

Sodium Hypochlorite and Chlorine Gas: Design, Handling, and Storage Issues

Presented By:
Water Treatment Practices Committee
AWWA Michigan Section
Spring Regionals - 2006

Overview

- Individual Look at Both Chemicals
 - Chemical Properties
 - Materials for Handling
 - Storage
 - Cost
 - Safety
- Some Comparisons
- Safety is Important, but Not the Main Focus of This Presentation

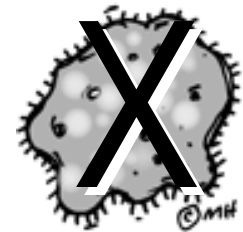
Chlorine - Beneficial Uses

- **Automotive**
 - Foam Seating
 - Paints
 - Plastic Bumpers
 - Molding Instruments
 - Floor Mats
 - Fabric
 - Seat Belts
 - Tire Cords
 - Dashboards
 - Hoses
- **Construction**
 - Carpeting
 - Upholstery
 - Wire Insulation
 - Pipes
 - Siding
 - Flooring
 - Paints
 - Coatings
- **Defense**
 - Bullet-Proof Vests
 - Helmets
 - Parachutes
 - Water Repellant Fibers
 - Shatter-Resistant Glass
 - Titanium Aircraft
 - Jet Engines
 - Missiles
- **Electronics**
 - Semiconductors
 - Computer Disks
 - Wire Insulation
- **Food Production & Handling**
 - Herbicides
 - Vitamins B1 & B6
 - Cleaners
 - Disinfectants
 - Thermal Insulation
 - Sterile Packaging
- **Health Care**
 - Electronic Instruments
 - Sterile Packaging
 - Surgical Equipment
 - Cleaning Compounds
 - Prescription Eye Wear
 - Laboratory Reagents
 - Antibiotics
- **Pulp and Paper**
- **Medicines**
 - Cancer Treatment
 - Pain Relievers
 - Local Anesthetics
 - Antihistamines
 - Decongestants
- **Metal Production**
 - Magnesium
 - Nickel
 - Bismuth
 - Titanium
 - Zirconium
 - Zinc
- **Outdoor Recreation**
 - Neoprene Wet Suits
 - Inflatable Rafts
 - Golf Grip
 - Surf Boards
 - Nylon Ropes
 - Tents
 - Sleeping Bags
 - Coats
 - Backpacks
 - Waterproof Clothing
- **Water Treatment**
 - Safe Drinking Water
 - Wastewater Treatment

Chlorine = Disinfection

Primary use of Chlorine is for the
Manufacture of Plastics

But, in the U.S. Water Industry,
Chlorine is the Primary Disinfectant



Common Forms Used in Water
Treatment are Chlorine Gas and Liquid
Sodium Hypochlorite (Bleach)

