Produce Water Treatment

AQUAPULSE SYSTEMS

Water Education Alliance For Horticulture

WaterEducationAlliance.org

ISGA International Sprout Growers Association

United Fresh PRODUCE ASSOCIATION

Horticulture Water Treatment

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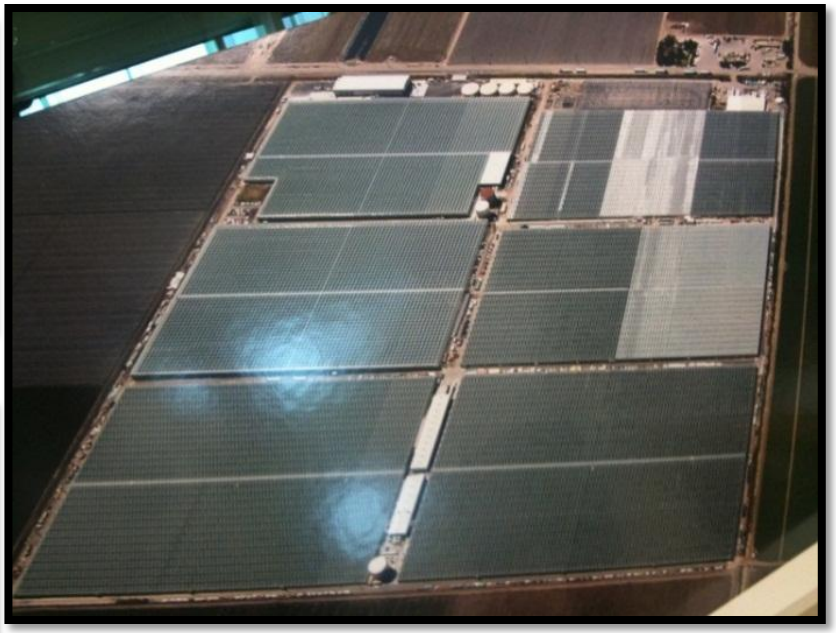

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Water Education Alliance For Horticulture

WaterEducationAlliance.org

Typical Pathogens

- *Generic E. Coli*
- *E. Coli O157:H7*
- *Salmonella*
- *Listeria*
- *Legionella*
- *Pseudomonas*
- *Cryptosporidium*
- *Norwalk Virus*
- *Giardia Lamblia*
- *Cyclospora*

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Pathogen Issue

- Free floating in suspension
- Trapped in Biofilm
- Biofilms grow in water distribution systems
- Biofilms are a harborage and growth medium
- Biofilms must be Killed *and* Removed

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Direct Benefits

- Remove and Kill Biofilm
- Microbial Reduction
- Prevent Product Contamination
- Improve Quality
- Reduced Chemical Use
- Consistent Water Flow
- Reduced equipment and pipe corrosion
- Reduced mineral contamination
- Reduce lost time and labor for sanitation
- Reduce deposits of scale and biofilm
- Loss of heat transfer and higher energy cost

Biofilm Development

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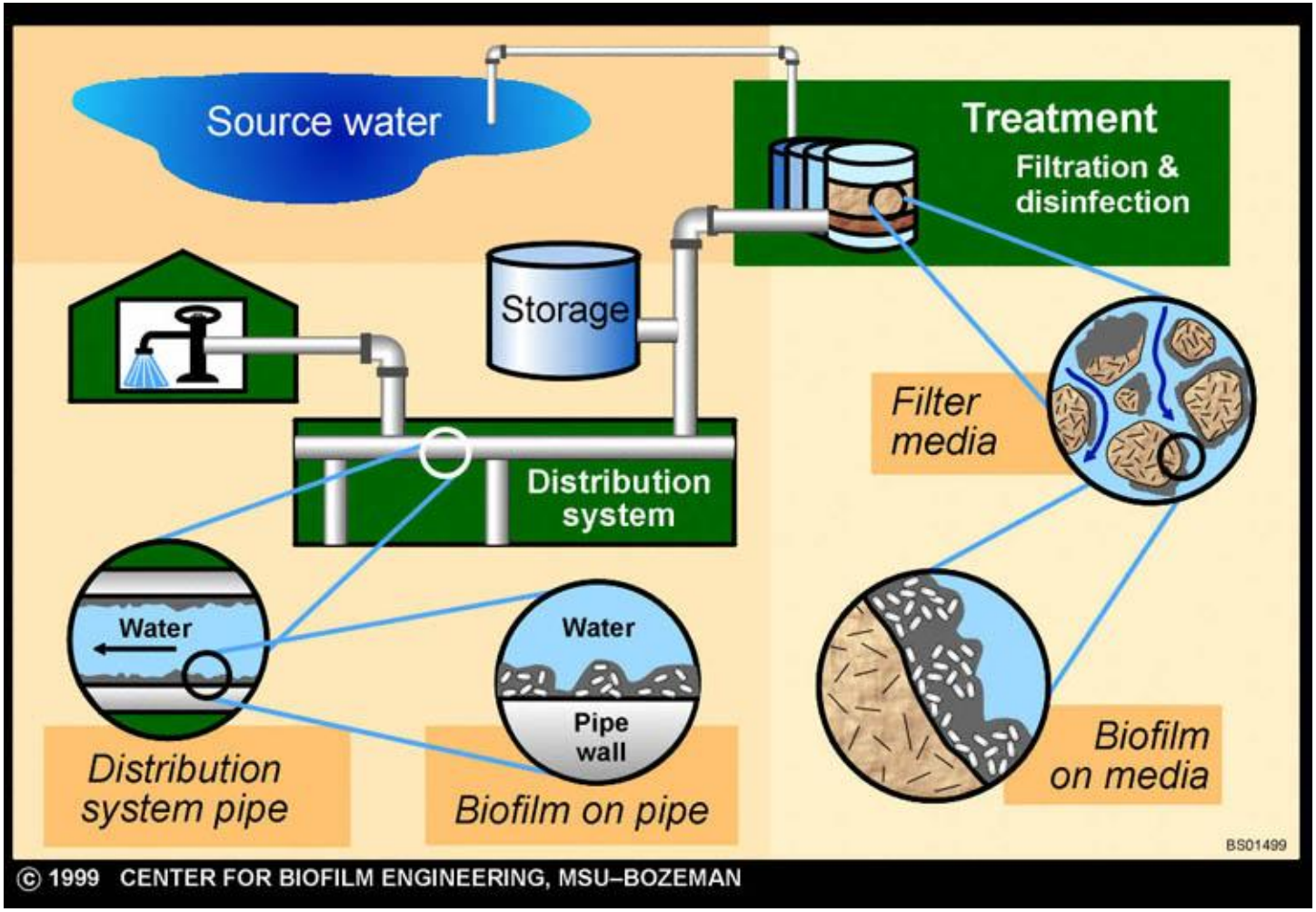
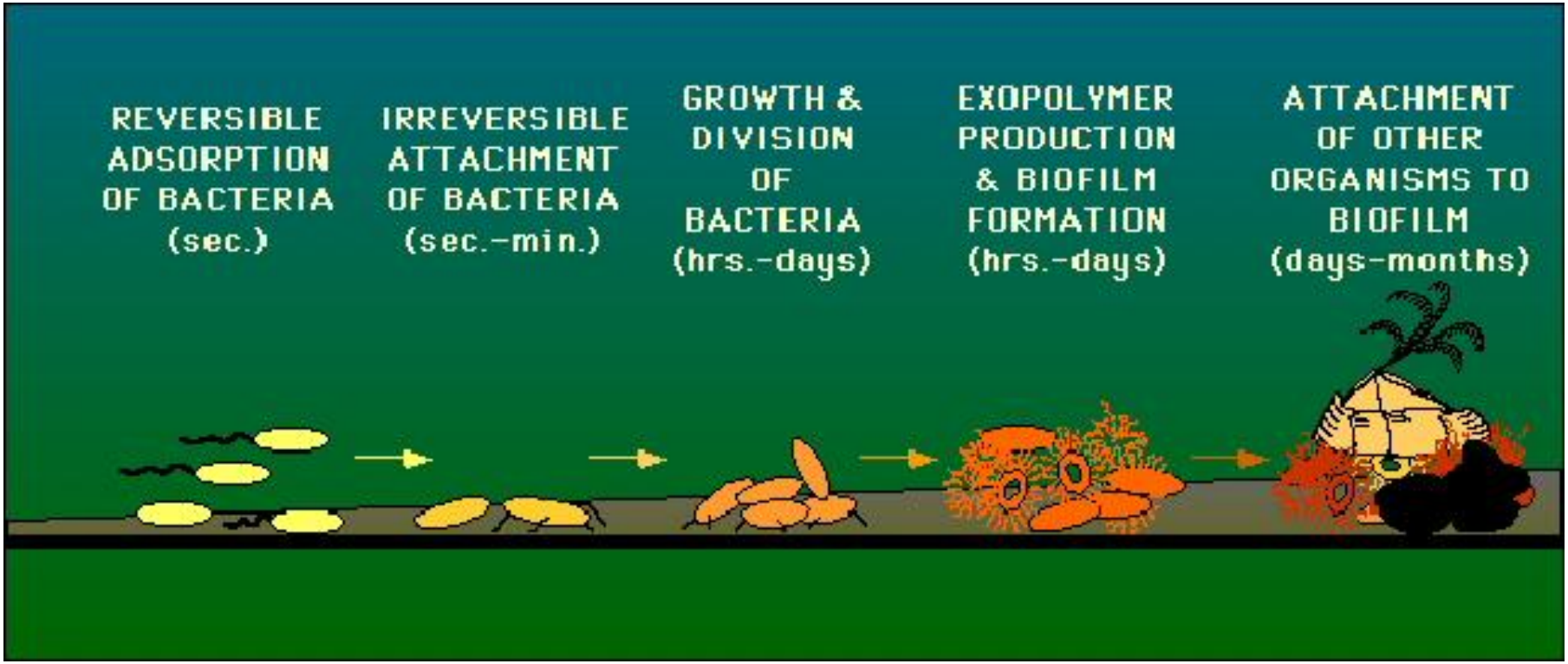


