Disinfection of Groundwater for Drinking Water Uses

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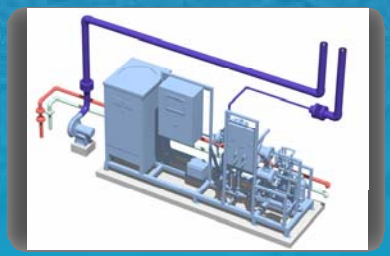


This Afternoon's Topics

- Review Objectives of Groundwater Disinfection
- Overview Disinfection Regulatory Requirements
- Disinfection Approaches
- Considerations for Chlorine Dosage
- Engineering Considerations for Hypochlorite Disinfection Systems
  - Concentrated Hypochlorite
  - On Site Hypochlorite Generation
  - Calcium Hypochlorite (Tablet System)

Some Objectives for disinfecting Groundwater for drinking water use

- Provide safe drinking water that meet or exceed regulatory requirements
- Provide residual chlorine within the distribution system to maintain safe drinking water supply
- Inactivation of target organisms
- Disinfect in a manner that does not generate excess levels of DBPs
- Disinfect with an a process that that does not degrade aesthetics of drinking water (e.g. manganese oxidation and T&O issues)
- Increase consumer confidence

USEPA Disinfection Regulatory Requirements

- Surface Water Treatment Rule (1989) and LT2 Rule – For Groundwater under the Direct Influence of Surface Water
- Stage 1 and Stage 2 Microbial Disinfection Byproduct Rules (1998/2006) – Establishes Disinfection Byproduct Limits for distribution systems: TTHMS 80ppb, HAA5 60 ppb
- Ground Water Rule (October 2006)

Groundwater Rule - Triggered Source Monitoring Provision

- If a groundwater system receives notification of a total coliform-positive distribution system sample collected under the TCR.
  - Must collect source sample within 24 hours
  - If triggered source sample is fecal indicator positive, system must collect 5 repeat source samples over next 24 hours.
  - States can also require immediate corrective action to address contamination

Options for Corrective Actions

- Correct all deficiencies
  - Wells Seals, cross connections..
- Provide alternate source
  - New well, alternate water supply
- Eliminate source of contamination
- Provide Treatment that reliably achieves at least 3-log virus inactivation and removal.
  - Disinfection (chlorination, UV, others)
  - Treatment (membrane filtration, filtration)

Disinfection Technologies

Type	Virus	Pathogens	Taste/Odor	DBPs
Gas Chlorine	●	●	●	●
Sodium Hypochlorite	●	●	●	●
Calcium Hypochlorite	●	●	●	●
On-Site Generation – Low	●	●	●	●
On-Site Generation – High	●	●	●	●
Ozone	●	●	●	●
UV	●	●	●	●
Chloramines	●	●	●	●
Chlorine Dioxide	●	●	●	●

● = Good ● = Fair ● = Poor

Groundwater Disinfection Approach – 2 options

Disinfection Treatment

- Provide sufficient dosage and contact time to achieve 3-log inactivation of viruses.

Residual Maintenance Disinfection

- Intended to maintain a residual disinfectant in distribution system
- Reduces potential for coliform occurrence in distribution system
- Ensure compliance with TCR
- Reduces formation of iron bacteria.

Most groundwater disinfection is associated with Residual Maintenance Disinfection and remainder of the presentation will discuss this disinfection approach

Residual Maintenance Disinfection with Hypochlorite (Liquid Bleach)

- Does not have the Process Safety Management Requirements of Chlorine Gas
- Low cost
- Familiar and proven technology – First applied in 1850 to disinfect Broad Street water pump station in London after Cholera outbreak due to sewage contamination
- Can be safely and easily handled
- Regulatory Acceptable
- Can be generated onsite in low strength solutions very applicable for groundwater disinfection.

