

CHLORINATION CONVERSION:

Making the right choice

Presented by:

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2013 PNWS-AWWA CONFERENCE
Spokane, Washington

OVERVIEW

- ~ **Disinfection History**
- ~ **Drivers for Chlorine Gas Conversion**
- ~ **Disinfection Technology Overview**
- ~ **Chlorine Gas Conversion Options**
- ~ **Evaluation Options**

HISTORY OF CHLORINATION

- ~ Chlorine isolated by Karl Wilhelm Scheele in the late 1700s
- ~ Chlorine first used to treat water in 1908, Jersey City

“...a tremendous boon in the safeguarding of public health all over the world and is probably the most important and efficient sanitary measure of protection ever introduced.”

-- Daniel D. Jackson, Sanitary and Chemical Engineer,
Executive Officer of the Department of Chemical Engineering
of Columbia University, November, 1928



View of Jersey City, circa 1910
Photo courtesy of The New Jersey Room
Jersey City Free Public Library

- ~ Chlorine is used in over 90% of water treatment today

DRIVERS FOR CHLORINE GAS CONVERSION

~ Chlorine Gas Regulations

- Containment
- Scrubbers and Venting
- Risk Management Plan (RMP)

~ Chlorine gas is a deadly hazard

- Heavier than air
- 2 ppm can cause harm

~ Public Safety Expectations have changed since 2001

- Chlorine gas can be a weapon

CHLORINE GAS HAZARDS TO STAFF AND PUBLIC

DANGER

CHLORINE GAS

Maximum Distance of Impact from Instantaneous Chlorine Release

Amount Released	Lethality	Permanent Injury	Reversible Injury
1 x 150 lb cylinder	0.38 miles	1 mile	1.8 miles
3 x 150 lb cylinders	0.5 miles	1.3 miles	2.3 miles
1 x One ton cylinder	0.85 miles	2.1 miles	3.6 miles
3 x One ton cylinders	1.3 miles	3.1 miles	5.3 miles

Gaseous Chlorine Reduction Initiative, Michigan DEQ – Computer Aided Management of Emergency Operations (CAMEO)

GOALS/CONSIDERATIONS OF ADDING DISINFECTANTS TO THE SUPPLY

~ Understanding of water quality

- Breakpoint chlorination analysis
- Residual in distribution system
- Disinfection byproducts

