The ABC’s of OSG
(On-Site Generation of Hypochlorite and Chlorine Gas)
TACWA Business Meeting
Fort Worth, Texas
November 18, 2011

Gary W. Bors, P.E.
Vice President, Technical Director

Tina Hanson, P.E.
Senior Associate, Texas Manager
Outline

- Current practices
- Alternative methodologies
- Buy it or make it?

- On-site technologies
- Design considerations
- Green initiatives
Typical CL$_2$ based disinfectants in use


AWWA reports migration away from gas with 81% surveyed selecting bulk
Stored gaseous chlorine concerns

DHS: Chlorine gas transport and storage is a growing concern
Why replace stored gaseous chlorine?

- Historical disinfectant of choice
  - Low Capital Cost
  - Low O&M Cost
- Highly toxic – direct exposure can be fatal
- Risks to community and workers
- Post-911 transport and storage security concerns

Technology advances provide lower risk alternatives
Considering the options

Many utilities are currently evaluating alternative disinfectants to address security concerns.
Alternative methodologies

- Continue use of gaseous chlorine **HIGH RISK / SECURITY**
- Purchase commercial 12% liquid sodium hypochlorite (a/k/a bleach)
- On-site generation
  - $\text{CL}_2$ gas on demand
  - 12% sodium hypochlorite
  - 0.8% sodium hypochlorite

On-site generation (OSG)

Bleach delivery (12% hypo.)
Alternatives to CL₂ pose less risk ..... But proper safeguards are still essential

12% liquid sodium hypochlorite

On-site generation

Liquid transport / spills

Hydrogen gas by-product
Buy disinfectant or make it?

Delivery

Storage

Treatment

Feed
Commercial sodium hypochlorite

- Purchased sodium hypochlorite solution (12 – 15%)
  - Higher operating cost
    - $0.65 to $1.25 per gallon (1 gallon = 1 lb CL₂)
  - Stability
    - Off-gassing (difficult to pump)
    - Degradation (loss of available chlorine)
    - Chlorate formation
  - Safety
    - Concentrated solution presents risks
- Lowest capital costs
- Market factors influence purchase price
Commercial bleach vs. on-site type systems

Assessment must consider local market drivers and existing utility fixed assets.
On-site systems and technologies

- On-site Chlorine Gas Generation (OSCG)
- On-site Sodium Hypochlorite Generation (OSHG)

50 ppd Uniclor OSHG System - 1988

1,500 ppd Klorigen OSCG System - 2004
On-site technologies continue to evolve

- Hybrid gas/hypochlorite/caustic systems
- Open-cell 0.8% systems
- Closed-cell 0.8% systems
On-site chlorine gas generation (OSCG)

- Electro-chemical process
- Municipal market:
  - Klorigen / Electrolytic Technologies Corporation
  - Conve – AVS Corporation
- Chlorine gas on demand
- Dilute liquid caustic and hydrogen gas by-products
- Hybrid option

Hybrid:
Gas + caustic = 12% hypo.
Chlor-alkali (electro-chemical) process

- **Chlorine gas production:**
  
  Salt + water + power $\rightarrow$ chlorine + sodium + hydrogen gas + hydroxide

  $\text{2NaCl + 2H}_2\text{O + power} \rightarrow \text{Cl}_2 + 2\text{NaOH + H}_2$

- **Sodium hypochlorite production:**
  
  Chlorine + sodium $\rightarrow$ sodium hypo + salt + water + hydroxide

  $\text{Cl}_2 + 2\text{NaOH (15%)} \rightarrow \text{NaOCl (12%)} + \text{NaCl + H}_2\text{O}$
CL\textsubscript{2} generation produces caustic by-product

A hybrid gas/liquid approach can prove beneficial
Membrane – electrolyzer plate assembly

- Modular “sandwich”
  - Anode
  - Membrane
  - Cathode

- Membrane isolates process
  - Brine & chlorine gas
  - Membrane
  - Caustic & hydrogen gas
OSCG - System efficiencies

- Typical membrane-electrolyzer skid efficiency
  - Power consumption = 2.0 – 2.2 kWh / lb Cl₂
  - Salt consumption = 1.8 – 2.0 lb salt / lb Cl₂

- Variables affecting skid efficiency:
  - Brine strength
  - Brine pretreatment / brine softening
  - Anode coating life
  - Membrane wear (punctures)
  - Mineral deposits
  - Proper water supply pretreatment
  - Salt – NSF 60 certified, high quality, food grade
OSCG ...... behind the scenes