Hypochlorite Chemistry

Hypochlorite

$$NaOCl + H_2O \Rightarrow HOCl^- + Na^+ + OH^-$$

74.5 52.5

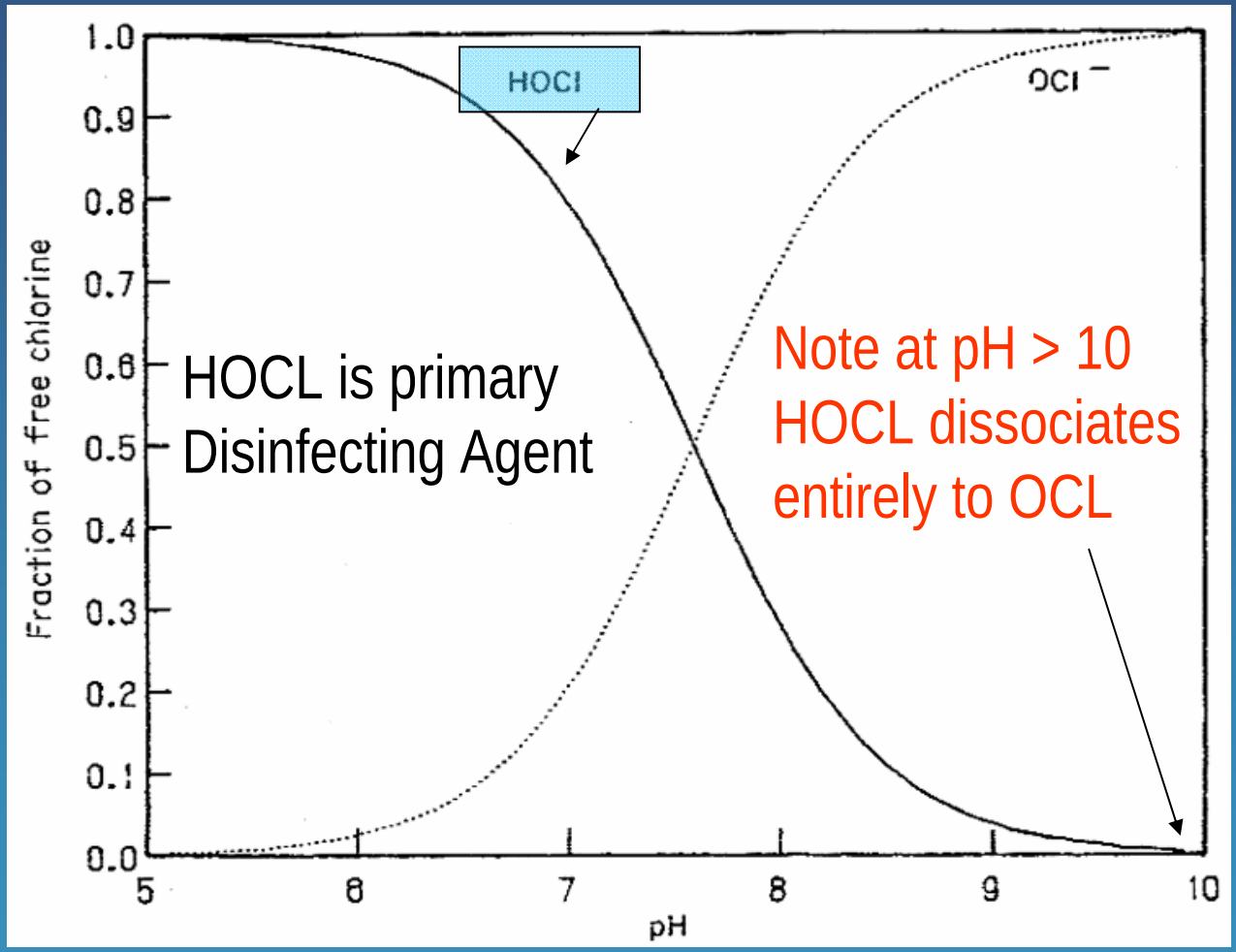
Dissolution of Hypochlorite liberates OH ion providing alkalinity and could slightly raise pH.

$$HOCL \Leftrightarrow [H+] + [OCL-]$$

Hypochlorous Acid [HOCL-] is primary disinfecting agent of hypochlorite. Fraction of HOCL is dependent on pH.

Hypochlorite ion [OCL-] is *not an effective disinfecting agent*

Effect of pH on Relative Amount of Hypochlorus Acid and Hypochlorite Ion at 20° C.