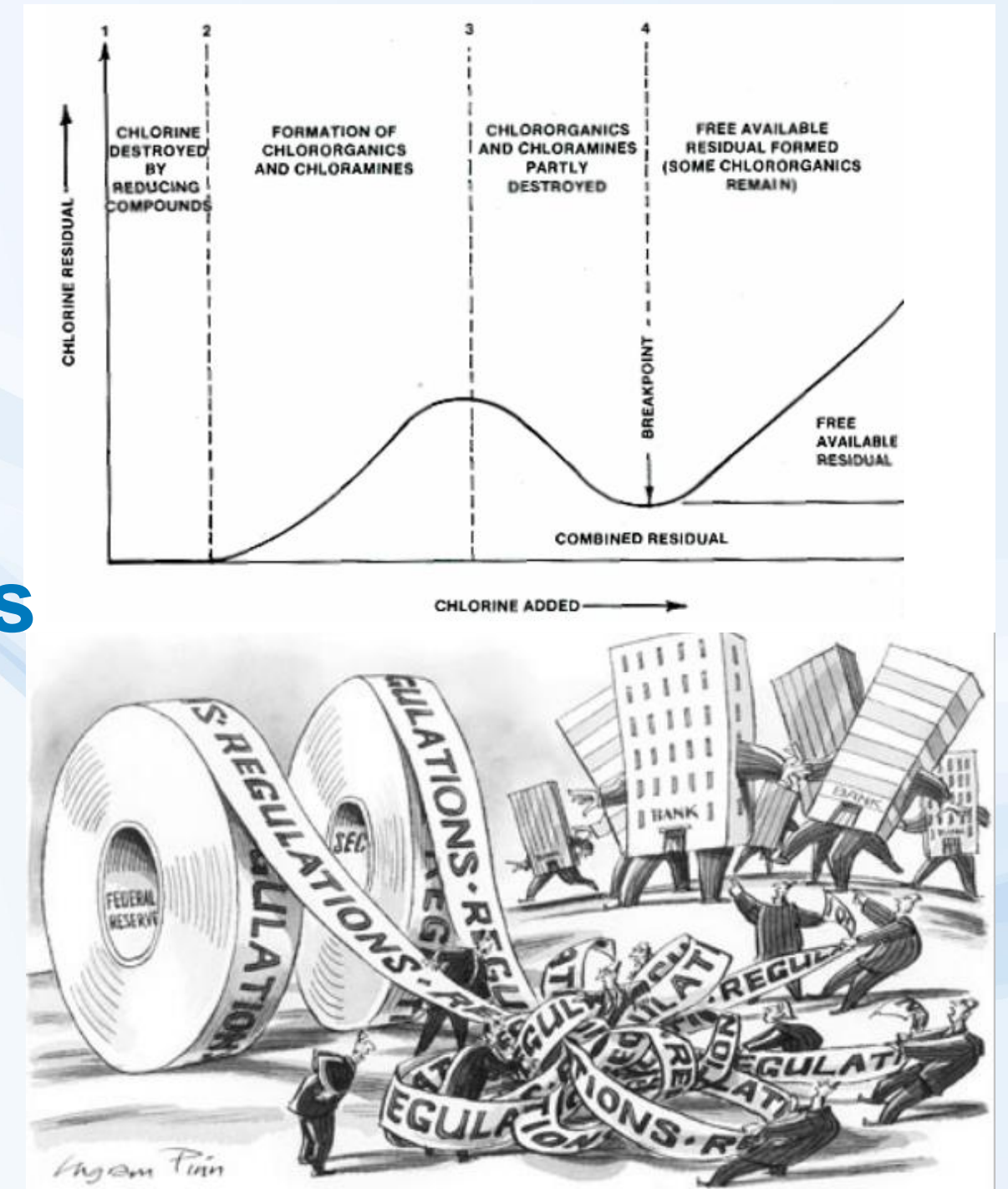
~ Facility restraints/Staff preferences

- Space, access, surrounding area

~ Regulatory requirements

- Safety
- Applicable codes

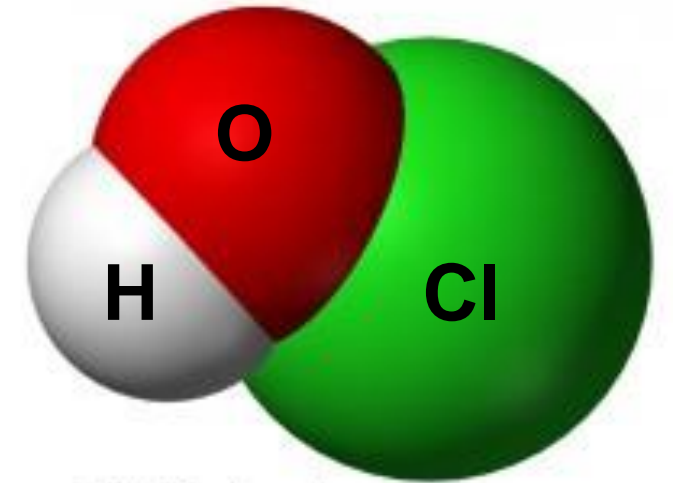
~ Minimize Cost to Maintain Disinfection



