An Overview of Disinfection Processes and Operational Considerations

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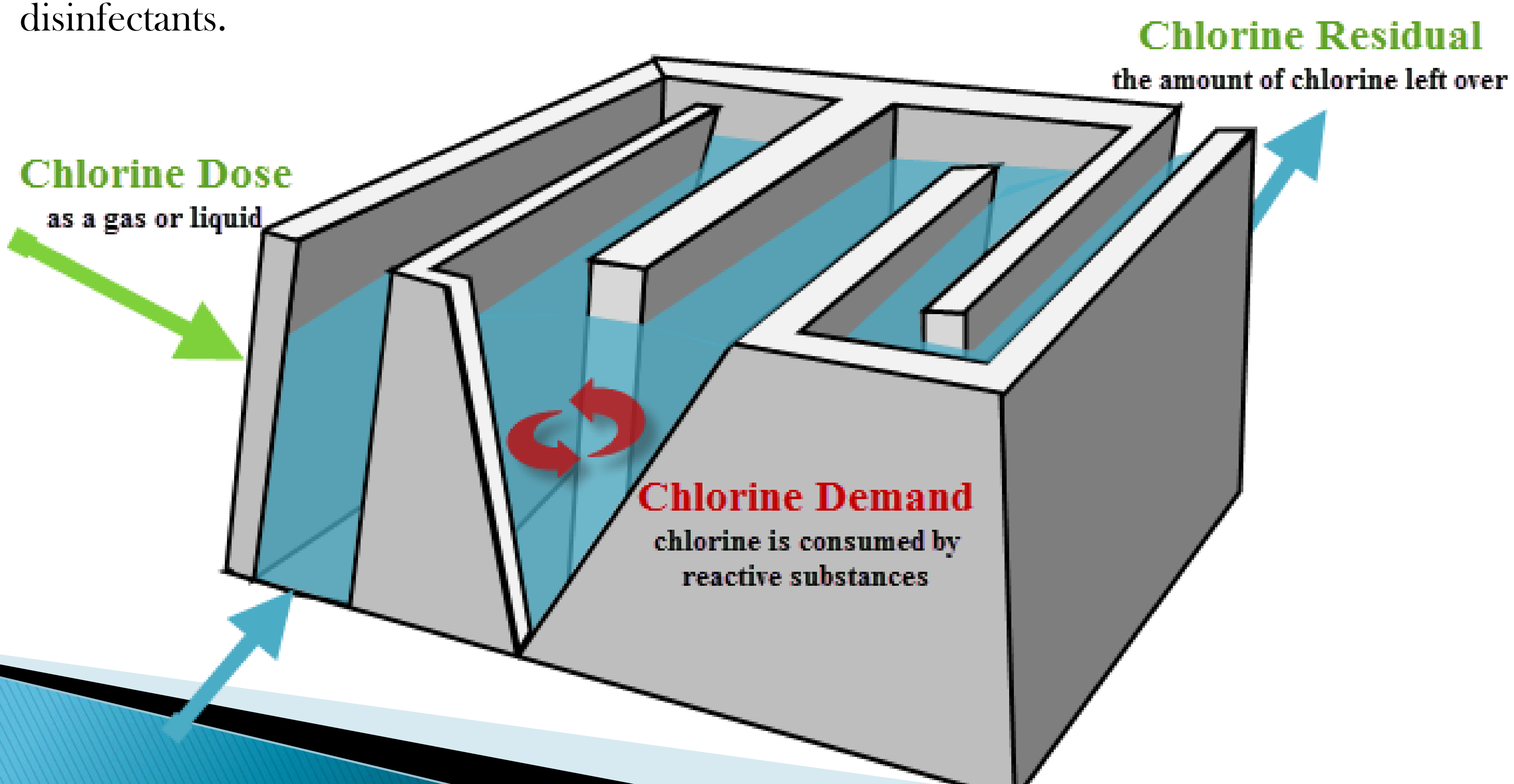
Disinfection destroys pathogenic organisms, (Sterilization destroys everything).

This can be accomplished using chemicals, ozone or radiation.

Chlorine (Cl2)

Chlorine is a powerful oxidizer and one of the main disinfectants used in wastewater treatment plants. Delivered as either a gas or liquid it reacts with water and forms disinfectants.




Disinfection Process

- **The Dose** is controlled by a rotometer, usually read in lbs/day. The concentration of chlorine is measured in mg/l.

- **The Demand** is the amount of chlorine that was consumed by substances, organics, organisms and sunlight.

- **The Residual** is the chlorine left over after the demand is satisfied.