Groundwater Quality Considerations and Determination of Hypochlorite Dosage

Dosage Determination

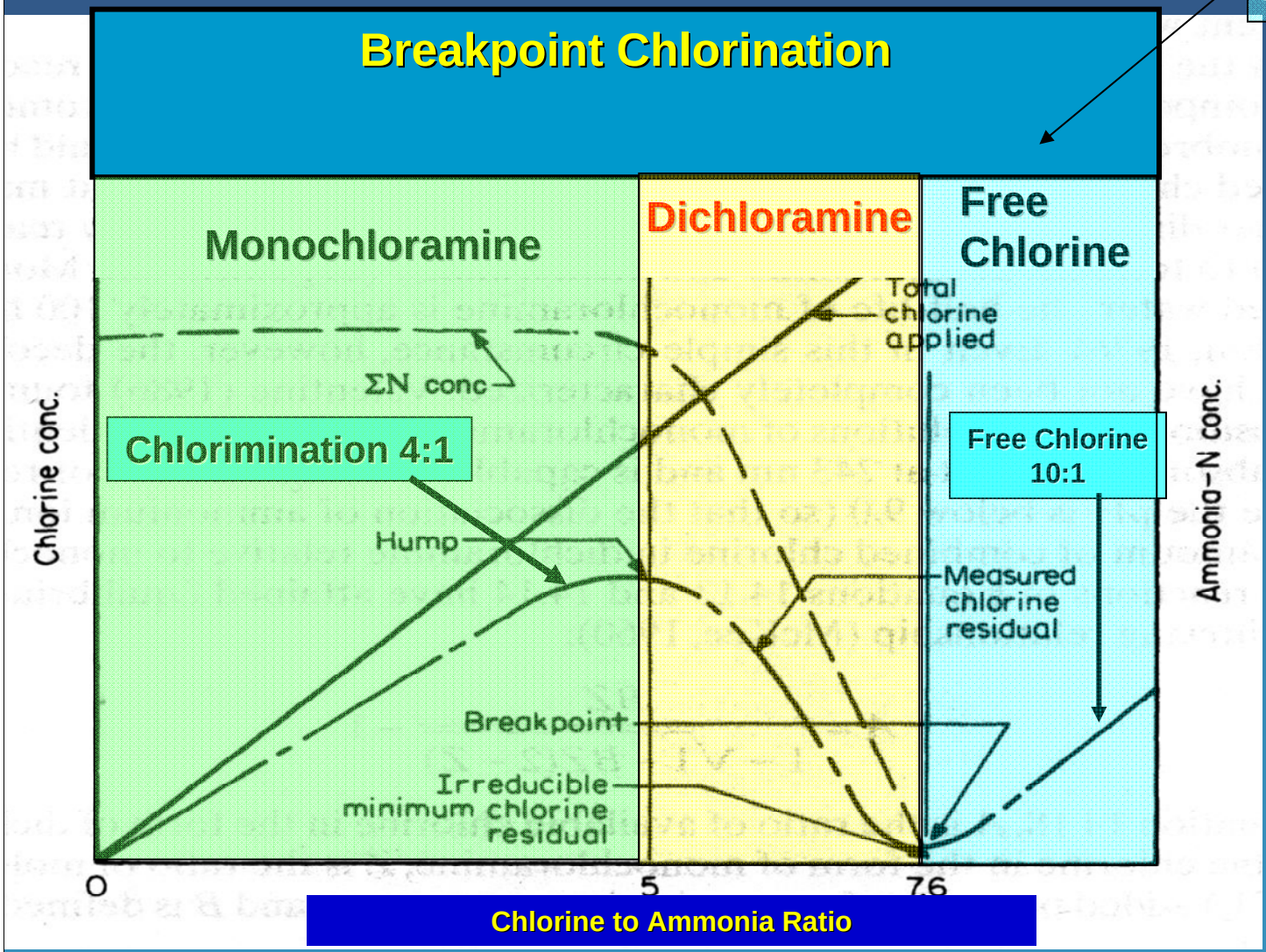
- Recommended Residual 0.25 mg/l to 0.5 mg/l free chlorine
- Chlorine Dosage will need to provide sufficient chlorine to develop target residual and satisfy chlorine demand in the water
- Chlorine Demand exerted by common Groundwater Compounds
  - Fe,Mn, H2S, TOC, Ammonia, Methane
- Consider Chlorine Demand Analysis Standard Methods: 2350A