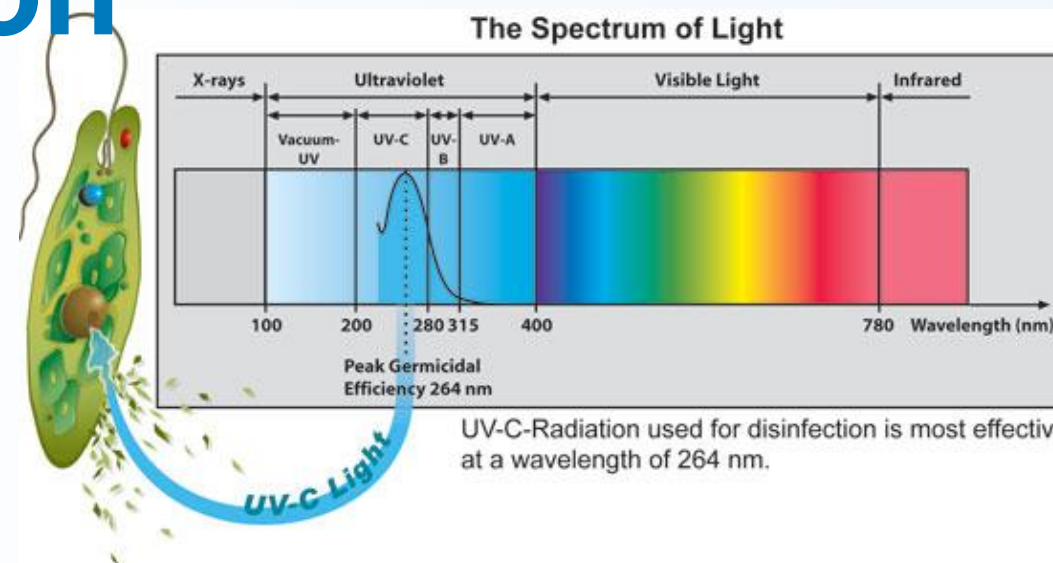
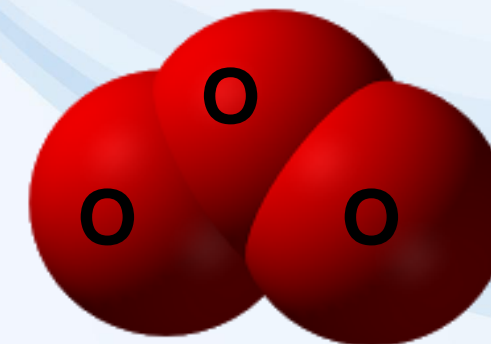
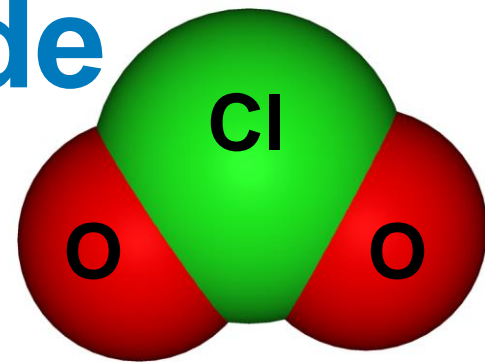
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DISINFECTION TECHNOLOGY OVERVIEW

- ~ Chlorine Gas
- ~ Sodium/Calcium Hypochlorite
- ~ Chlorine Dioxide
- ~ Ozone
- ~ UV/Filtration