- Brine pretreatment – membrane protection
- Brine softening – ion exchange
- Acid storage & feed – pH control
- Caustic storage & feed – pH control
- Depleted brine Cl\(_2\) stripper
- Sodium bisulfite – brine dechlorination
- Hypochlorite conversion (hybrid systems)
- “Wet” chlorine gas solution feed system
- Hot process – cooling tower
- Hydrogen – air / nitrogen purge system
City of Baltimore
Back River WWTP

- Back River WWTP:
  - 180 mgd AADF
  - 270 mgd MDF
  - 10 -15,000 ppd of bulk hypochlorite consumed

- Bulk costs rose to over $ 1.05/lb. (gal.) by the mid-2000’s
Baltimore considers hybrid OSCG facility

- H&S and staff considered all on-site technologies
- Conducted site visits to representative systems of each type and manufacture
- Selected hybrid on-site chlorine/caustic/hypochlorite technology
- 60% facility design documents prepared
Equipment procurement

- Equipment technical specifications and system pre-purchase documents issued
- Potential bidders:
  - Electrolytic Technologies Corporation
  - Conve – AVS Corporation (De Nora, S.A)
One bid received (Electrolytic Technologies Corp.)
- $8.86 million (equipment & 2 year warranty)
- $1.92 million (2 years O&M services)

Bid exceeds vendor’s “budget quote” by 73%

Economic Conditions Change
- Available capital resources shrink
- Area bulk costs plummet to below $0.60/gal.
- City re-negotiates 5 year bulk hypochlorite contract

September, 2009 – project placed on-hold
OSCG system summary

Pro’s:
- Generates chlorine gas on demand
- No appreciable gas volume is contained on site
- Hybrid option provides liquid hypo. for backup

Con’s:
- Numerous auxiliary systems & chemicals
- Highly complex process
- Limited municipal installation base & maintenance history
On-site hypochlorite generation (OSHG)

- Severn Trent: CLORTEC
- Siemens: OSEC
- Process Solutions, Inc.: MicroOclor
- Miox (Now Parkson)
A typical electrolyzer cell

- Multiple titanium anode / cathode plates
- Bi-polar & mono-polar plate designs
- Anode plates are coated to produce \( \text{CL}_2 \) instead of \( \text{O}_2 \)
- **Vendors typically state replacement after 7–10 years of service**
- **Users report actual replacement after 2-3 years**

\[ \text{NaCl} + \text{H}_2\text{O} \rightarrow \text{H}_2(\text{g}) + \text{NaOCl(aq)} \]
Two basic cell configurations

- Horizontal tubes with vertical plates (closed cells)
- Rectangular cassettes with vertical plates (open cells)
OSHG – System efficiencies

- Typical electrolyzer skid efficiency
  - Power consumption = 2.0 – 2.2 kWh / lb Cl₂
  - Salt consumption = 2.6 – 3.0 lb salt / lb Cl₂

- Variables affecting electrolyzer skid efficiency:
  - Water temperature (50° < TEMP < 85 °F)
  - Brine concentration
  - Anode coating life
  - Mineral deposits

- Proper water supply pretreatment
- Salt quality – NSF 60 certified solar salt
OSHG – System summary

Pro’s:
- Dilute hypochlorite solution reduces handling risks
- Hydrogen gas by product can be hazardous
- Dilute hypochlorite product is stable …. long shelf life
- Relatively simple, constant rate, batch process
- Open cell designs freely vent hydrogen off gas

Con’s:
- Two-phase hydrogen gas/liquid product handling
- Mineral build-up on plates & safety devices
- Past closed cell electrolyzer system designs have over-pressurized
- Maintenance & plate replacement – an issue
All systems contain elements of risk

- High strength chemical handling
- Chlorine gas exposure can be lethal
- Hydrogen is a flammable gas
- $\text{H}_2$ between 4 and 75% v/v in air is explosive
- Ignition source (spark or flame)

Proper design and training can mitigate most risks
Design considerations:

- Product piping
- Area ventilation
- Operator protection
- Monitoring / access control
- **Thinking green**
  - A 1,000 ppd OSG system:
    - Produces about 29 pounds of H₂ gas
    - Equal to about 13.2 gal. of gas
  - H₂ cleaning required
Summary

- **Commercial bleach**
  - Lowest complexity and capital cost
  - Market driven chemical costs

- **On-site gas generation**
  - High complexity & capital cost
  - Limited installed base
  - Limited vendors
  - Lower salt consumption
  - Higher salt cost/lb.
  - Requires additional chemical purchase, handling & storage

- **On-site hypochlorite generation**
  - Moderate complexity and capital cost
  - Large installed base
  - Numerous vendors
  - Higher salt consumption
  - Lower salt cost/lb.

- **Economics can vary regionally**
Thank You