- **To measure the effectiveness** of the process, the effluent is measured for **pathogenic concentrations**. Commonly tested are Total Coliform and E.Coli; these are indicator bacteria.

Chemical Reactions

- When mixed with water, chlorine forms **Hypochlorous** and **Hydrochloric** acids that are used to disinfect.

- If ammonia is present then it reacts and forms **Chloramines**, also used as a disinfectant.

- Other substances in the water will react and consume chlorine, resulting in an increase demand (increases amount of chlorine needed to disinfect).

- Once all reactions with ammonia and other substances have been reached, then the left over chlorine is called **Free Available Chlorine** and is the strongest disinfectant of them all.

Physical Reactions

- One volume of liquid chlorine yields about 460 volumes of chlorine gas.

For example: 1pound or (about 11 fluid ounces) of liquid chlorine yields approximately 5.4 cubic feet of 100% chlorine at 70°F temperature.

Therefore, one 150-lb cylinder would completely fill a 10 x 10 x 8- foot room with 100% chlorine gas.

Chlorine Delivery System

CYLINDERS

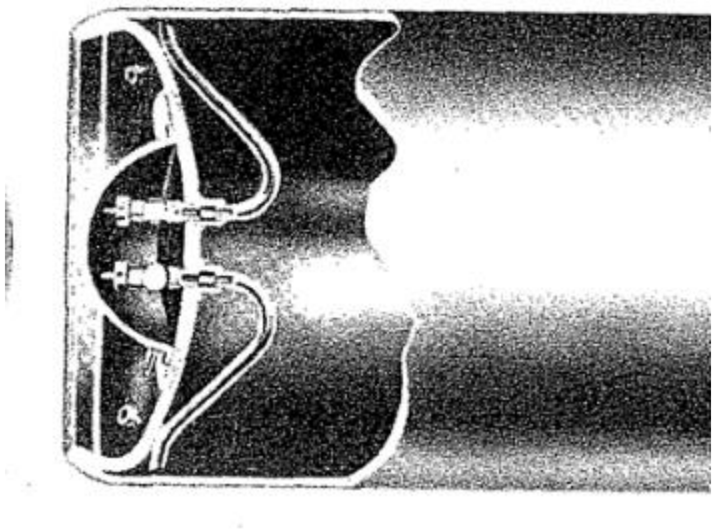
- Typically 100 or 150 lbs.
- Always stands upright, when online delivers gas
- Has fusible plugs that melt & open around 165^{o}F for safety
- Max Withdraw rate typically **1 lbs./day- per degree F** (ambient temp)

Chlorine Delivery System

ONE TON CONTAINERS

- Steel cylindrical containers, 1650 lbs. Tare, contains 2000 lbs Cl_2 (1 ton)
- Horizontal position when online, two valves for chlorine access

  top valve delivers gas, **bottom valve delivers liquid**



- Max Withdraw rate typically **8 lbs./day- per degree F** (ambient temp)

Chlorine Delivery System

Cargo Tanks

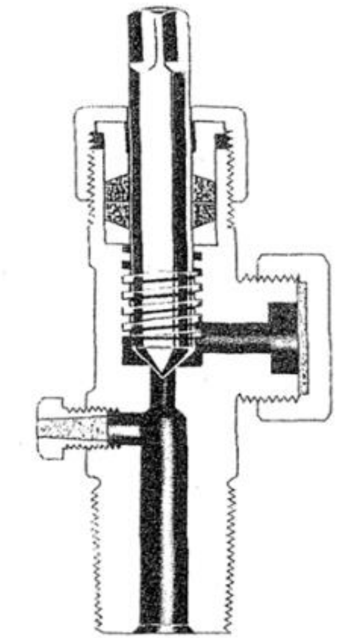
- Capacity of 15-22 tons of cl2
- Used to transport cl2 over roads, highways
- Special training