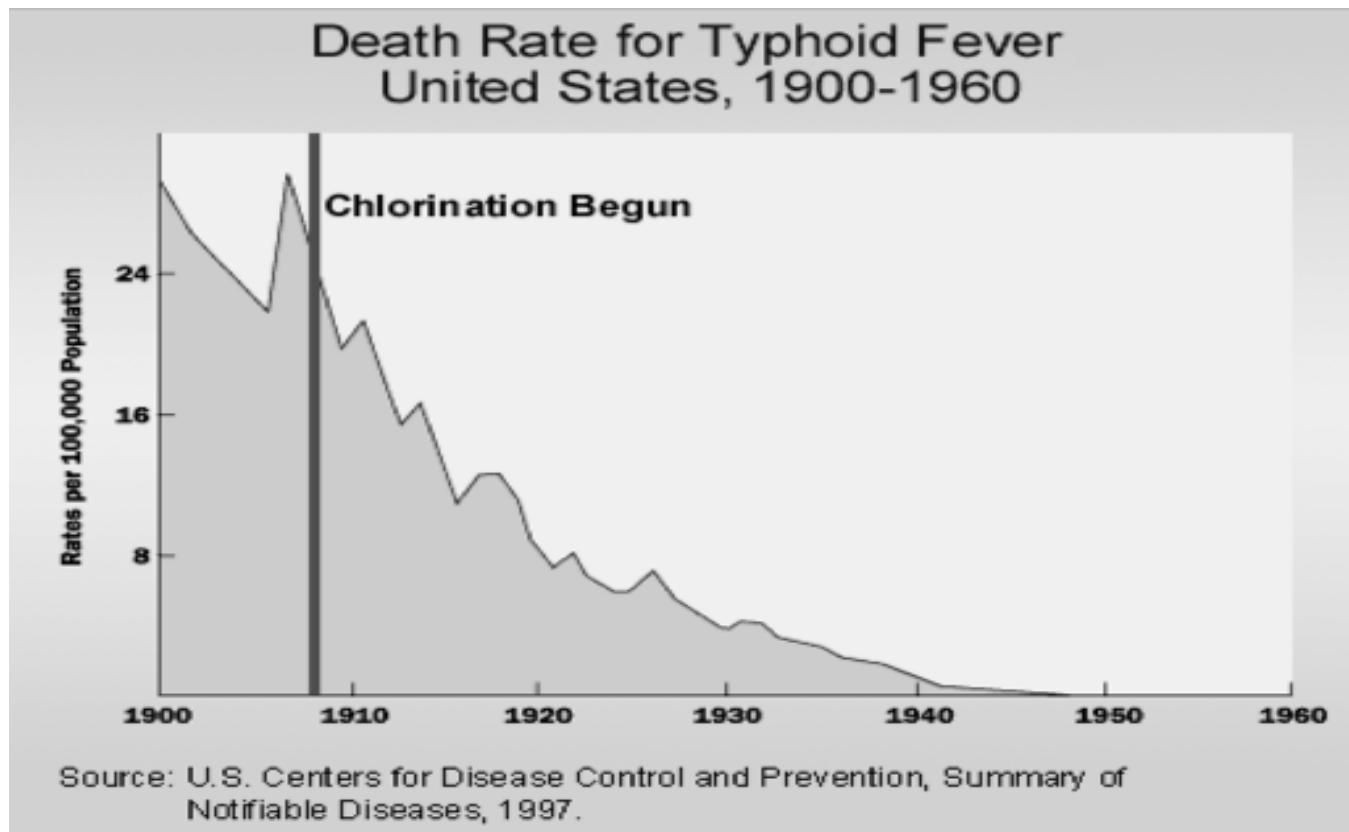
Disinfection & Filtration

Disinfection

- Essential part of water treatment
- *Crypto* resists traditional disinfectants

Filtration

- Most surface water systems filter
- Physical process can remove *Crypto*
- Disinfection still necessary



Chlorine/Sodium Hypochlorite Use in Michigan

- **Approximately 540 Public Water Systems Add "Chlorine"**
- **90 Use Chlorine Gas**
- **450 Use Sodium Hypochlorite**

Chlorine Gas

MSDS Facts

- **Chemical Formula: Cl₂**
- **Boiling Point: -29.4°F**
- **Freezing Point: -150°F**
- **Appearance:**
 - Gas is Greenish in Color**
 - Has Strong, Pungent Odor**
- **"Dry" Cl₂ is non-corrosive**
- **"Wet" is highly corrosive to metals**
(Wet Cl₂ has >150 ppm water)
- **Chlorine + Water = ACID**

More Chlorine Gas MSDS

- **Heavier than air**
- **Specific Volume: 1 lb = 4.99 cubic ft**
(150 lb cylinder can fill a 10 ft x 10 ft x 7.5 ft room with 100% Cl₂ gas, displacing all the air)
- **pH: Acidic**
- **Non Combustible, but Supports Combustion**
- **Reacts Violently with Many Chemicals**

More Chlorine Gas MSDS

ACUTE HEALTH EFFECTS: CHLORINE IS A POTENT IRRITANT TO THE MUCOUS MEMBRANES OF THE EYES, NOSE AND THROAT, AND TO THE LININGS OF THE ENTIRE RESPIRATORY TRACT. THE EXTENT OF INJURY DEPENDS UPON CONCENTRATION AND DURATION OF EXPOSURE. DEATH MAY OCCUR UNDER SEVERE EXPOSURE. IN HIGH CONCENTRATIONS, CHLORINE MAY CAUSE SKIN IRRITATION, WITH SENSATIONS OF BURNING AND PRICKLING, INFLAMMATION AND BLISTER FORMATION. LIQUID CHLORINE MAY CAUSE SERIOUS DIRECT AND EYE BURNS ON CONTACT.