Considerations in Disinfecting Groundwater

- Iron and Manganese: can cause Staining and Color Events
  - Pretreatment with Sequestering Agents/Removal
- Organic Carbon: Can cause DBPs
- Hydrogen Sulfide: Can be mitigated with Chlorine Oxidation
- Ammonia: Can result in Dichloramines
  - Breakpoint Chlorination

Occurrence of Ammonia in Groundwater could drive the need for Breakpoint Chlorination

HOCL most effective Germicidal Agent



Breakpoint Chlorine Dosage 10ppm to 1 ppm Ammonia by wt.

Insufficient dosage could result in formation of dichloramines which are distasteful

Hypochlorite Options and Engineering Considerations

- Concentration Sodium Hypochlorite (Bulk delivery)
- On Site Sodium Hypochlorite Generation
- Calcium Hypochlorite (Solid Form/Tablet System)

Concentrated Sodium Hypochlorite Disinfection – Chemical Considerations

Hypochlorite Concentration Conventions:

As Sold Trade Strength:

- Trade Strength Varies typically 12% to 15%
- Represented as Percent by Volume
- Concentration of Cl2 expressed as a percentage (%)
- Note 1% = 10,000 mg/l

Actual Concentration – To be used for Dosage and Storage Design

- Represented as the available Cl2 by weight.
- Actual Strength by Weight = Trade Strength/Specific Gravity

Example: Actual Chlorine Strength Calculation

Trade Strength 15%, at a SG = 1.25

- SG 1.25 results in bulk density = 10.4 lbs Solution/gallon

- Actual Cl_2 Strength by Wt = 15%/1.25 = 12%

- Available chlorine = 10.4 lb/gal x 12% = 1.25 lb Cl_2/ gal *

Actual available chlorine needs to be used in planning dosage and storage

Alternate Approach:

- Trade Strength X 0.08345 = Available Cl2 (#/gal)
  (Chlorination Handbook Clifford White)

Concentrated Sodium Hypochlorite Disinfection – Chemical Considerations

Hypochlorite Stability

- Degradation of Hypochlorite solution has been observed to degrade according to second order decay kinetics:

$$dC/dt = -kC^2$$

- Degradation Varies as a function of the square of concentration (strength) Hypochlorite.

Factors Effecting the Degradation of Sodium Hypochlorite

- Metals: Iron, Copper, Cobalt, Nickel (product quality)
- UV Light
- Temperature (< 70 Deg F)

Effects of Degradation and Storage Volume on Design Dose

15% Solution

Days	Loss	Conc	lb Cl_2/gal
0	0	15.0%	1.25
5	6%	14.1%	1.18
10	11%	13.4%	1.11
15	16%	12.6%	1.05
20	20%	12.0%	1.00
30	28%	10.8%	0.90

← For 2 Weeks of Storage or greater, use 1 lb/gal

Concentrated Hypochlorite Engineering Considerations

Storage considerations

- Smaller volumes such as short loads, totes have higher unit cost.
- Excessive stored product > 30 days could result in degradation
- Consider Spill containment volumes greater 50 gallon
- H-Occupancy Facility for volumes > 500 gallon.
- Tank Level readout or sight gauges at unloading stations
- Attacks Concrete: provide coatings
- Recommended Storage Tank Material:
    - FRP
    - HDXLPE with Oxidation Resistant Liner