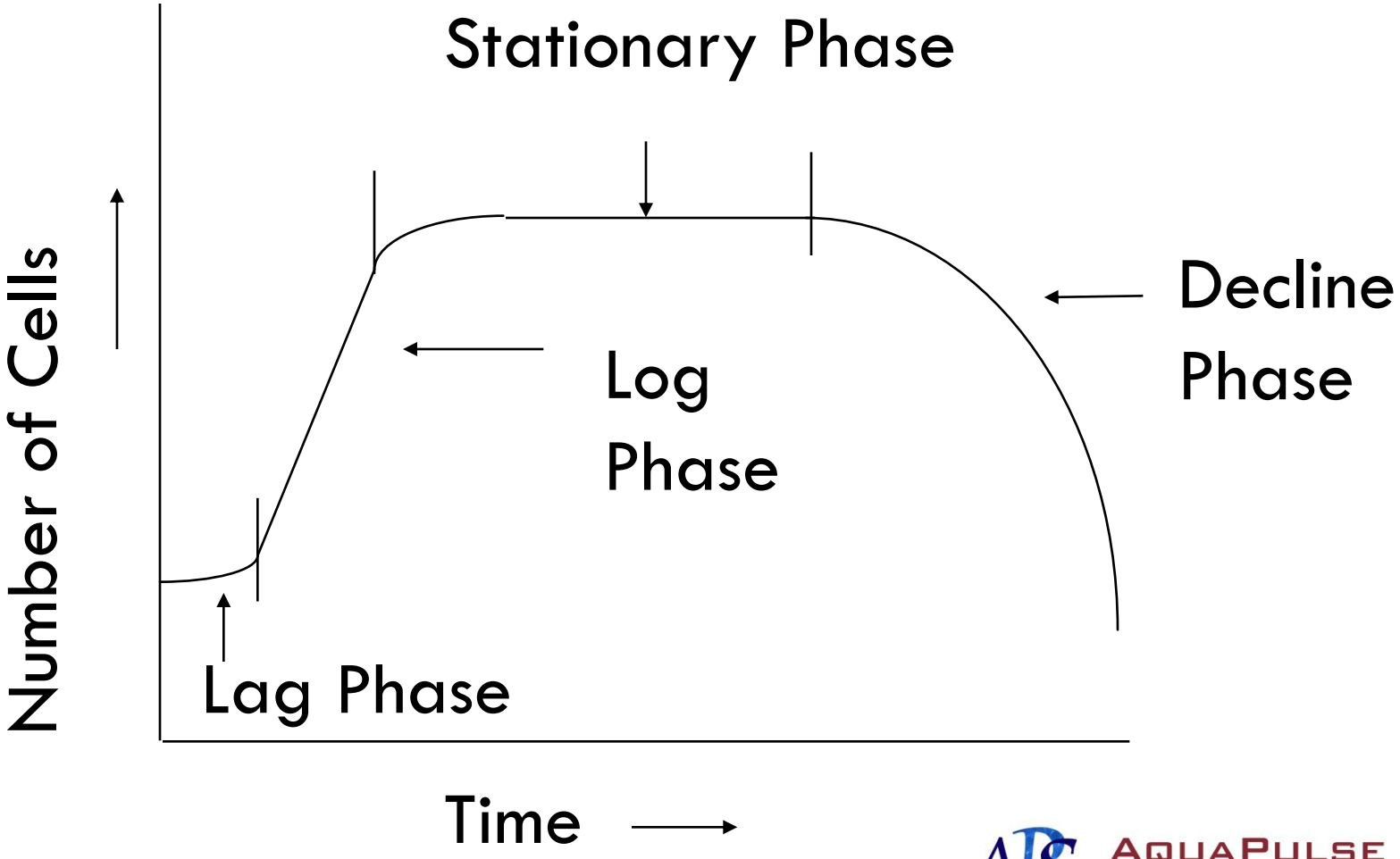
Biofilms

AQUAPULSE SYSTEMS



John Lennox, 2008 (http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/)