Rail Tanks

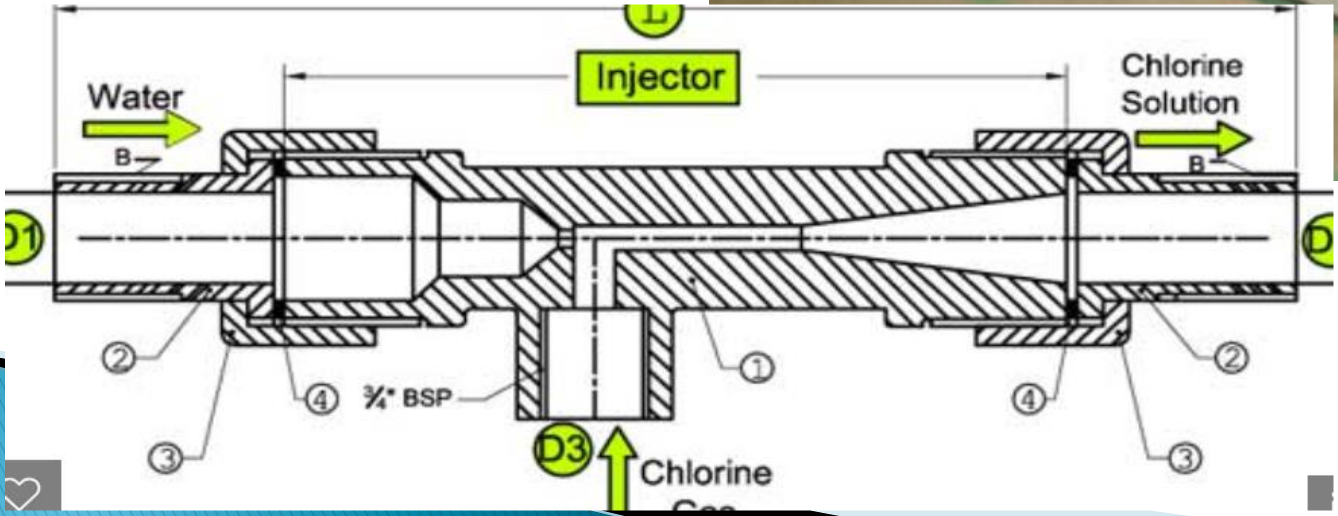
- Capacity of 55 – 90 tons of cl2
- Special training

Chlorine Delivery System
Connection

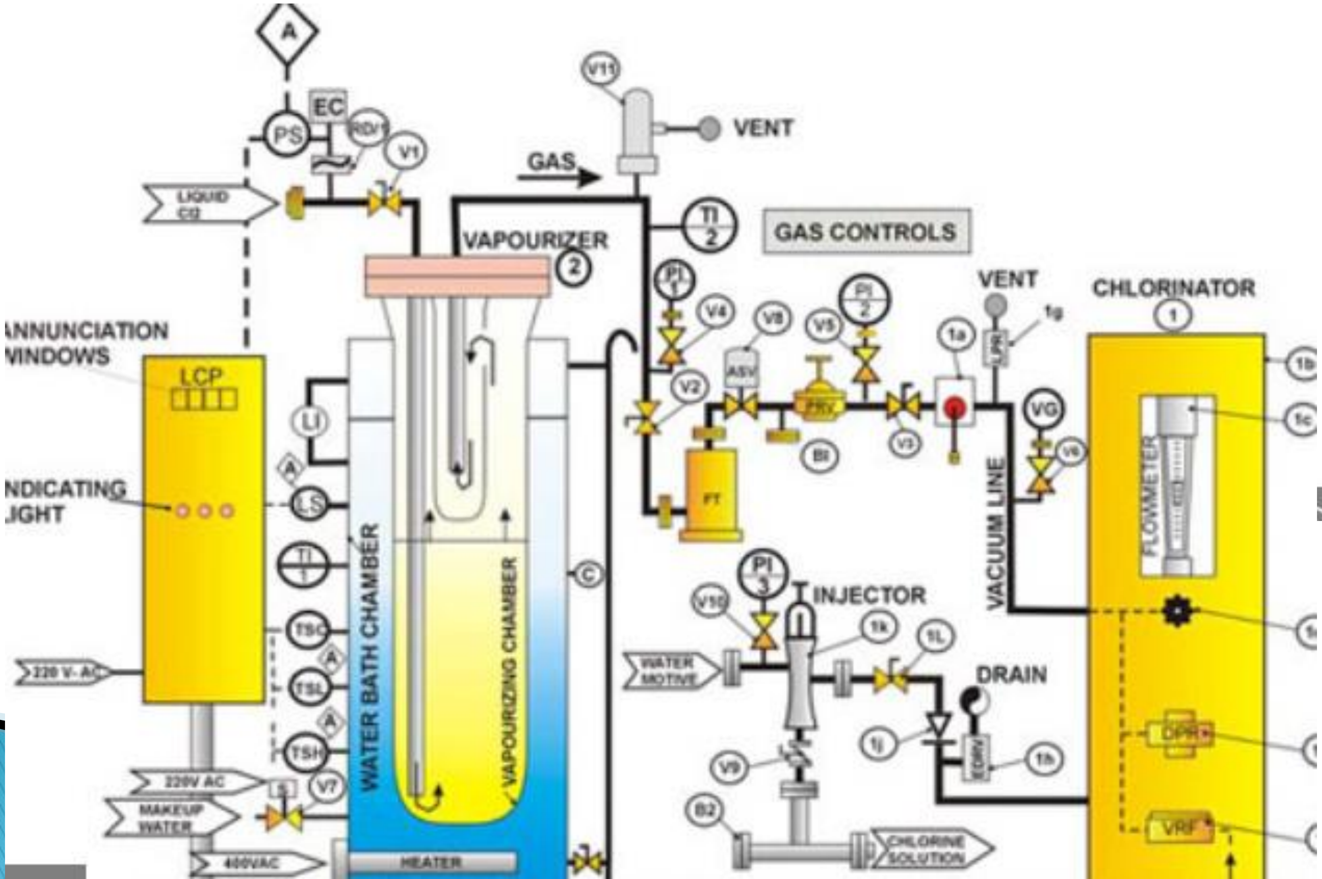
- Valves
  - Washers (lead, fiberglass)
  - Testing for leaks
  - SCBA



