the tank.

## Important Considerations

- Residence time
- Rate of mixing
- Material compatibility



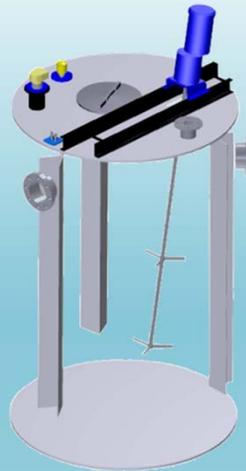
# System Components – Tank Agitation

In tank mixers are the ideal choice for tank agitation due to their capacity.

## Rate of Mixing:

1.5 x tank volume pumping rate required for well mixed solution.

Due to the ideal model of the CSTR, multiple stages are more efficient than one large stage.

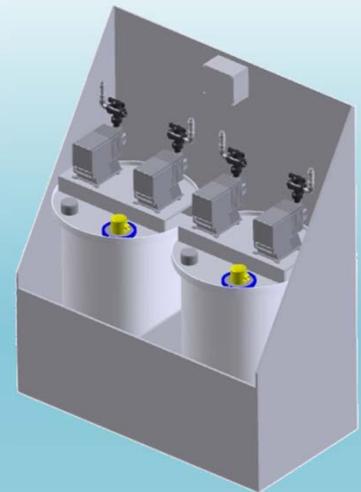


## System Components – Chemical Injection



Since a CSTR model allows for uniform pH across the treatment tank, reagent injection must be properly injected into the mixer wash and controlled to avoid swings in pH and to allow for adequate mixing for other reagents.

The most common reagents for pH adjustment are sulfuric acid and sodium hydroxide. Additionally, carbon dioxide gas can be used.

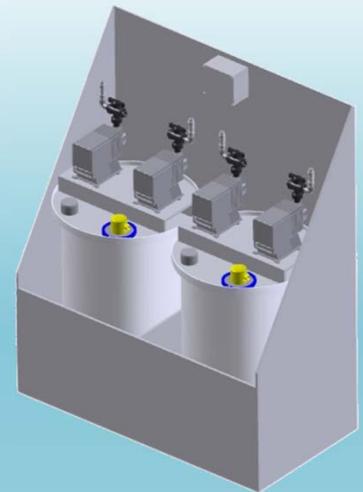


## System Components – Chemical Injection



### Important Considerations

- Turn down for reagent injection proportional to logarithmic pH scale.
- Careful not to oversize to avoid instability in controlling pH.
- Other Reagents adds on a volumetric basis for additional treatment



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# System Components – Equalization Tanks

Equalization tanks are an option that can be added to treatment systems. Equalization storage serves two main purposes:

1. Equalize flows
2. Allow for specific volume transfer.

This is an important feature in establishing a proper CSTR design or batch size and can allow for some self neutralization.



# System Components – Control Schemes

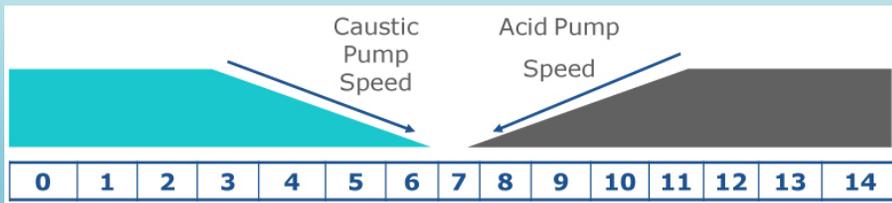
**Proportional control** is the most common control scheme for pH adjustment systems.

It is based on the logarithmic nature of pH and adjusts the chemical addition proportionally to the pH reading or any other waste constituent you can measure in real time.



# System Components – Instrumentation & Controls

## pH Scale



## The 5 Truths - Active pH Treatment Systems



Truth #3  
Size Matters!