CHRONIC HEALTH EFFECTS: CHRONIC EXPOSURE TO CHLORINE GAS CAN CAUSE CORROSION OF THE TEETH, DISEASES OF THE LUNG, AND MAY PREDISPOSE THE INDIVIDUAL TO LUNG INFECTIONS, INCLUDING TUBERCULOSIS.

INHALATION: MAY CAUSE SEVERE IRRITATION TO THE RESPIRATORY TRACT FOLLOWED BY COUGHING, BURNING, CHEST PAIN, VOMITING, HEADACHE, ANXIETY AND FEELING OF SUFFOCATION. SEVERE EXPOSURE MAY CAUSE PNEUMONITIS AND PULMONARY EDEMA. REPEATED EXPOSURE TO CHLORINE MAY RESULT IN REDUCED PULMONARY CAPACITY AND DENTAL EROSION.

DIRECT CONTACT: MAY CAUSE BURNS, BLISTERING AND TISSUE DESTRUCTION

EYE CONTACT: LIQUID AND OR HIGH CONCENTRATIONS OF CHLORINE GAS IN CONTACT WITH THE EYES WILL CAUSE EXTREME IRRITATION AND OR BURNS

Chlorine Feed System

Key Design Considerations

- **Current General Design Practice is to Have Gas Under Vacuum to Carrier Water Stream**
- **Carrier Water Flow Through Eductor, Opens Vacuum Regulator Allowing Gas Flow**