Growth Curve



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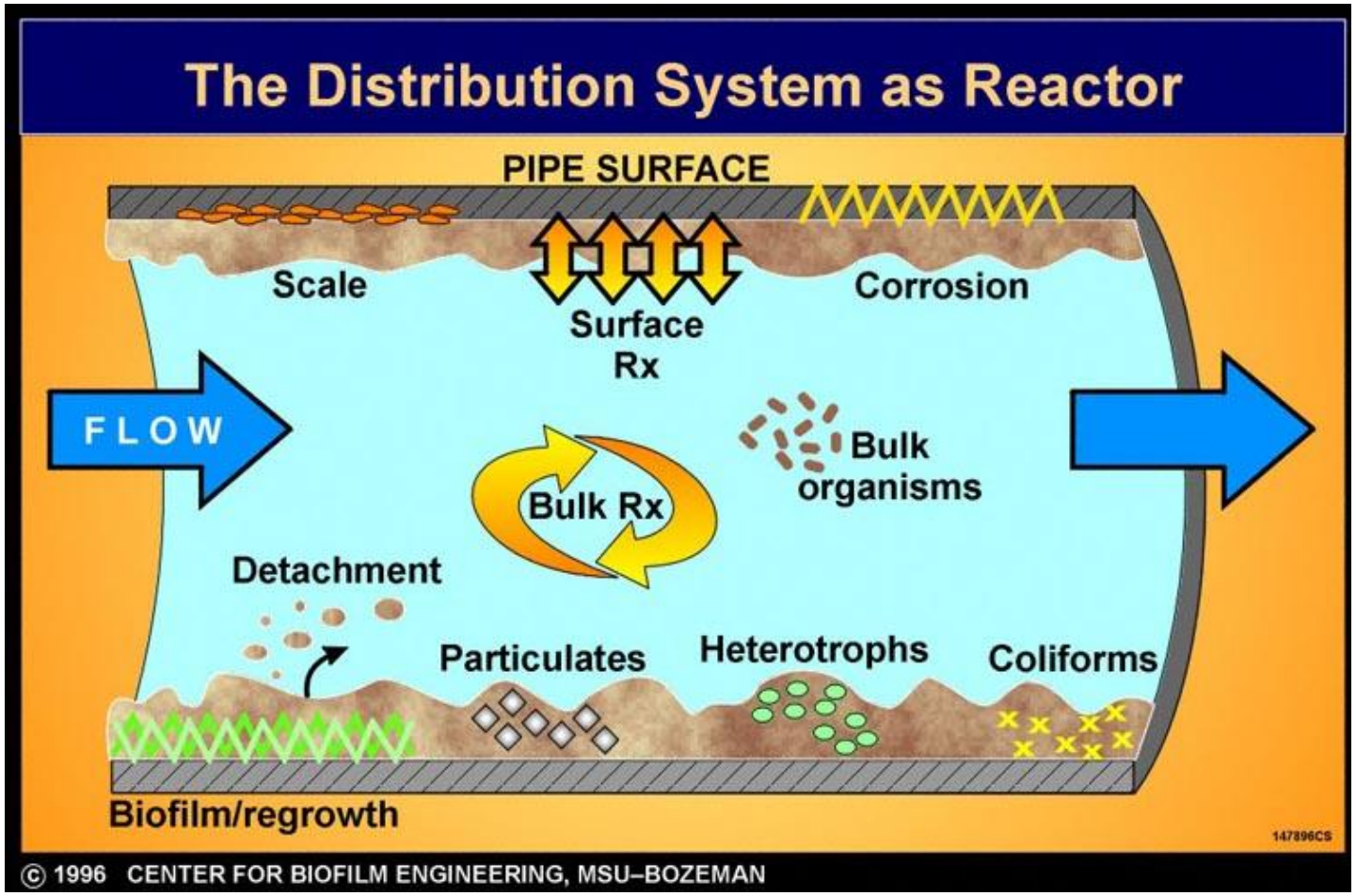
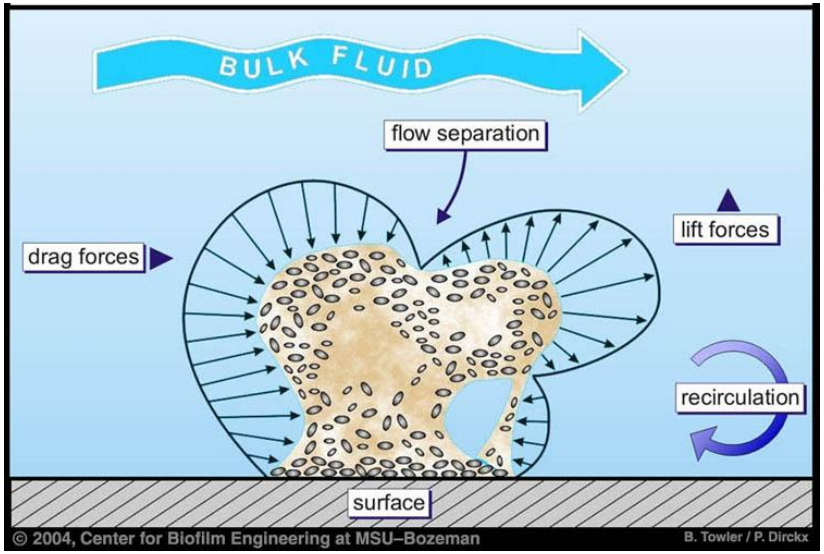
Biofilm in Distribution Pipes