- Chlorinators
  - Pressure valve
  - rotometer
  - Regulator
  - Vacuum injection
  - Only used for gas



- Evaporators
  - heater
  - Water bath
  - filters
  - Only used when withdrawing liquid



Chlorine Delivery System

Leak Response

- Use of ammonia to detect leaks, white cloud formation, do not use liquid or soapy water, do not use nose

- Self-contained breathing apparatus (SCBA) required onsite, accessible outside of storage room (for small leak),
- HAZMAT level A required for entry into a large leak, training & certification required

Chlorine (Cl2)

Advantages

It is easily available, **inexpensive** and **extremely effective**.

It can also be used for odor and corrosion control.

Disadvantages

Extremely dangerous to handle.

Increased costs associated with training & safety.

Unwanted byproducts created from side reactions with organics.

Hypochlorite

Chlorine can also come in a liquid solution referred to as **Sodium Hypochlorite**. Hypochlorite can come in different chlorine concentrations, normally 12 & 16%. Used in the same way as chlorine gas, Hypochlorite has some different properties and operational considerations.

Advantages

It is much **safer to use** and handle.
Safety training requirements are less.
It can also be used for odor and corrosion control.

Disadvantages

More expensive than gaseous chlorine.
Unwanted byproducts created from side reactions with organics.
Increases pH of the water.

De-chlorination

Chlorine is dangerous to aquatic life so prior to discharging to receiving water the chlorine residual must be removed. This process is called de-chlorination and can be achieved in a combination of ways but primarily through chemical treatment.

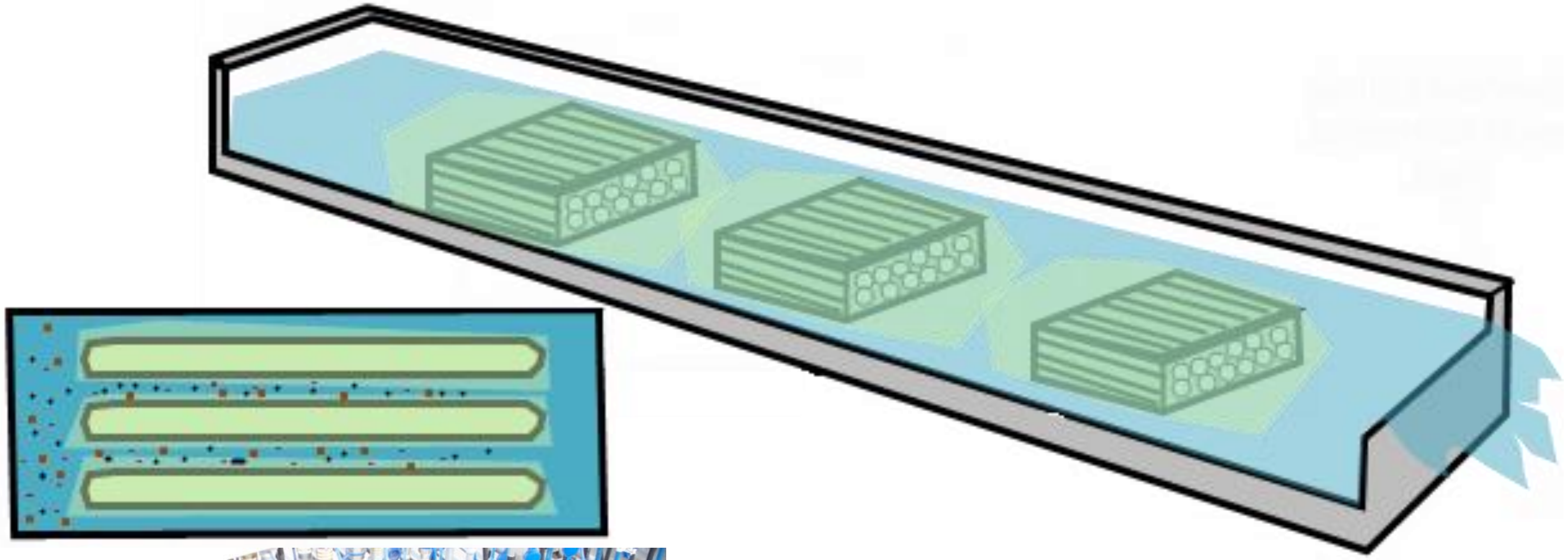
- Chemical Reactions: **Sulfur Dioxide** is used with chlorine on a 1:1 basis. Sulfur Dioxide can come in gas form and use the same equipment set up as chlorine gas uses. When Hypochlorite is used then **Sodium Bisulfite** is utilized to dechlorinate the water.