Concentrated Hypochlorite Engineering Considerations

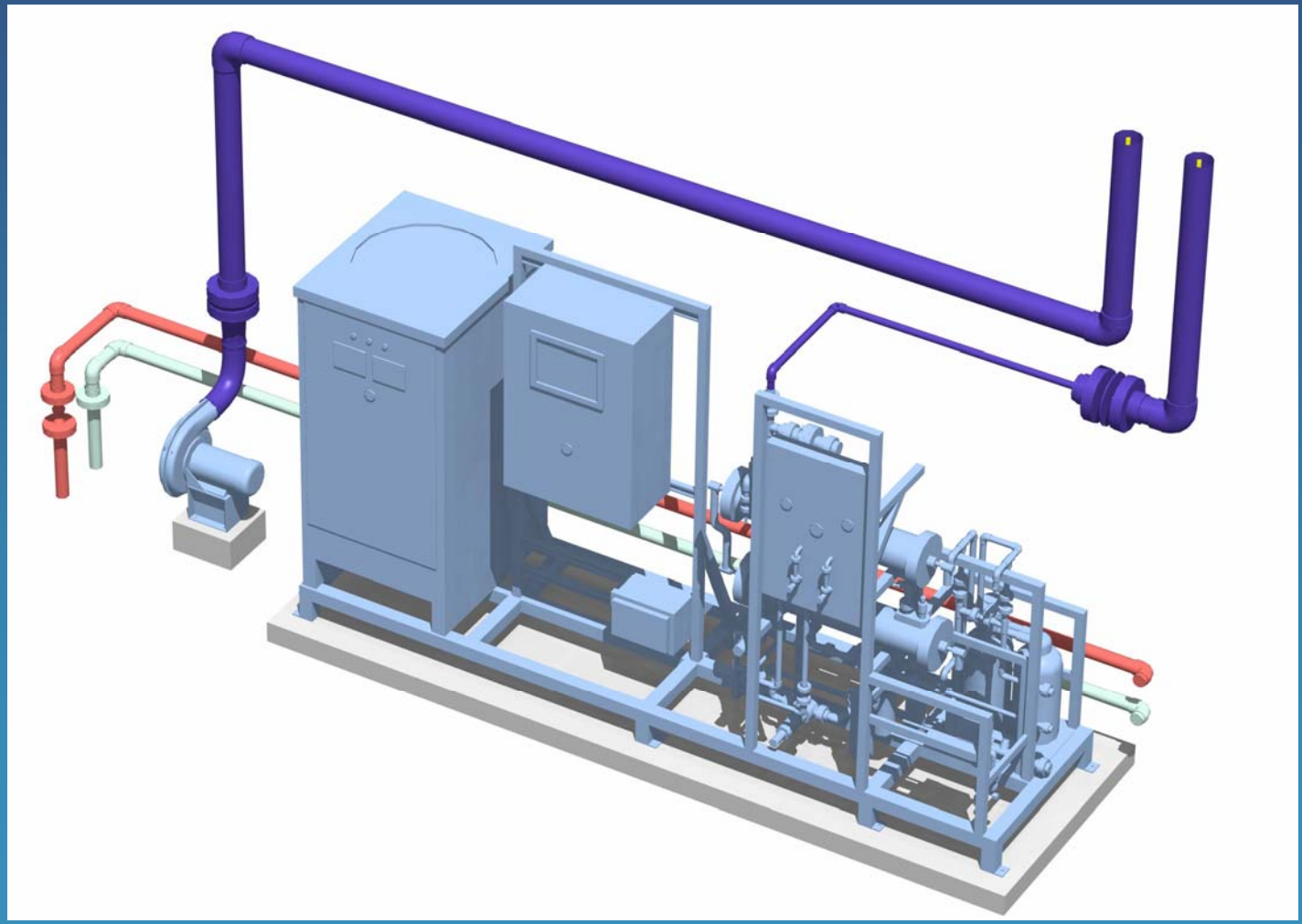
Pumping and Conveyance

- Provide Flooded suction for metering pumps
- Provide Metering pumps with Degassing feature
- Consider Flushing connection/carrier water for dilution with softened water for hard water applications
- Do not Isolate un-vented Pipe sections filled with hypochlorite
- Ball valves shall be Vented

Important Safety Considerations for Concentrated Hypochlorite

- Chemical Compatibility
  - Balance pH 11-12 depending on strength
  - Addition of chemicals ($FeCl_3$) that would depress of pH will result in Cl_2 gas release
  - Ammonia combined with Hypochlorite aggressively react form toxic NCl_3 gas
- Eyes - severe Irritation and burns can result in impairment to vision and damage to cornea
- Skin – Severe irritation and burns of epidermis
- Emergency Eye Wash Combination Shower often Required to mitigate injuries of exposure for outdoor exposure consider tempered water
- Spill Containment