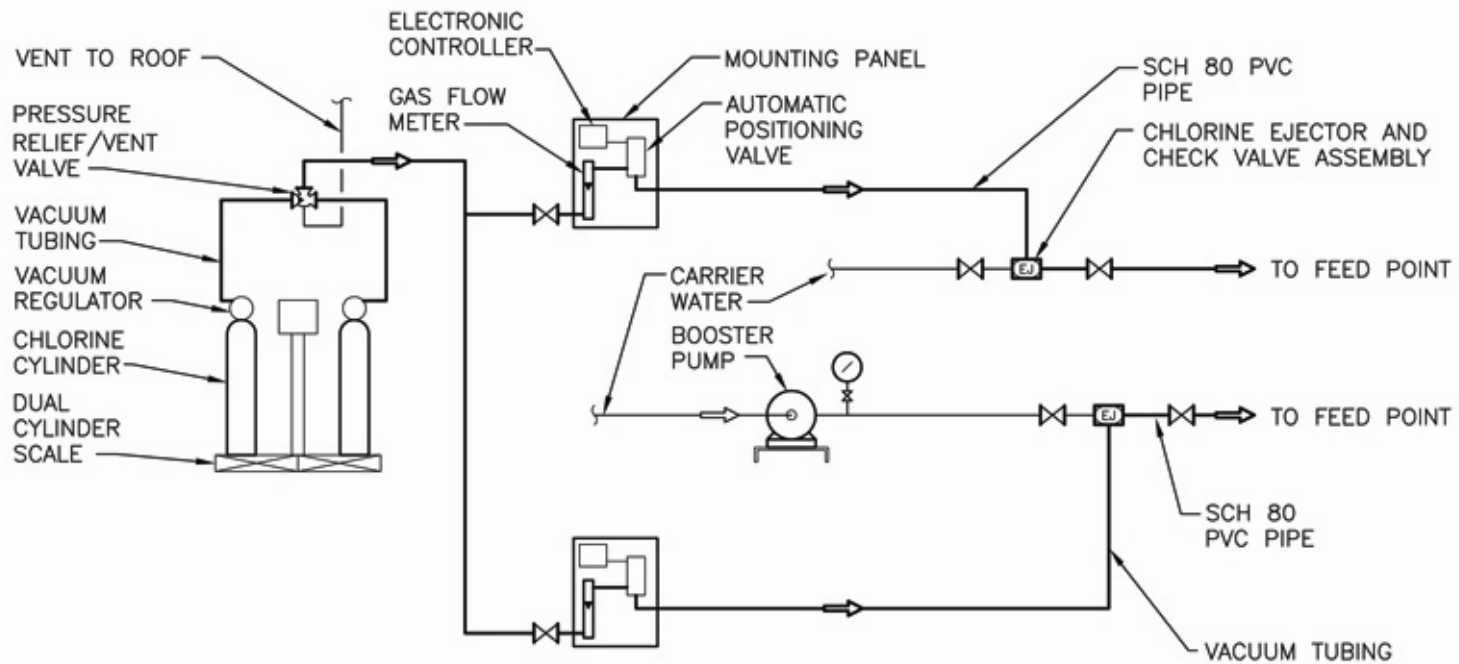
Chlorine Feed System

Key Design Considerations

- **Some Large Installations Use Pressure Manifolds**
- **Some Very Large Installations Use Liquid Chlorine Evaporators for High Withdrawal Requirements (1,000s of lbs/day)**



Gas Chlorine Feed Schematic



GAS CHLORINE FEED SYSTEM
NO SCALE

Gas Chlorine Feed System

Key Design Considerations

- **May Need Booster Pumping for Proper Injection Pressure**
- **Gas Withdrawal Rate from Cylinder is Limited at Standard Temp., Pres.**
 - 70 lbs/24 hrs for 150 lb cylinders
 - 560 lbs/24 hrs for ton cylinders
 - Any Faster and Freezing Will Occur

Gas Chlorine Feed System

Key Design Considerations

- **Schedule 80 PVC Piping is Good Choice for Chlorine Solution (Solvent Welded)**
- **Other Compatible Materials**
 - PVDF - Polyvinylidene Fluoride
 - PTFE - Polytetrafluoroethylene (Teflon)
 - CPVC - Chlorinated Polyvinylchloride
 - Titanium (for component hardware)
 - 316L Stainless Steel
- **Piping Identification:**
 - Color - Yellow
 - Labels
 - Flow Arrows

Gas Chlorine Feed System

Key Design Considerations

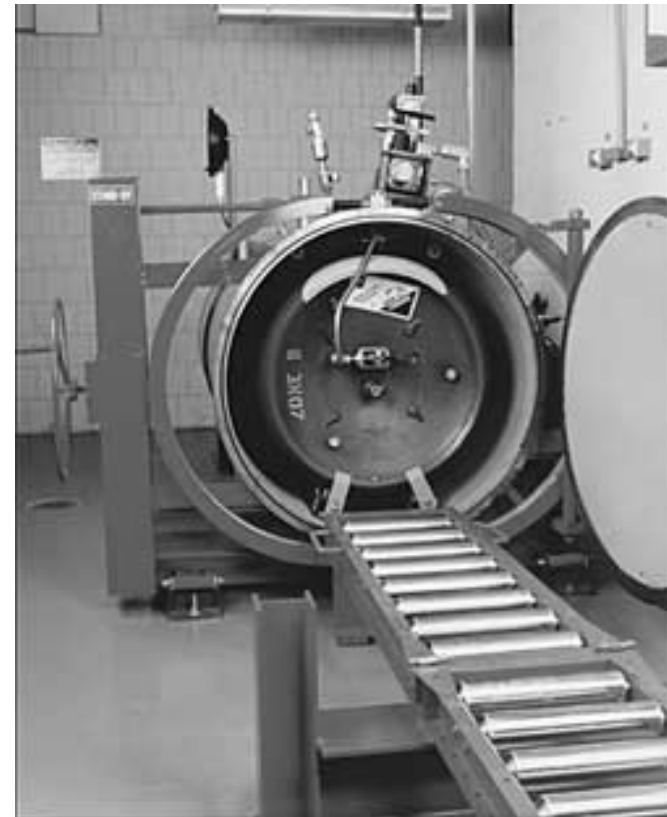
- **Entrance to Chlorine Room From Exterior Only**
- **Viewing Window to Room Required in Interior Space**
 - Gas detector and scale readouts
- **HVAC**
 - Intake Duct Near Floor (Gas is Heavier than Air)
 - Exhaust Discharge **AWAY** From Entrance
 - Chlorine Gas Monitoring Required

Chlorine Gas Regulatory Considerations

- **Clean Air Act Section 112(r):
Prevention of Accidental Releases**
 - Over 2,500 lb Threshold Quantity Requires a Risk Management Plan (RMP)
- **SARA Title III (Emergency Planning and Community Right-to-Know Act)**
 - **Threshold Planning Quantity: 100 lbs**
 - Notify State Emergency Response Commission and Local Emergency Planning Committee