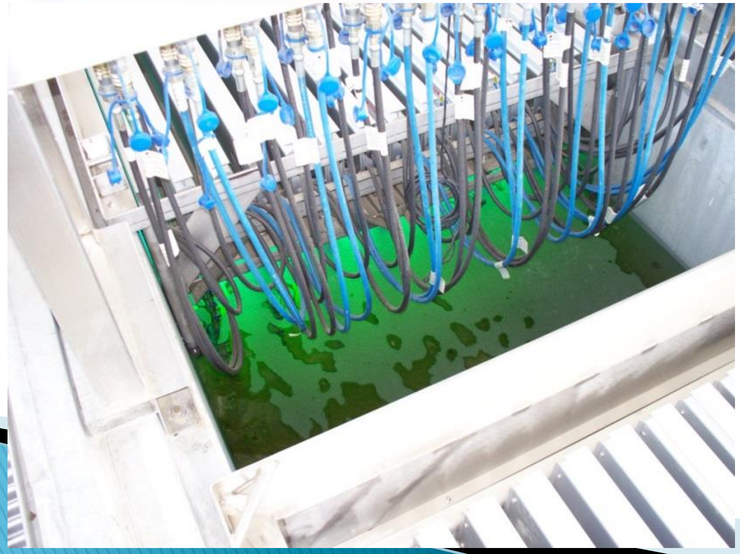
- **Long Detention Time**: Storing chlorinated water long enough for the chlorine to dissipate (not practical in most applications).

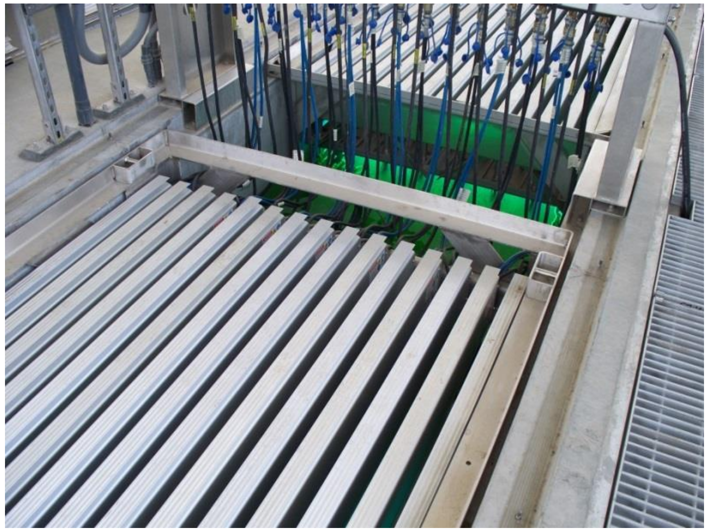
- **Sunlight:** will consume chlorine, but water must be spread in a thin layer to be effective.

Ultra-Violet Radiation

This process does not eliminate but rather uses ultra-violet radiation to alter the DNA of pathogenic organisms. This disables the organisms' ability to reproduce and spread disease.