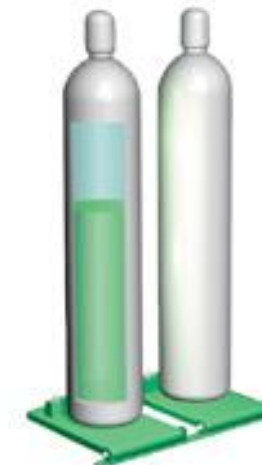
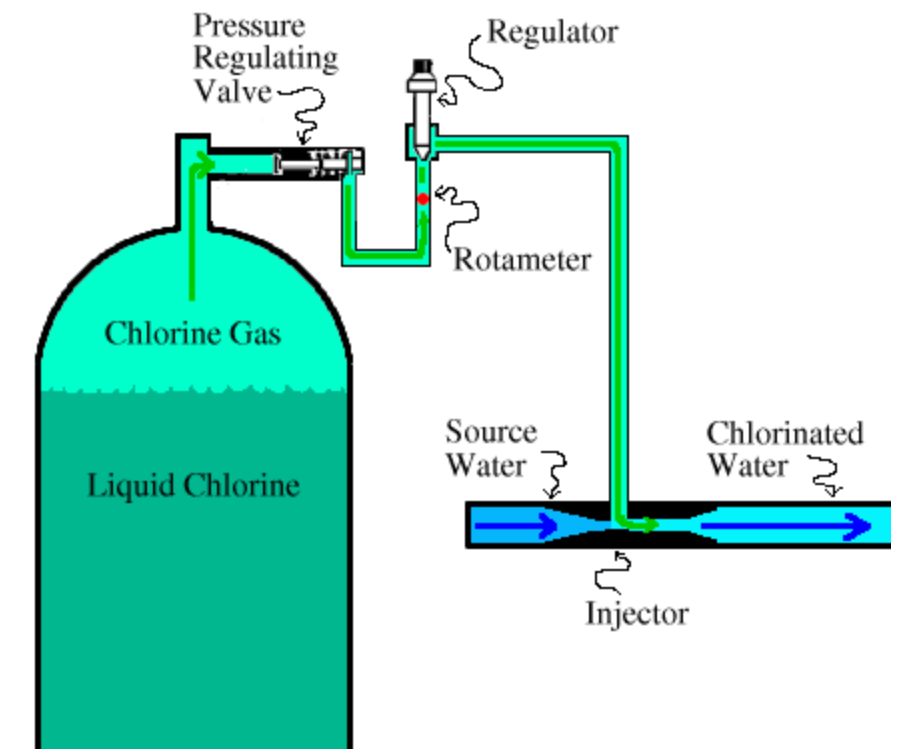
Hypochlorous Acid Molecule
'Free Chlorine'



DISINFECTION TECHNOLOGY OVERVIEW

~ Chlorine Gas

- Delivered in 150 lb up to 2000 lb cylinders
- Active disinfectant is hypochlorous acid (HOCl)
- Provides primary treatment and collection system chlorine residual



DISINFECTION TECHNOLOGY OVERVIEW

~ Hypochlorites

- Two forms NaOCl and Ca(OCl)_2
- NaOCl is delivered in bulk 12.5% solution or generated onsite at 0.8% solution
- Ca(OCl)_2 is delivered in powder/granular or tablets
- Active disinfectant is hypochlorous acid (HOCl)

Sodium hypochlorite + Water \rightarrow Hypochlorous Acid + Sodium Hydroxide
 $\text{NaOCl} + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{NaOH}$

Calcium hypochlorite + Water \rightarrow Hypochlorous Acid + Calcium Hydroxide
 $\text{Ca(OCl)}_2 + 2 \text{H}_2\text{O} \rightarrow 2 \text{HOCl} + \text{Ca(OH)}_2$



DISINFECTION TECHNOLOGY OVERVIEW

~ Chlorine Dioxide

- Strong oxidizing agent, limited residual
- Must be generated on site

~ Ozone

- Very strong oxidizing agent, but no residual
- Must be generated on site

~ UV/Filtration

- Effective for treatment, but no residual
- Headloss impacts

AVAILABLE ALTERNATIVE EVALUATION TOOLS



Homeland Security

Science and Technology Directorate
Homeland Security Advanced Research Projects Agency

Chlorine Gas Decision Tool for Water Utilities

National Association for
Clean Water Agencies
<http://www.nacwa.org/>

CONVERSION OPTIONS

- ~ **Chlorine Gas with Scrubbers**
- ~ **Purchased?**
 - **Bulk Sodium Hypochlorite**
 - **Calcium Hypochlorite**
- ~ **Site-generated Sodium Hypochlorite?**

GAS CHLORINATION

- ~ Containment/scrubber venting requirements
- ~ Continued Risk Management Plan Implementation
- ~ Delivered in 150 lb and 2000 lb cylinders