Gas Chlorine Accident Prevention

- **Containment**
 - Available for Ton Cylinders and 150 lb Cylinders
 - Automatic Cylinder Shut Off Valves
- **Scrubbers**
 - Wet Type
 - Dry Type



Gas Chlorine Feed System Storage Considerations

- **Keep Cylinders “Cool”**
 - **Pressure Relief Plugs Melt at 158°F**
- **Store Above Ground in Dry Area**
- **Secure Cylinders from Movement**
- **Active Cylinders on Scale to Monitor Use**

Sodium Hypochlorite

MSDS Facts

- **Chemical Formula: NaOCl**
- **Commercially Available:**
Typically 10% - 15% by Wt.
- **Often Referred to as "Bleach", but is Much Stronger than the Household Variety**
- **pH = 11 – 13**
- **Freezing Point: -11°F @ 12.5%**
- **Boiling Point: >212°F @ 12.5%**

More Sodium Hypochlorite MSDS

- **Specific Gravity: ~ 1.2**
- **Bulk Density: ~ 9.8 lb/gal**
- **Solubility in Water: Complete**
- **Appearance:**
 - Yellow Colored Liquid**
 - Chlorine Odor**
- **Corrosive**

More Sodium Hypochlorite MSDS

Health Hazards Acute & Chronic:

SKIN:MAY CAUSE SEVERE IRRITATION &/OR BURNS. PROLONGED EXPOSURE MAY CAUSE DESTRUCTION OF THE DERMIS W/ IMPAIRMENT OF THE SKIN. BURNS MAY NOT BE IMMEDIATELY APPARENT. EYES:SEVERE IRRITATION &/OR BURNS CAN OCCUR. CONTACT MAY CAUSE IMPAIRMENT OF VISION & CORNEAL DAMAGE.

INHALATION:IRRITATING TO NOSE, MOUTH, THROAT, & LUNGS. MAY CAUSE BURNS TO THE RESP. TRACT W/ THE PRODUCTION OF LUNG EDEMA. INHALATION OF HIGH CONC. OF MIST CAN RESULT IN PERM. LUNG DAMAGE.

INGESTION:IRRITATION &/OR BURNS CAN OCCUR TO THE ENTIRE GASTROINTESTINAL TRACT. CHRONIC: MAY CAUSE LUNG DAMAGE, TISSUE DESTRUCTION, & EYE BURNS. MAY ACT AS A SENSITIZER.