UV Components

- Lamps
- Quartz Sleeve
- Ballast
- UV Intensity Probe
- Level Sensor
- Optional Automated Cleaning

Operational Considerations

- Clarity of water
- Lamp fouling
- Frequency of lamp cleaning
- Dose: mW second/cm^2

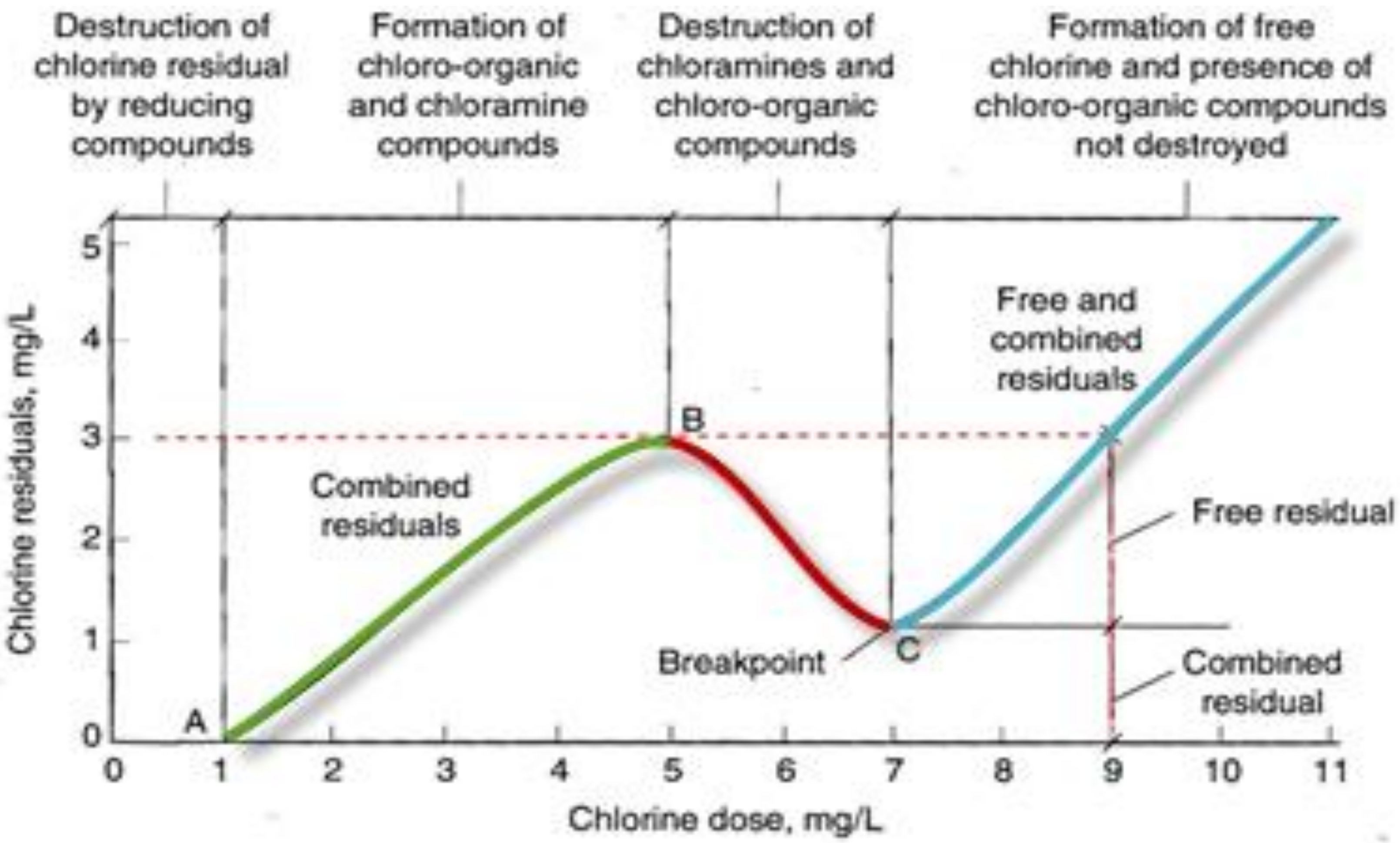
Advantages

- No Chlorine to have to dechlorinate
- Less safety hazards, and need for safety training and equipment. Lessens costs
- Less hazardous chemicals onsite (Cl2,S02, NH3)
- Avoid harmful chlorine by-products

Disadvantages

- Greater power costs
- Additional labor for cleaning lamps
- Unable to remove ammonia

Breakpoint Chlorination



Signs of breakpoint chlorination

- Chrystal clear effluent
- Dropping chlorine residual when the dosing is increasing.
- Uncommon positive coliform results

Solutions

- Add small amounts of ammonia back to form chloramines and avoid problems associated with free chlorine. (Best solution)
- Add more chlorine to move way beyond the breakpoint. (Requires additional chlorine and dechlorination chemicals.)
- Use alternative disinfection methods such as UV
- adjust MCRT to add/limit ammonia.