Onsite Sodium Hypochlorite Generation (low strength – 0.8%)



Generation of Hypochlorite

Raw Materials Required

- Salt
- Water
- Electricity

Wallace Tiernan 25 ppd OSEC
for Beaverton ASR No. 4 Well

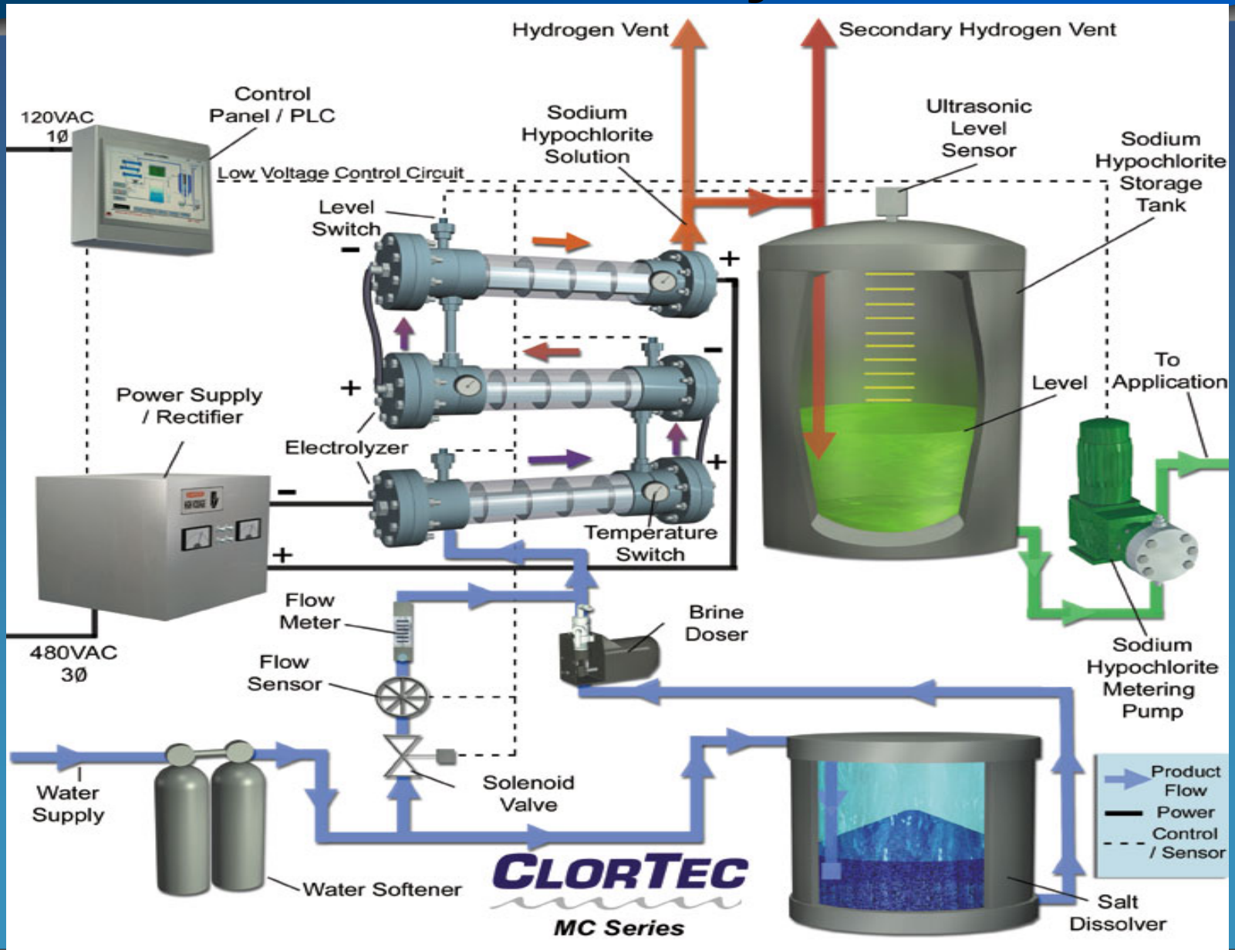
$$NaCl + H_2O + 2E \longrightarrow NaOCl + H_2\uparrow$$