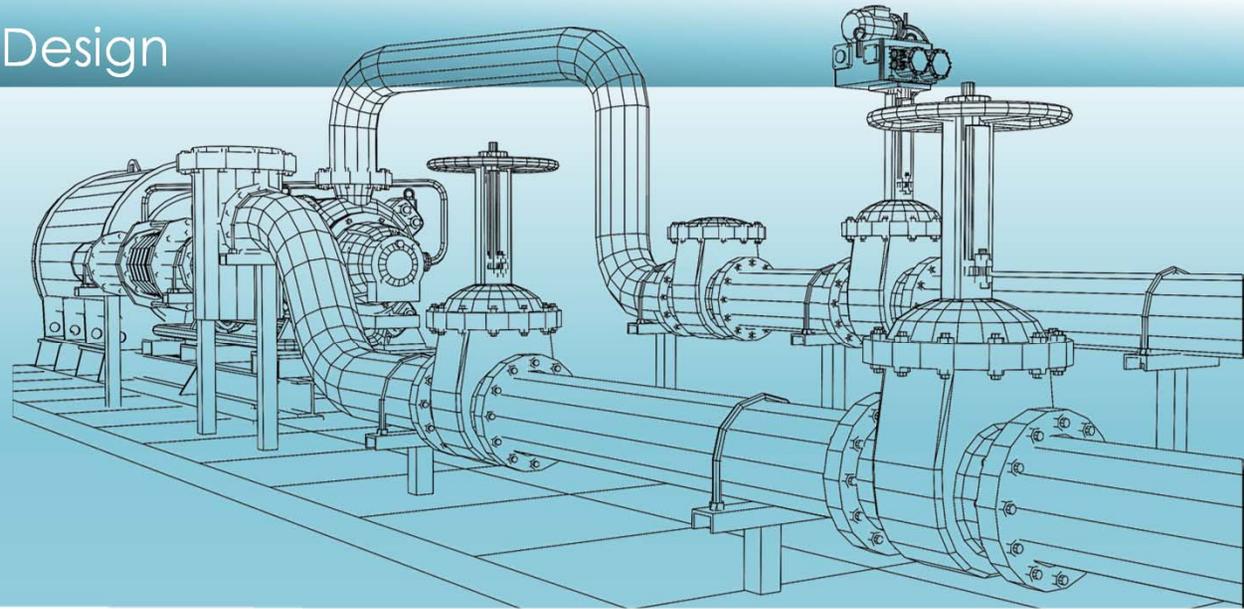
# System Components – Design

There are three primary factors that you need to know:

Volume of the Waste

Nature of the waste

Available footprint



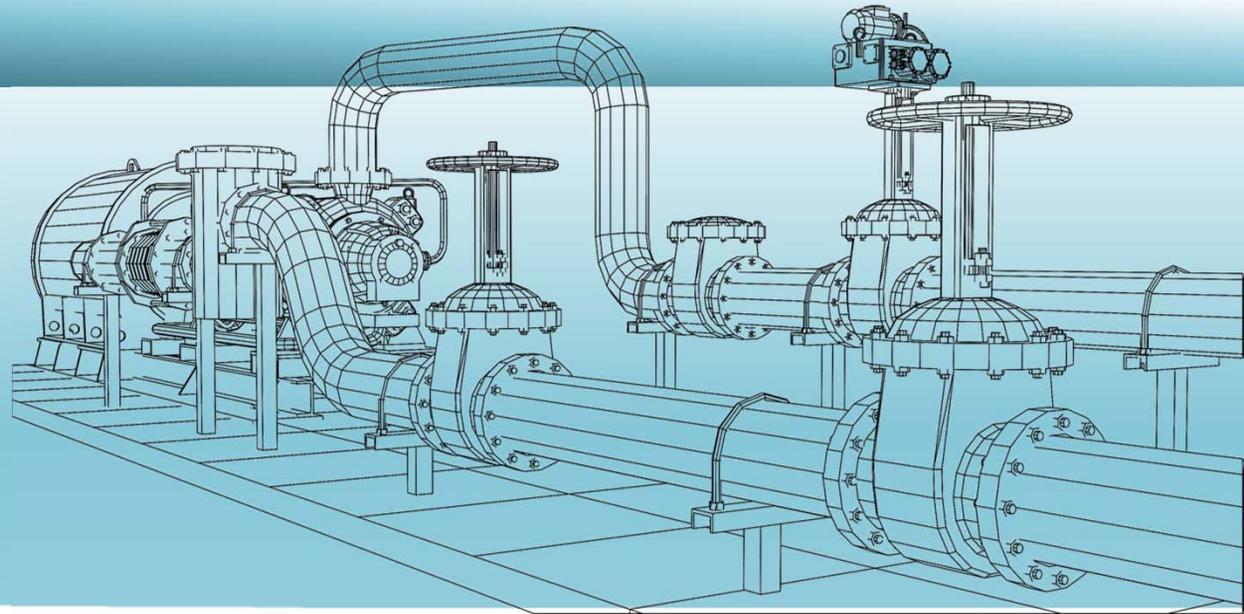
# System Design

## Volume Determinations

Determining the waste volume is critical in system selection.

### Batch System Sizing

Batch systems require influent waste to be transferred to the system in predetermined volumes and then held for treatment. As such, any batch system can only be run in controlled volume conditions or with an up-front equalization tank.



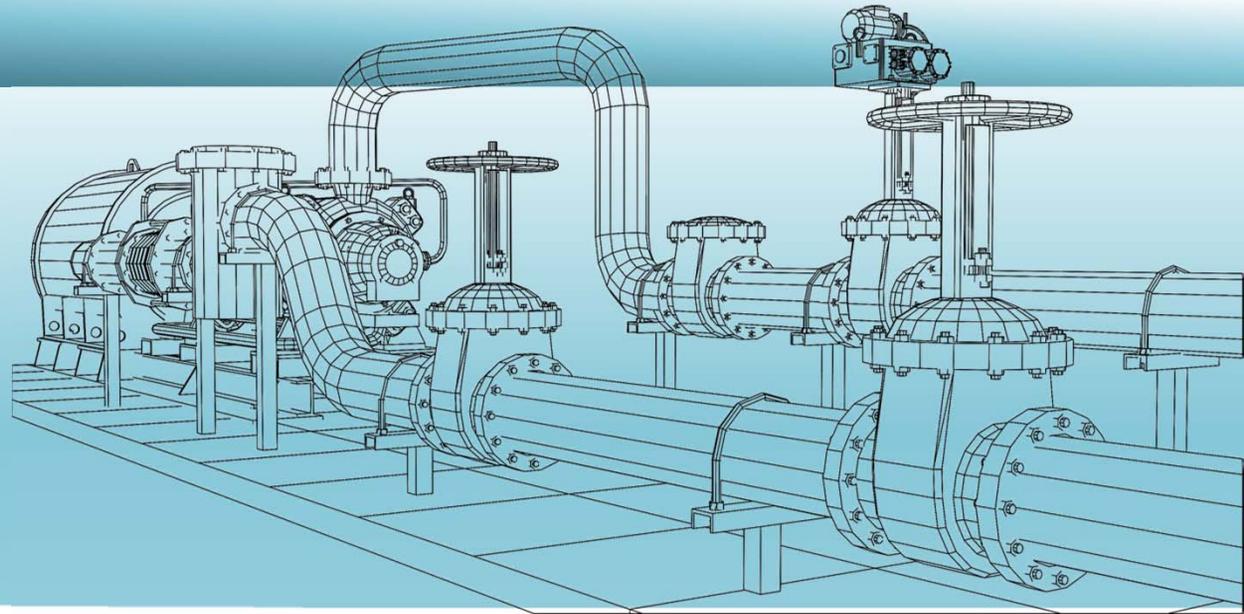
# System Design

## Volume Determinations

Determining the waste volume is critical in system selection.