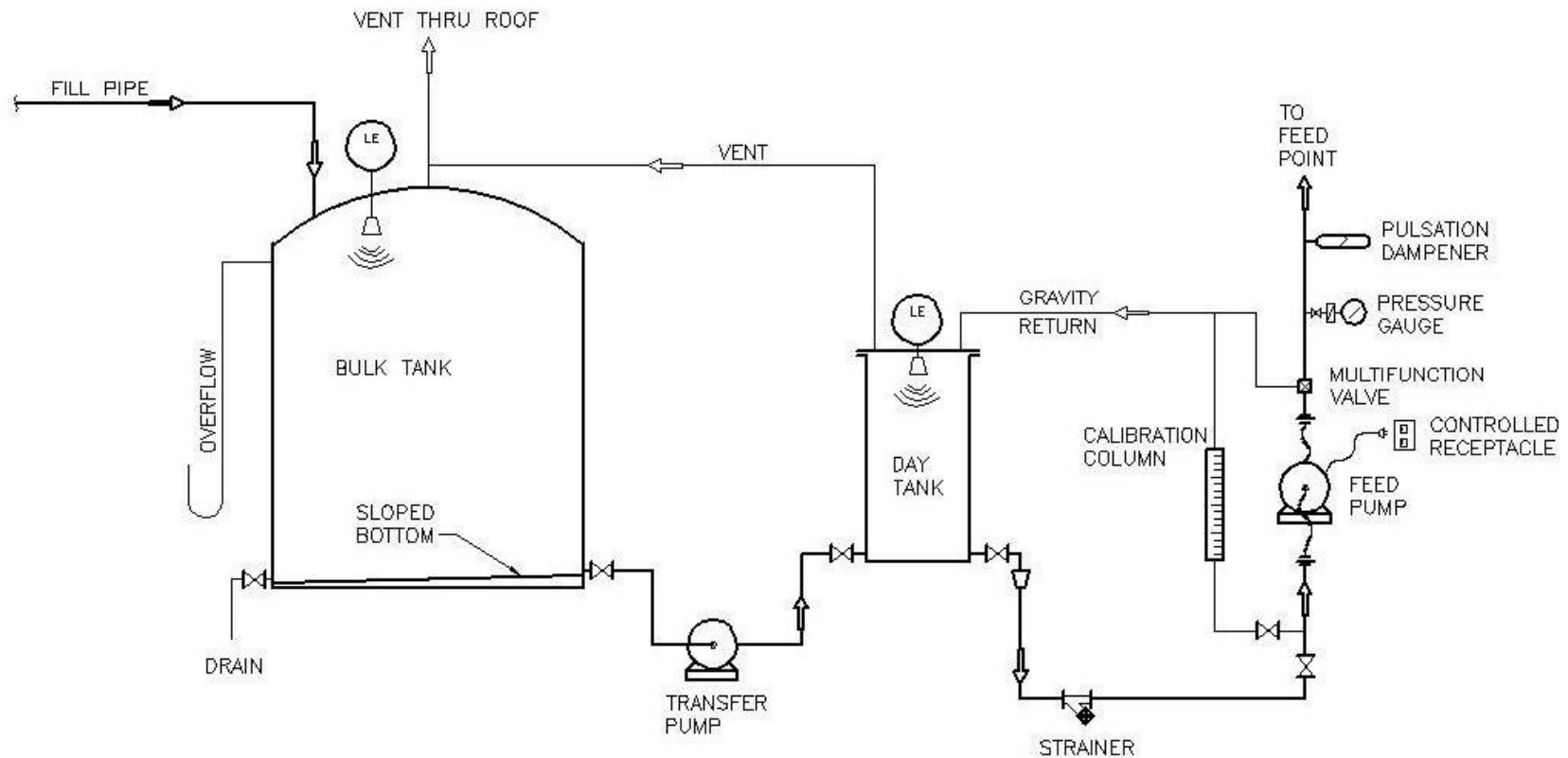
Signs & Symptoms of Overexposure:

SKIN: REDNESS, SWELLING AND SCAB FORMATION. EYES: SEVERE IRRITATION.

INHALATION: SHORTNESS OF BREATH, WHEEZING, CHOKING, CHEST PAIN.

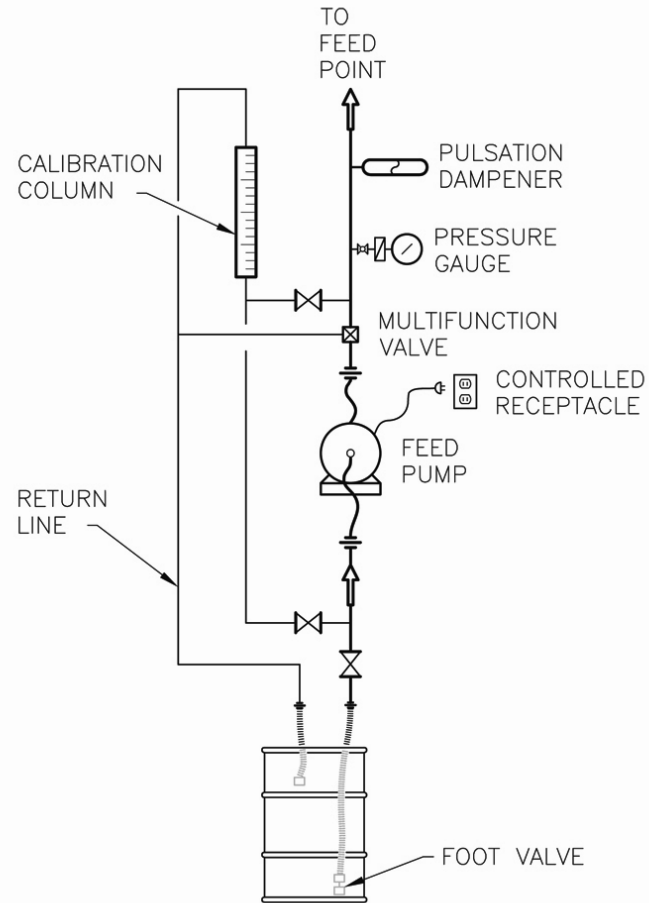
INGESTION:NAUSEA, VOMITING, DIARRHEA, ABDOMINAL PAIN, BLEEDING AND/OR TISSUE ULCERATION.