3 lb + 15 gals. + 2.5 KwH ⟶ 15 Gals 0.8% Hypochlorite (1 # Cl2)
and Hydrogen gas

Benefits of Onsite Hypochlorite Generation

- Generates 0.8% Hypochlorite solution
  - Non Hazardous (no spill containment)
  - Easily to handle, does not have gas binding issues with concentrated hypochlorite
  - Safe product
  - stable hypochlorite solution that does not degrade
- More cost effective relative to life cycle costs
  - Smaller Carbon Footprint Not transporting the water within Hypochlorite

Major Elements of Onsite Hypochlorite Generation System



Onsite Hypochlorite Generation

Major Equipment Manufactures:

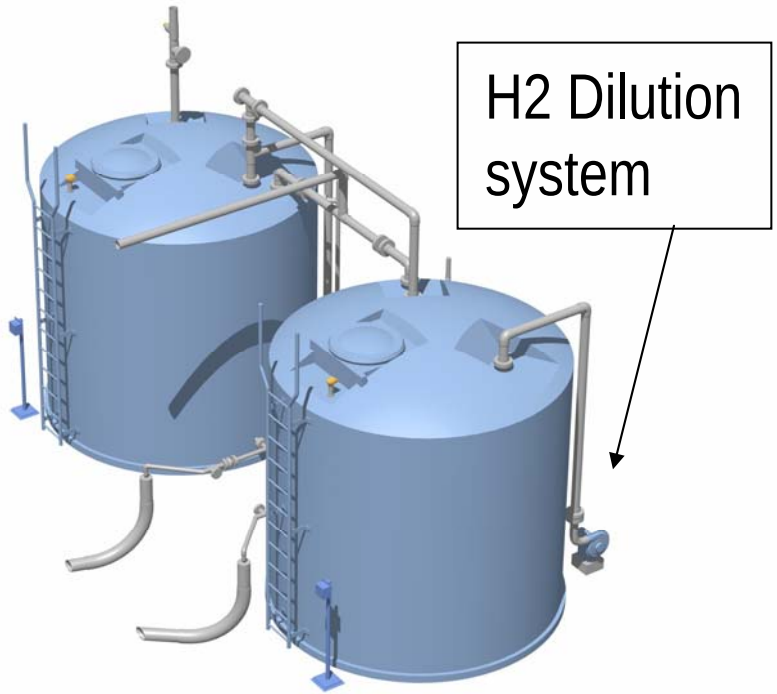
- Chlortec (Severn Trent)
- Wallace Tiernan OSEC System
- MIOX

Range of Equipment Size

- Smaller Systems 2-25 ppd.
- Medium Systems 25-150 ppd
- Large Systems 150 to 3000 ppd

Chlortec 225 ppd

Considerations for OSHG Systems



- Positive pressure Hydrogen Dilution System
- Provide relief diaphragms/valves for electrolytic cells
- Quality Make up water required
  - 10.1 gpm per 100 ppd
  - Softened
  - Free of iron and manganese
- Salt Storage Required (3 pounds Salt per Pound of Cl_2)
  - Small Systems: Pallets
  - Large Systems: Salt Silo

  Storage Day Tank Required (size for 2-4 days)
  - Larger Storage needed for Dilute Solution (approx. 1500 gal/100 pound Cl_2)
  - Consider having tank compatible with concentrated hypo in event generator failure.
- Increased Electrical Load for the site

Calcium Hypochlorite – Tablet System

- Typically used for Small System Applications
- Low capital cost approach
- Higher chemical Costs
- Process consists of dissolving Solid Calcium Hypochlorite tablets in erosion chamber for generation of hypochlorite solution
- Calcium Hypochlorite classified as strong oxidizer and reactive – May require Hazardous Occupancy for Storage

SUMMARY

- Disinfection remains a cornerstone barrier for public health in Drinking Water Industry
- Consider Unique Groundwater Chemistry in planning disinfection approach
- Consider options available for hypochlorite disinfection especially safety and life cycle costs
- Understand and respect unique hazards of hypochlorite
- The right choice depends on each utility's needs

Thank You – Questions ?

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