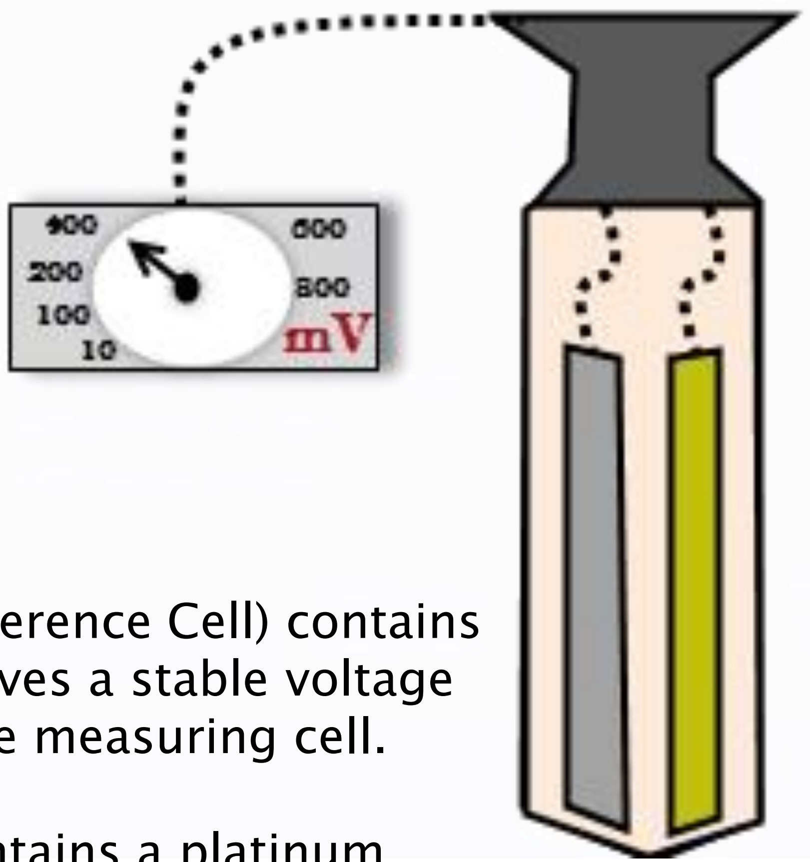
Oxidation Reduction Potential (ORP)

- Designed to measure the oxidation potential when disinfecting the water.

- Useful because it shows the exact amount of disinfectant needed to destroy the pathogens.

- This **prevents chronic overfeeding of disinfectant chemicals**, by only dosing what is required to disinfect the pathogens and excludes the demand that is created by other constituents, sun light and detention time.

The transferring of electrons can be measured by the probe in millivolts. The higher the millivolt reading is the higher the potential for oxidation. So as the pathogenic concentrations increase, the oxidation potential will decrease.



One cell (called the Reference Cell) contains a silver element that gives a stable voltage to reference against the measuring cell.

The Measuring Cell contains a platinum element that generates voltage based on how much oxidizer is in the water. The difference of the two voltages is the ORP measurement.

Benefits of ORP

- Preventing chronic overfeeding of disinfectant & de-chlorinate chemicals, saving on chemical costs.

Disadvantages

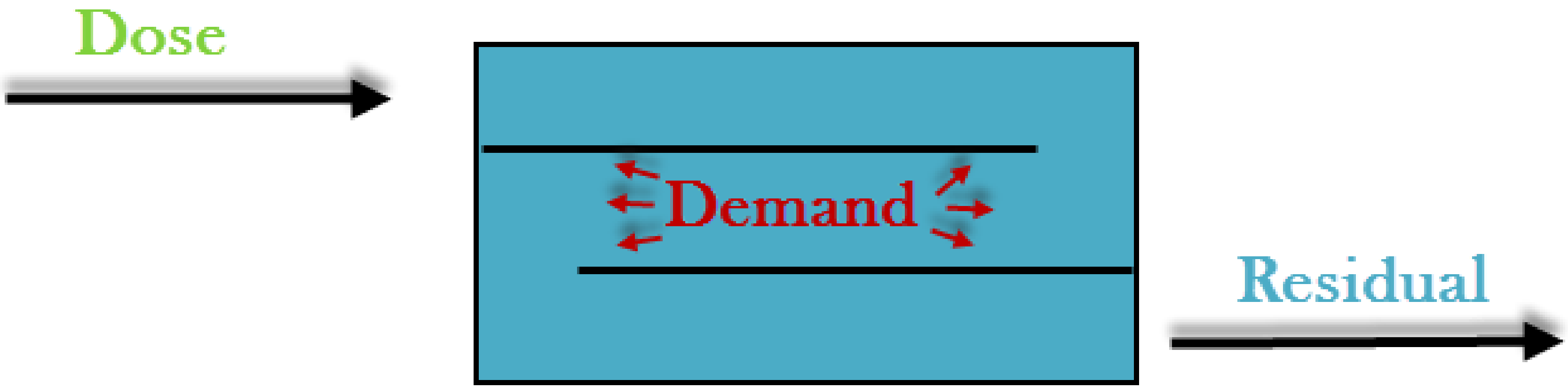
- There is a potential for improper installation & calibration, causing unsatisfactory results.
- Water velocity in channel has to remain constant, or multiple probes have to be used.
- Scaling on probe causes unsatisfactory results, additional maintenance required.