### Batch System Sizing

To size a batch system you need to know the exact flow profile and volumes of your waste streams as well as have the foot print to support the holding tanks that will be required for the system to function properly.

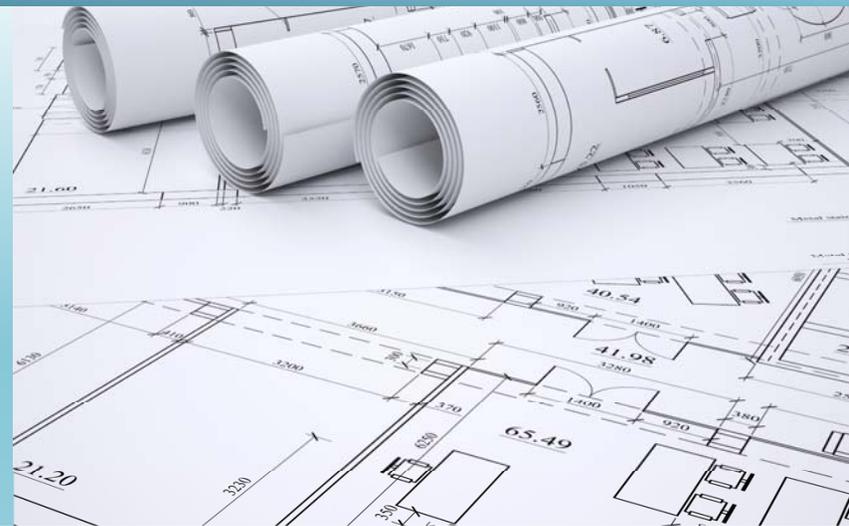


# System Design

## Sizing Flow through Systems

Flow through systems can handle waste of any flow rate but to size the system one must determine the maximum flow rate the system can see at any time.

To do this, values have to be assigned to individual devices that will be connected to the system.



# System Design

## Sizing Flow through Systems

To Determine the flow, below are empirically determined values for different common plumbing devices.

### Assumptions:

- Lab Sink = 1 GPM
- Fume Hood = 0.25 GPM
- Cup Sink = 0.5 GPM
- Actual Usage is 20% to 30% (Diversity)



# System Design

## Sizing Flow through Systems

Cage Washer, Autoclaves, and Dishwashers are assumed to operate at their maximum flow rates and are outside of normal diversity factors.

Processes that generate constant waste streams need to be added in at the maximum flow rate. As an example, overflow from process rinse is a continuous waste stream.



# The 5 Truths - Active pH Treatment Systems

## Truth #4

Composition Is Everything...  
Almost.

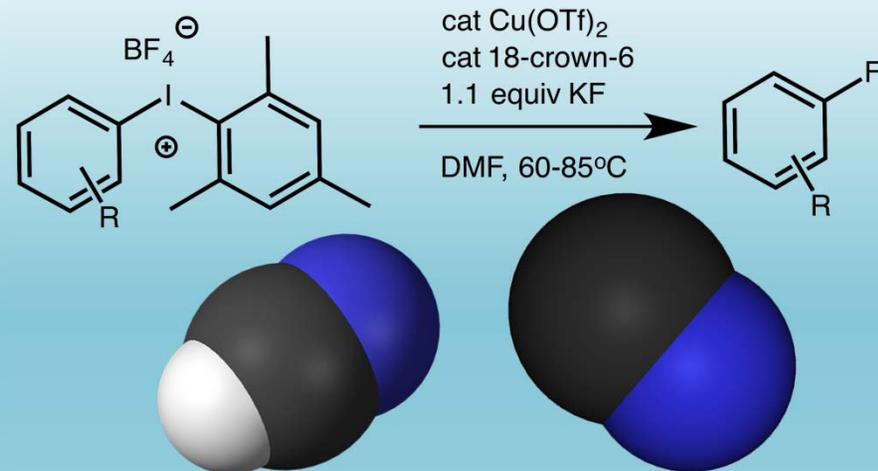


# System Design

## Nature of the Waste

Determining the nature of the waste is critical in system selection in addition to enhanced treatment options:

- Influent pH
- Alkalinity
- Contaminant species
- Metals
- Organics (Cyanide and Fluorine)
- Turbidity
- Thermal



# System Design



## Nature of the Waste Influent pH

Influent pH dictates the number of stages for flow through systems and batch times for batch systems.



# System Design

Nature of Waste Influent pH



# Nature of Waste Influent pH

## Reagent Grade Waste

- Waste Stream 1%+ acid/caustic
- Generally batch treatment only
- Requires in-process temperature control to mitigate heat from neutralization reaction
- Treatment time is very long, residence time not applicable.
- Limiting temperature build up dictates treatment time.

## Standard Grade Waste

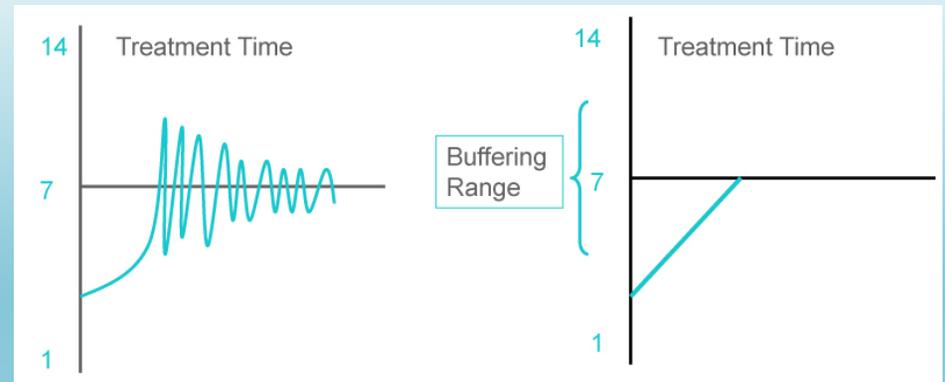
- Waste Stream 2-6 and 8-12 pH range
- Flow through, batch and hybrid systems applicable
- Residence time and number of stages based on flow rate and pH.



# Nature of Waste - Alkalinity

Alkalinity is a measure of buffering capability or the ability to neutralize acid and bases in a solution.

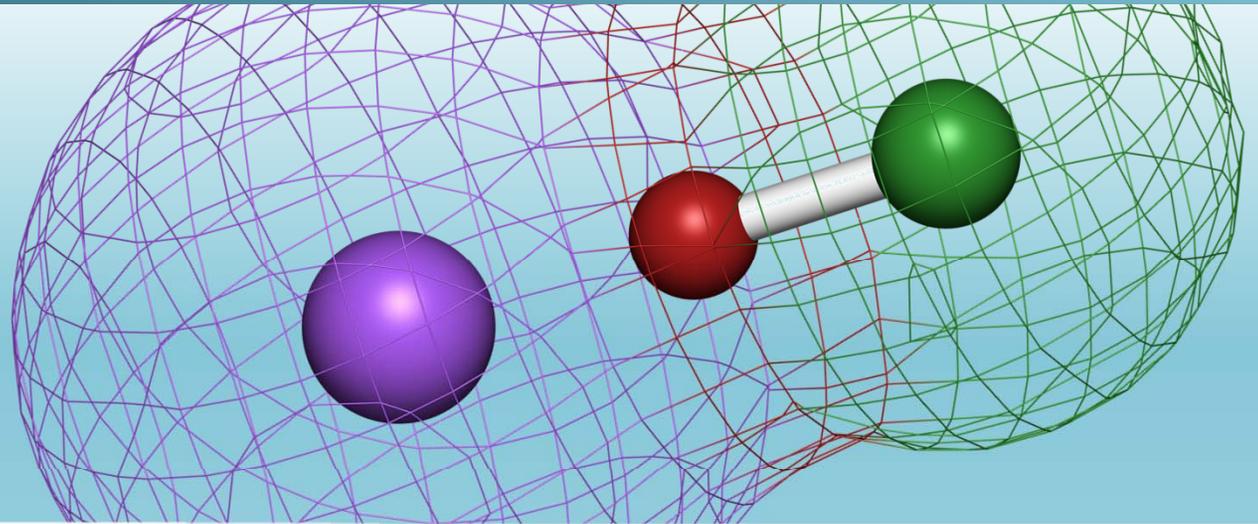
- Alkalinity is a major problem in high purity waste water (WFI, RODI, etc.)
- Buffer injection will cut down on chemical use and treatment time.