AQUAPULSE SYSTEMS

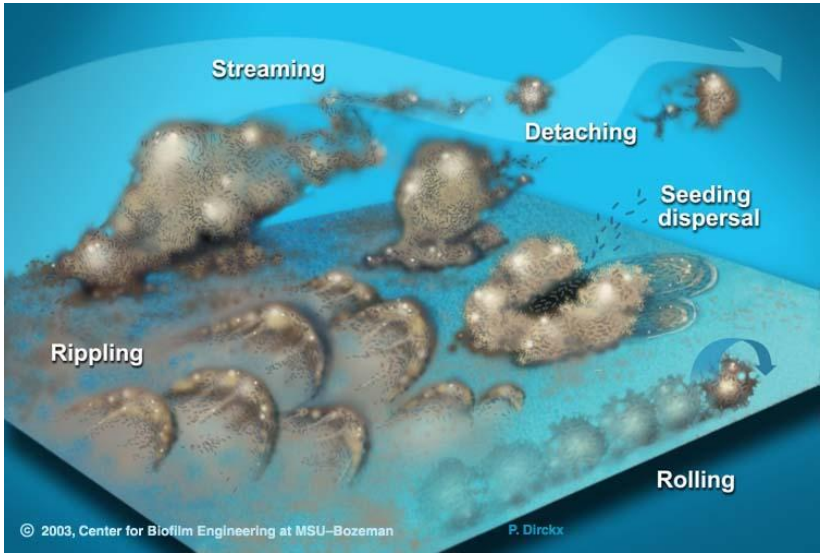


Biofilm in Water Flow

Fluid Dynamics



Biofilm in Water Flow



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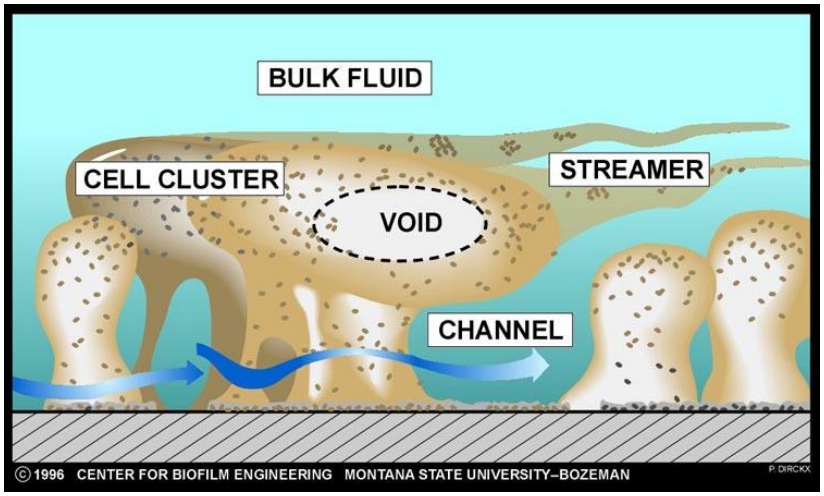
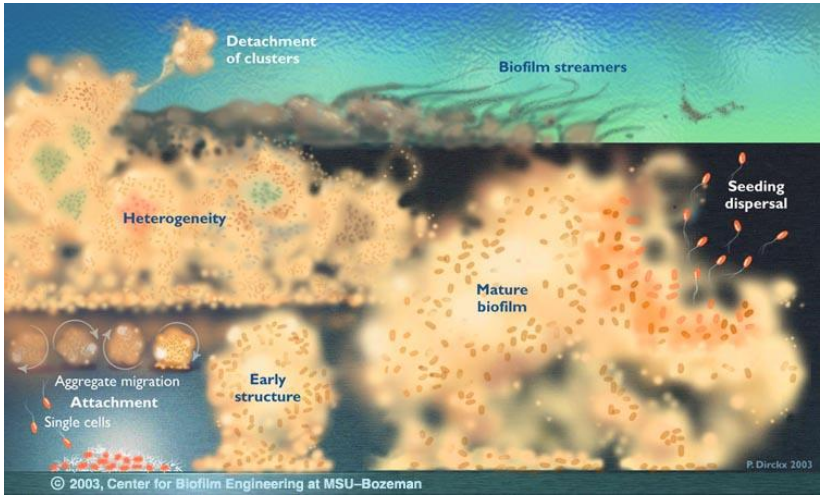
Biofilm Characterization

Biofilm Dynamics



Biofilm Environment



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Pathogens *grow* in Biofilms

- Listeria and Facultative anaerobes
  - Grows in the presence & absence of oxygen
- Temperature
  - Growth 32 – 113°F
  - Growth at pH 4.4 - 9.6
    - Optimum pH 6.5-7.5
    - Survival can occur at pH <4.3
  - pH tolerance is temperature and acid dependent

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Dr. Karen Killinger
Washington State University

Respiratory activity inside biofilm

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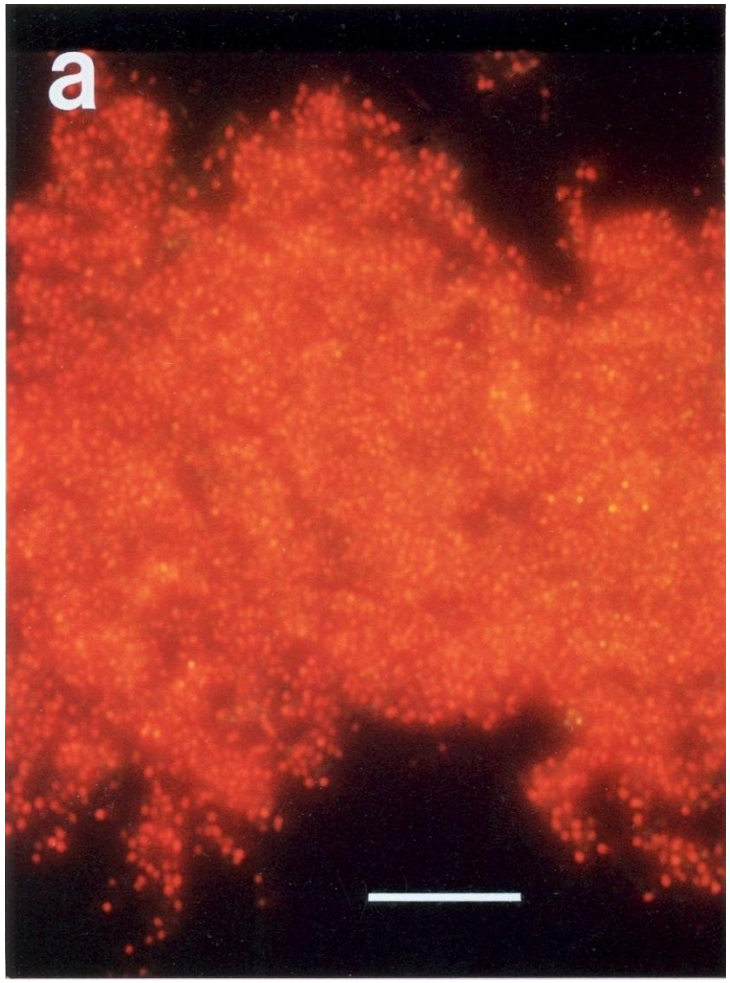
Respiratory activity