EST™ Type DHS 400 Dry Emergency Chlorine Scrubber



TGO Technologies 150# ChlorTainer

BULK SODIUM HYPOCHLORITE

- ~ 1 lb Cl_2 gas equivalent to 1 gallon of NaOCl
- ~ Delivery range is 2.5 gallon jugs, 300 gallon tote or 5,000 gallon tank trucks
- ~ Onsite storage tanks require insulation unless within a building structure
- ~ Stability of solution is poor and rapidly decomposes



FRP Tanker Trailer



SODIUM HYPOCHLORITE DEGRADATION –

Average Manufacturer @ 70 Degrees F

- ~ Time of Manufacture - 12.5 Trade Percent
- ~ 2 Days Later – 12.43 Trade Percent
- ~ 7 Days Later – 12.25 Trade Percent
- ~ 14 Days Later – 12.01 Trade Percent
- ~ 21 Days Later – 11.78 Trade Percent
- ~ 28 Days Later – 11.55 Trade Percent
- ~ 35 Days Later – 11.34 Trade Percent (@ 80 F 10.21 %)

ONSITE SODIUM HYPOCHLORITE

- ~ 0.8% produced from salt and softened water
- ~ System uses high-purity food grade salt
- ~ Requires larger onsite storage
- ~ Feed rates range from 20 pounds/day and up
- ~ Hydrogen gas byproduct needs to be vented



ClorTec® On-site Hypochlorite Generation System

CALCIUM HYPOCHLORITE

- ~ Typically in the 65% available chlorine in tablet producing 1% to 2% solution
- ~ Delivered in 50 lb pales
- ~ Feed rates up to 400 lbs per day
- ~ Chlorine solution variable



ALTERNATIVE ANALYSIS

~ Evaluation Criteria

– Monetary

- Capital/Present Worth Cost Comparison

– Non-Monetary

- Utility/Customer drivers
- Safety Concerns
- Operation and Maintenance Ease
- Regulatory drivers
- Water quality impacts

MONETARY ANALYSIS

COST EVALUATION

CAPITAL COSTS

- Site Specific
 - Extent of building modifications
 - Amount of storage
- Onsite systems are 2 to 4 times the cost of bulk NaOCl or Ca(OCl)₂
 - Examples:
 - City of Woodburn
 - Asotin County PUD
 - City of Lakeville, MN

OPERATIONAL COSTS

Site Specific/Chemical Costs

Chlorine Gas	Bulk NaOCl (12.5%)	Onsite NaOCl (0.8%)	Ca(OCl) ₂ (65%)
150 lb cylinder	300 gal tote	Per lb of salt	Per 50 lb pail
\$150	\$600	\$0.25/lb (bag)	\$125
\$1.33/lb Cl ₂	\$2.25/lb Cl ₂	\$0.95/lb Cl ₂	\$3.85/lb Cl ₂

Cost Comparison

- Replacement schedule considerations
- Typically a 20 year design life
 - Present Worth based on this Onsite systems are approximately 1.5 times the cost of bulk NaOCl or Ca(OCl)₂

NON-MONETARY ANALYSIS

~ Safety Concerns

- Impacts to neighborhood, area traffic, operator acceptance
- Security

~ Operation and Maintenance Ease

- Operators familiar with the process
- Chemical handling and storage



NON-MONETARY ANALYSIS

~ Regulatory Drivers

- Site specific (containment, scrubbers)
- Emergency Action Plan requirements
- Water quality impact
- Process driven