# Nature of Waste

When other contaminants are involved additional treatment in combination with the pH adjustment can be used.

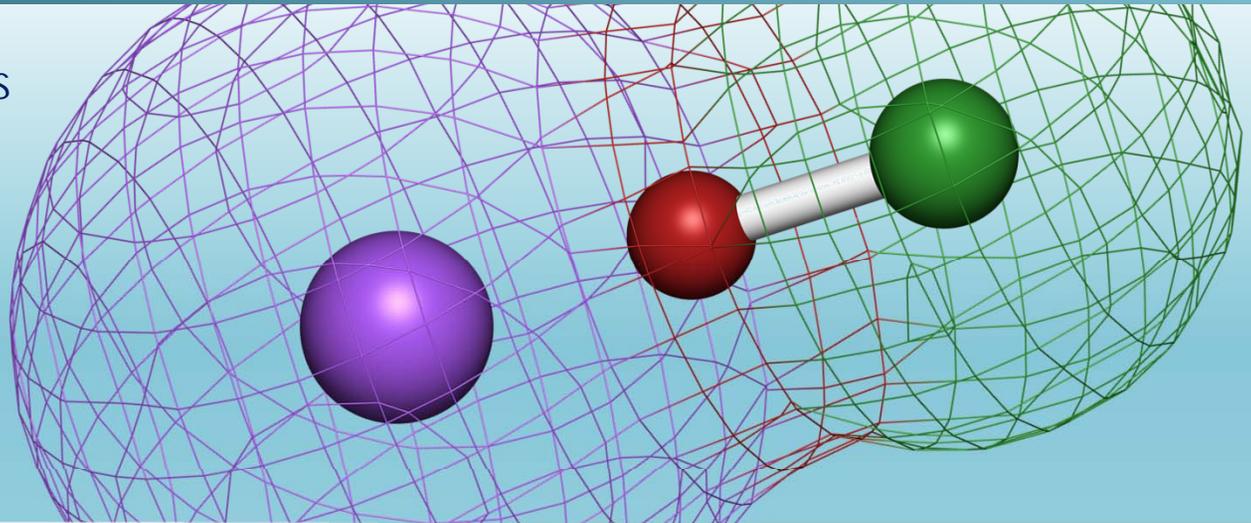
These can be used with either the flow through or batch system depending on the volume of the waste.



# Nature of Waste

## Example Contaminant species

- Metals
- Organic Species
- Biochemical Oxidization Demand (BOD)
- Chemical Oxidation Demand (COD)
- Volatile Organics
- Temperature



# System Design

## Additional Treatment Options

- Membrane Treatment
- Ion Exchange
- Precipitation
- Destruct Systems



# The 5 Truths - Active pH Treatment Systems

## Truth #5

Waste Treatment Systems Are Big! Plan For Them Early In Your Project Or ...



## Putting It All Together - Case Studies

pH System  
Video



**Thank You.**  
*Any Questions?*



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