Sodium Hypochlorite Feed Schematic Bulk System



SODIUM HYPOCHLORITE FEED SYSTEM - BULK
NO SCALE

Sodium Hypochlorite Feed Schematic



SODIUM HYPOCHLORITE FEED SYSTEM - DRUM
NO SCALE

NaOCl Feed System

Key Design Considerations



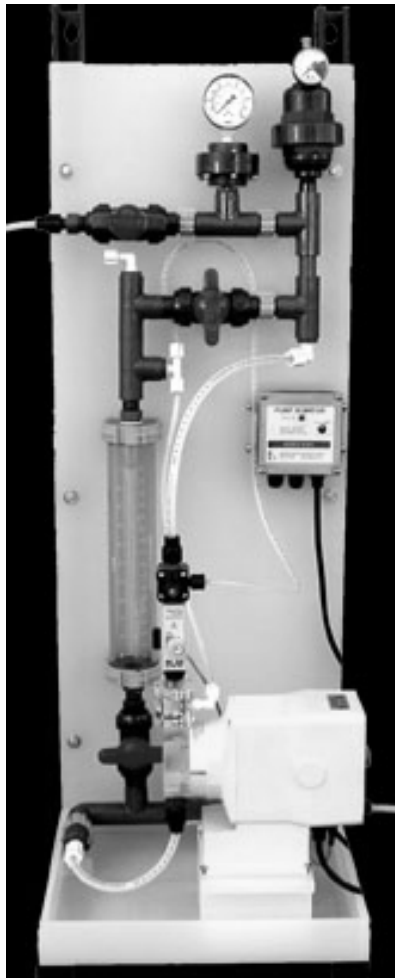
- **Peristaltic Pumps are a Good Choice for Pumping Sodium Hypochlorite**

- **Smooth Delivery of Chemical**
- **No Wetted Parts**
- **Less Concern with Offgasing**
- **Need to Change Tubing Frequently to Assure Consistent Chemical Delivery**



NaOCl Feed System

Key Design Considerations



- **Motor Driven or Solenoid Driven Diaphragm Pumps**
 - Common, Proven
 - Need Pulsation Dampening
- **May be More Concern with Offgasing**
- **4-Way Function Valves**



NaOCl Feed System

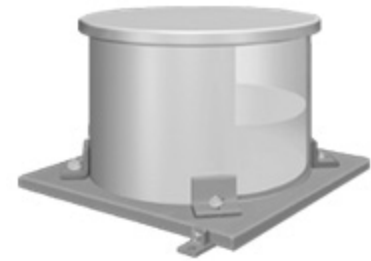
Key Design Considerations

- **Storage Tank Material:**

- **Fiberglass Reinforced Plastic (FRP)**
- **Cross-Linked Polyethylene**
 - Limited in Design Flexibility

- **Bulk Tanks (FRP):**

- **Properly Sized Vent for Truck Unloading**
 - **Side Manway or No Side Manway?**
 - **Slope Bottom for Positive Drainage for Cleaning**
- **Load Cells or Level Measurement to Track Usage and Inventory**



NaOCl Feed System

Key Design Considerations

- **Schedule 80 PVC is Good Choice for Piping and Valves**
- **Diaphragm Valves are Recommended; True Union PVC Ball Valves are a Lower Cost Alternative**
- **Piping Identification:**
 - **Color - Yellow**
 - **Labels**
 - **Flow Arrows**

NaOCl Feed System

Key Design Considerations

- **Secondary Containment - 100% of Largest Container Stored in Area**
 - (6,000 gal tank = 16 ft x 16 ft x 3 ft)
 - 330 gal. tote = (10 ft x 10 ft x ½ ft)
 - 55 gal. drum = (4 ft x 4 ft x ½ ft)
- **Consider Need for Secondary Containment for Outdoor Chemical Unloading Areas**