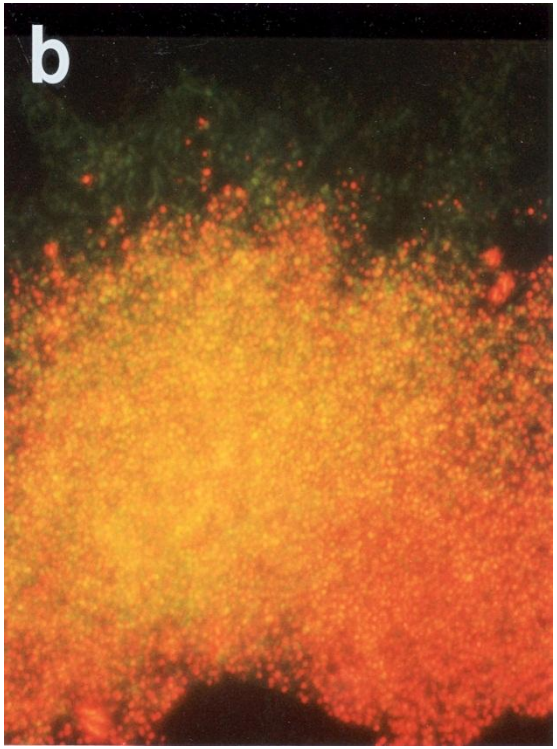


Untreated Control

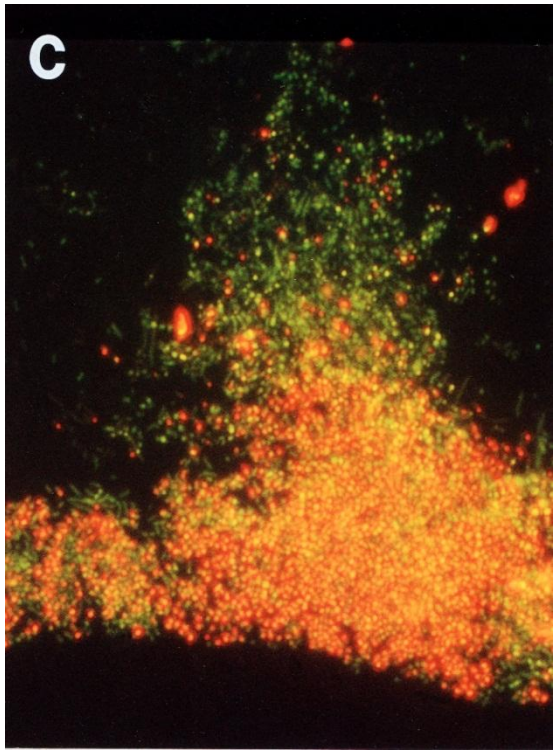
Huang et al (1995) *Applied Environmental Microbiology* **61**:2252.

Respiratory activity inside the Biofilm

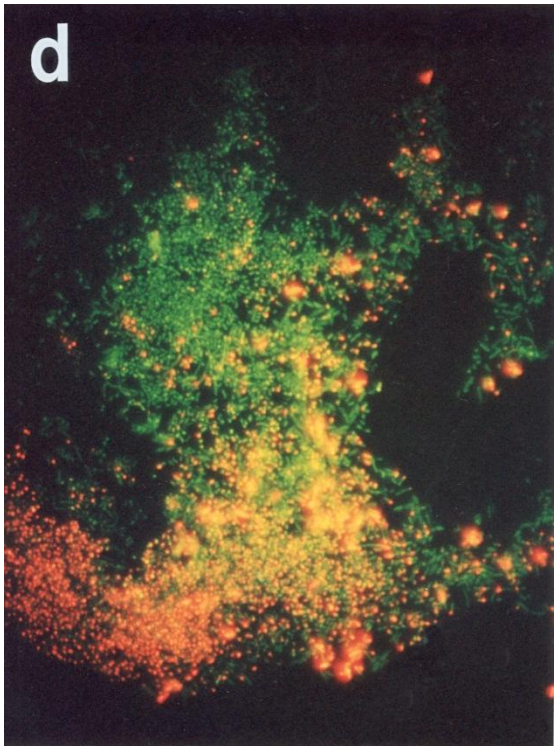
Chemical Treatment



After 30 min



After 60 min

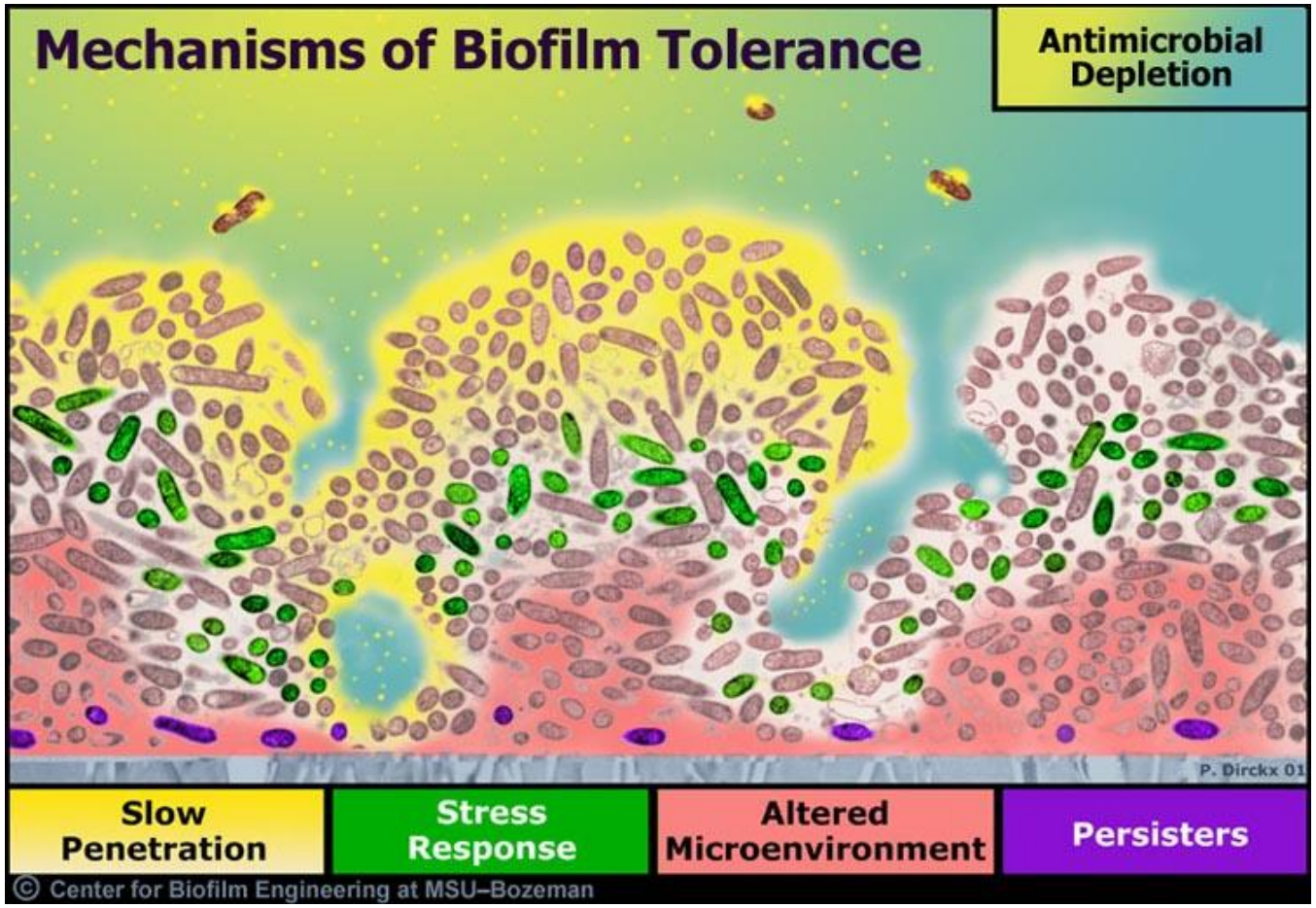


After 120 min

Huang et al (1995) *Applied Environmental Microbiology* **61**:2252.