Dose - Demand = Residual

Dose is how much chemical was added.

Demand is how much was needed or used up.

Residual is how much was left over.



Dose - Demand = Residual

Dose - Residual = Demand

Demand + Residual = Dose

Chlorine residual leaving a contact basin is a 2.3ppm. The demand was calculated at a 3.3ppm. If flow through the contact basin was 15 MGD, how many pounds of Chlorine is required to dose?

Solution

Dose = Demand + Residual

3.3 PPM + 2.3 PPM = 5.6 PPM

Lbs./Day = Q (MGD) x Conc. (PPM) x 8.34 (Lbs./Gal)

15 MGD x 5.6 PPM x 8.35 Lbs./Gal =

700.56 Lbs./Day

Chlorine demand in a contact basin was measured at 3.6 ppm. The dose was set at 170 lbs/day. If flow through the contact basin was 5 MGD, how many lbs of cl2 was the residual and at what concentration?

Solution

Residual = Dose – Demand

Lbs./Day = Q (MGD) x Conc. (PPM) x 8.34 (Lbs./Gal)

Demand = 5 MGD x 3.6 PPM x 8.34 Lbs./Gal = 150.12 Lbs./D

Residual (Lbs./Day) = 170 Lbs./Day (Dose) - 150.12 Lbs./Day (Demand) =
19.88 Lbs./Day (Residual)

Conc. = Lbs./Day ÷ Q (MGD) ÷ 8.34 (Lbs./Gal)

19.88 Lbs./Gal ÷ 5MGD ÷ 8.34 Lbs./Gal = **0.476 PPM**

A Sodium Hypochlorite solution (sp. Gravity 1.1 with 12% available chlorine) was used to disinfect a plant's effluent. 150 lbs/D of pure chlorine was used to dose. Calculate the hypochlorite solution dose flow rate in G/D.

Solution

Specific Gravity is a substances weight relative to water.

12% Available Chlorine means that the hypochlorite contains 12% Chlorine and the rest is water and other substances. We need to dose enough Hypochlorite to deliver the required chlorine to meet the dose setpoint.

Water weight = 8.34 Lbs./Gal

Hypochlorite weight = 8.34 Lbs./Gal x 1.1 = 9.174 Lbs./Gal

150 Lbs./Day ÷ 0.12 = 1,250 Lbs./Day of Hypochlorite needed

1,250 Lbs./Day Hypochlorite ÷ 9.174 Lbs./Gal (Hypochlorite) =

136.25 Gal/Day Hypochlorite needed

A 0.65% alum solution is applied to a tertiary filter at a dose of 4.2 ppm. The filter influent flow is 1260 GPM. What should the alum dosing rate be in GPH?

Solution

Lbs./Day = Q (MGD) x Conc. (PPM) x 8.34 (Lbs./Gal)

1,260 GPM x 1440 Min/Day = 1,814,400 Gal/Day

1,814,400 Gal/Day ÷ 1,000,000 Gal/MG = 1.8144 MGD

Lbs/Day = 1.8144 MGD x 4.2 PPM x 8.34 Lbs./Gal = 63.55 Lbs./Day Pure Alum Needed

The alum solution only contains 0.65% pure alum

63.55 Lbs./Day (Pure Alum) ÷ 0.0065 = 9,776.92 Lbs./Day Alum Solution

9,776.92 Lbs./Day ÷ 8.34 Lbs./Gal = 1,172.29 Gal/Day Alum Solution Needed

1,172.29 Gal/Day ÷ 24 Hours/Day = **48.85 Gal/Hour Alum Solution Needed**