NaOCl Feed System

Key Design Considerations

- **Storage Volume: 30 Days Plus Delivery Is Common**
- **Product Degradation:**
 - **12.5% NaOCl May Degrade To 10% In 6 to 8 Weeks, Then Degradation Rate Slows**
 - **Can Dilute Product Upon Delivery To Less Than 10% If Adequate Storage Available; Adjust pH To 11 - 13**
- **Store Chemical in a Cool, Dark Area to Minimize Degradation**

Other Considerations

- **Want to Get “Fresh” Chemical From Suppliers to Maximize Shelf Life**
- **AWWA has a Specification for NaOCl**
- **Need To Consider Chemical Strength When Setting Dose**
- **Laboratory Testing Procedures And Test Kits (HACH) Available To Verify And Monitor Chemical Strength**

Other Considerations

- **HACH Test Kit: Hypochlorite, Model CN-HRDT, 100 Tests, Digital Titration**
 - Good for 5% to 15% solution
 - Test Kit: \$181 for 100 tests
 - Digital Titrator: \$112 one time purchase



Maintenance Considerations

- **Common Problem with NaOCl Systems is Offgasing**
- **Vinegar Soak to Clean Assemblies**
- **May need softened Water for Carrier Water to Avoid Scaling**
- **Can also Add Phosphate to Prevent Scaling**

Bulk Chemical Delivery

- **Make Sure Fill Nozzles are Clearly Identified**
- **Bulk lines need to be locked or otherwise secured**
- **Shut off Valve Down Stream of the Fill Point**
- **An Operator Should Be Present Whenever a Tanker is Downloading**



Gas Chlorine Costs

1 Ton Cylinder \$0.36/lb Cl₂

150 lb Cylinder \$1.01/lb Cl₂

Notes:

Includes freight

Prices are for 2 – 5 cylinders

The more you buy, the less per lb

Prices do not including cylinder deposit

Sodium Hypochlorite Costs

Bulk	\$0.70/gal (+ freight)
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330 gal totes, 55 gal drums	\$1.40/gal
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Notes:

Bulk = >1,000 gallons

Freight typically varies from \$500 to \$1,500

The more you buy, the lower the cost per gallon

1 gal 12.5% NaOCl solution contains ~ 1 lb Chlorine

Cost Comparison

Cost to feed 1 mg/L to 1 million gallons:

$$1 \text{ mg/L} \times 1 \text{ MG} \times 8.34 = 8.34 \text{ lb/MG}$$

12.5% NaOCl: = 8.34 gal @ \$0.85/gal (w/freight)
(bulk) = \$ 7.09/MG

12.5% NaOCl: = 8.34 gal @ \$1.40/gal (w/freight)
(drums) = \$ 11.68/MG

Gas Cl₂ = 8.34 lb @ \$0.36/lb
(ton cyl.) = \$ 3.00/MG

Gas Cl₂ = 8.34 lb @ \$1.01/lb
(150# cyl.) = \$ 8.42/MG

Summary

- **Gas Chlorine And Sodium Hypochlorite Are Critical To A Safe Water Supply**
- **Both Have Advantages and Disadvantages Regarding Safety, Cost, and Operations**
- **Use of Sodium Hypochlorite Simplifies Regulatory Compliance, But is NOT Without Safety Hazards**
- **Good Design Practices and Good Operational Practices Assure Effective Treatment and Minimize Safety Risks**

Special Thanks to

Alexander Chemical Corporation

References:

- ❖ 10 States' Standards
- ❖ Chlorine Institute
- ❖ Alexander Chemical Corp.
- ❖ Powell Fabrication and Manuf.
- ❖ US Filter
- ❖ Chemical Injection Technologies
- ❖ LMI Pumps
- ❖ Force Flow
- ❖ Hach
- ❖ Watson Marlow
- ❖ Scaleton

Water Treatment Practices Committee Gimmicks and Gadgets Contest

- ❖ Entries are due by June 1, 2006
- ❖ You can e-mail (preferred), US Mail or fax your entry:
 - ❖ email: wtpcomm@mi-water.org
 - ❖ mail: Water Treatment Practices Committee
 c/o Michigan Section AWWA
 PO Box 16337
 Lansing, MI 48901-6337
 - ❖ fax: (616) 942-5787

Questions and Comments...

Water Treatment Practices Committee
AWWA - Michigan Section