Biofilm Sanitizer Treatment

Treatment of Biofilms with chlorine water sanitizers result in poor penetration



Treatment with 50 mg/l Quat

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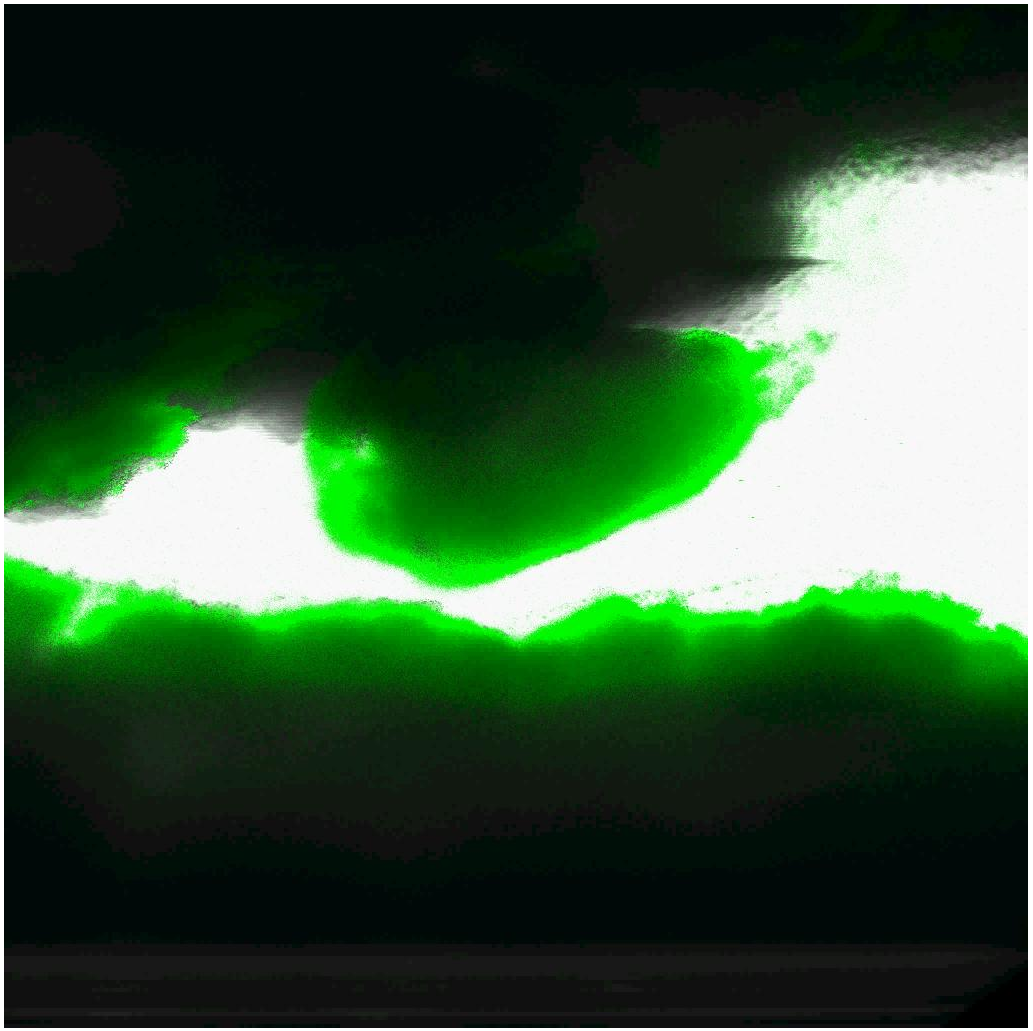
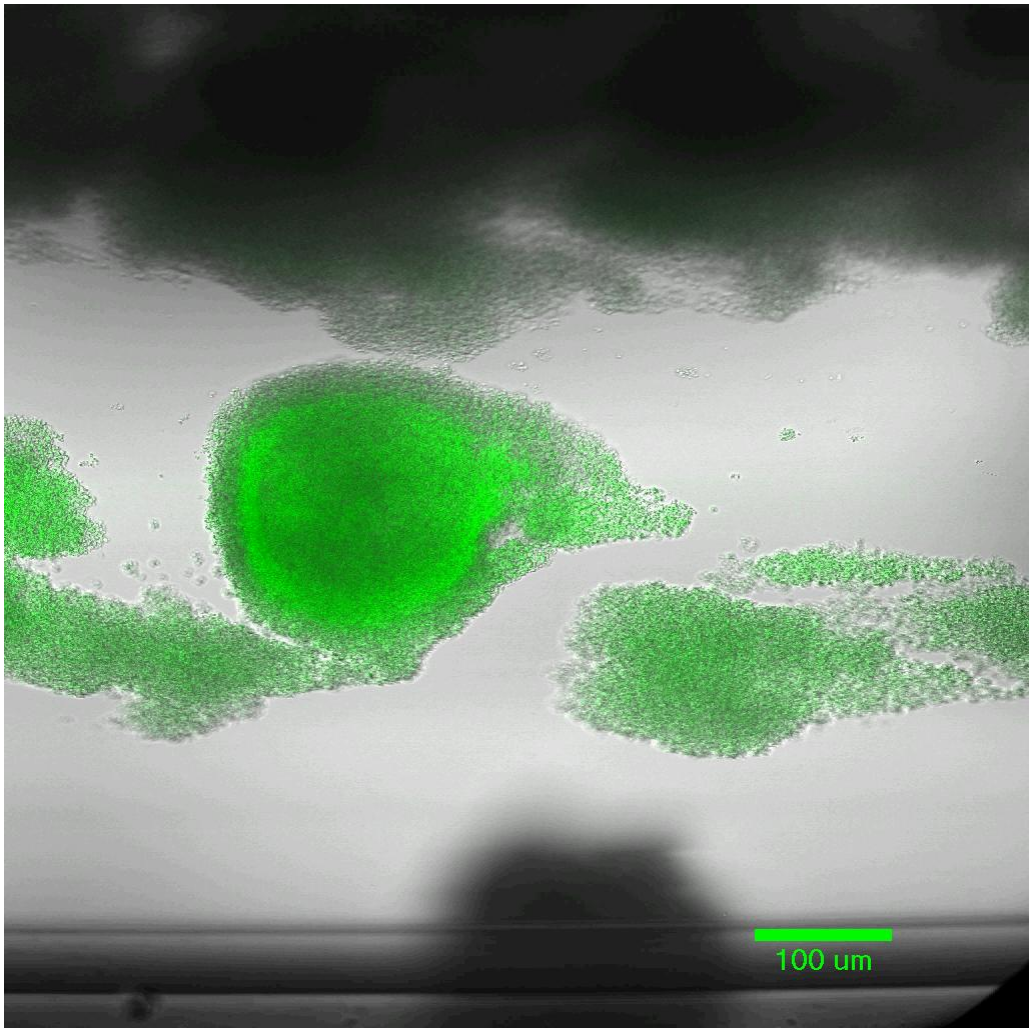