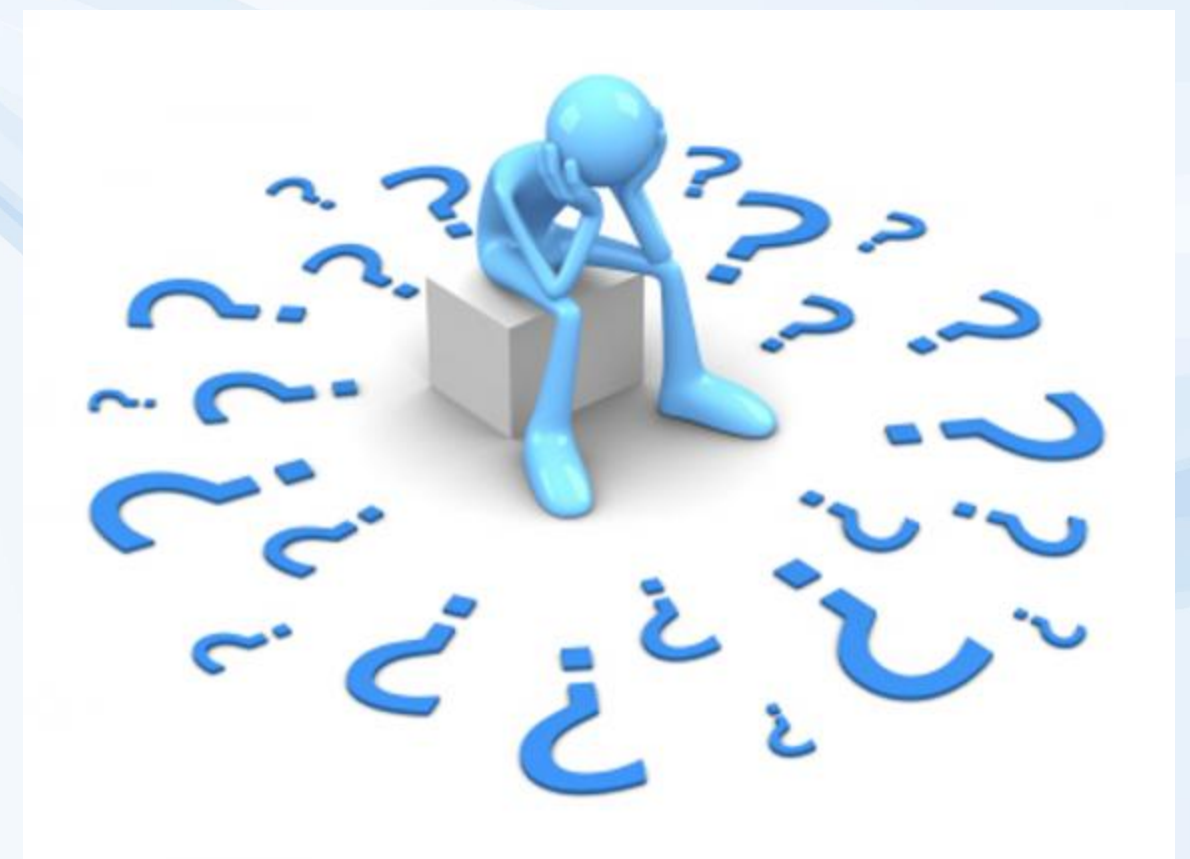


ALTERNATIVE DISINFECTION CONSIDERATIONS

	Chlorine Gas	Bulk Sodium Hypochlorite	Onsite Sodium Hypochlorite	Calcium Hypochlorite
Advantages	<ul style="list-style-type: none"> - Traditional treatment - Systems already in place 	<ul style="list-style-type: none"> - Reduces process safety management - Supply readily available - Easy to use 	<ul style="list-style-type: none"> - Reduces process safety management - No bulk storage needed and transportation of hazardous chemicals - Production chemicals readily available 	<ul style="list-style-type: none"> - Reduces process safety management - Simple package system, with no bulk storage - Chemicals readily available
Potential Disadvantages	<ul style="list-style-type: none"> - Need for scrubbers and containment - Operator/public safety - Transportation risk 	<ul style="list-style-type: none"> - Decay with light and temperature - Large on-site storage potentially, requiring containment - Scaling of piping and feed system 	<ul style="list-style-type: none"> - Generates hydrogen gas - More maintenance intensive - Cell replacement 	<ul style="list-style-type: none"> - Variable chemical concentration - Treatment capacity limitations - Higher chemical costs

SUMMARY/CONCLUSION

- ~ Monetary analysis coupled with Non-monetary criteria analysis
- ~ No one-size fits all solution



<http://www.experimentswithdata.com/2012/02/15/is-it-the-right-choice/>