60 min

Treatment with 50 mg/l Nisin

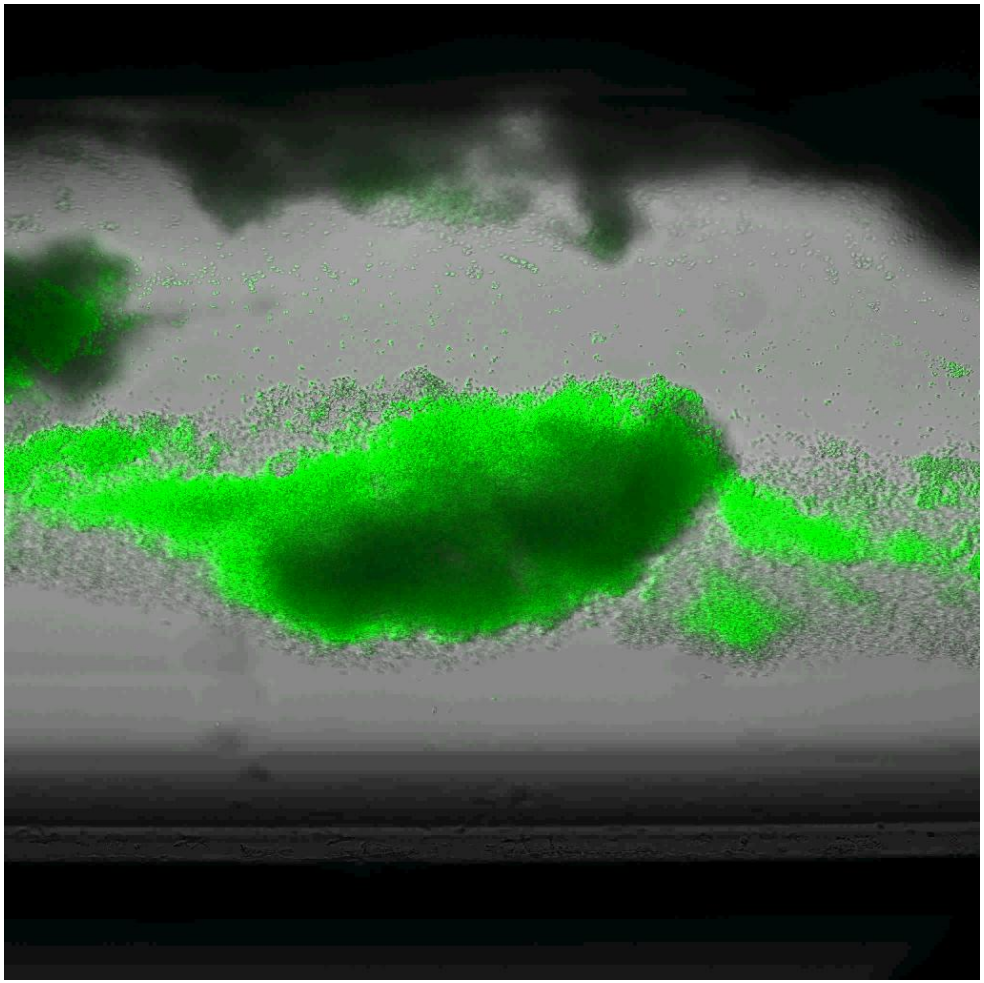
AQUAPULSE SYSTEMS



60 min

Treatment with 50 mg/l Chlorine

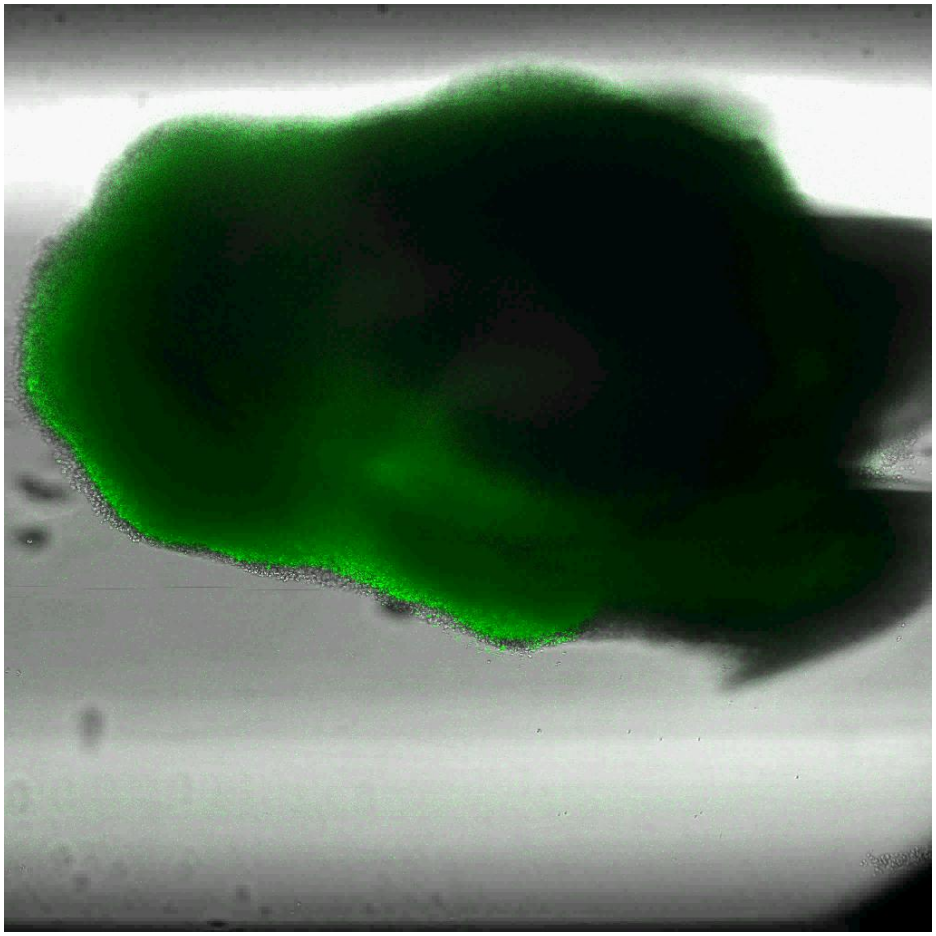
AQUAPULSE SYSTEMS



60 min

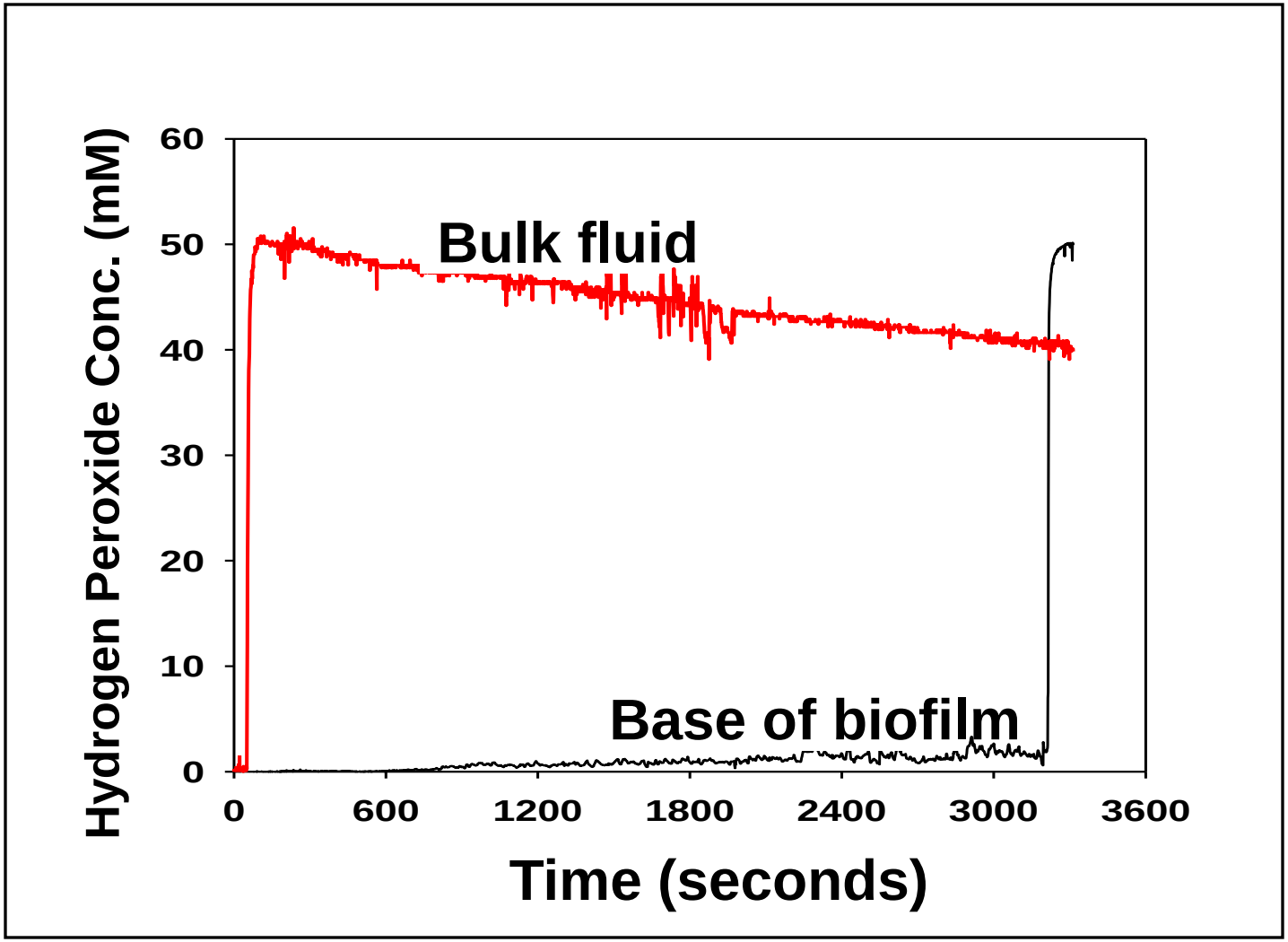
Treatment with 10 mg/l Chlorine Dioxide

AQUAPULSE SYSTEMS



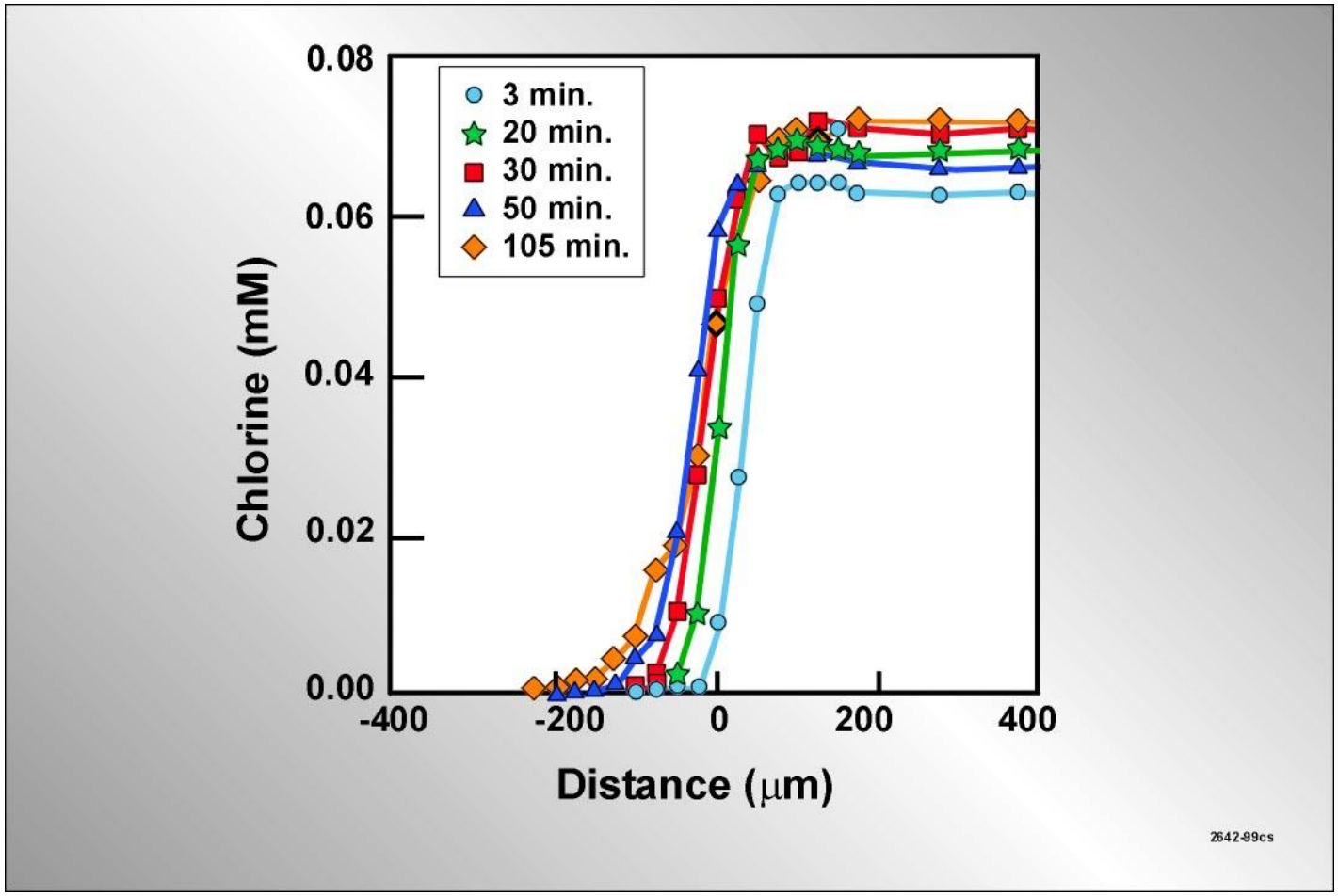
60 min

Hydrogen Peroxide cannot penetrate Biofilm



Stewart et al (2000) *Appl. Environ. Microbiol.* **66**:836.

Chlorine cannot penetrate Biofilm



de Beer et al (1994) *Appl. Environ. Microbiol.* **60**:4339.

Oxidizer Potential

- Oxidation Strength describes the strength of the reaction and reactivity. A higher number means it reacts with more things.
- Oxidation Capacity indicates how many electrons are transferred.

Oxidizer	Oxidation Strength	Oxidation Capacity
Ozone (O_3)	2.07	2 e^-
Hydrogen Peroxide (H_2O_2)	1.78	2 e^-
Hypochlorous Acid (HOCl)	1.49	2 e^-
Hypobromous Acid (HOBr)	1.33	2 e^-
Chlorine Dioxide (ClO_2)	0.95	5 e^-

Regrowth of Biofilms

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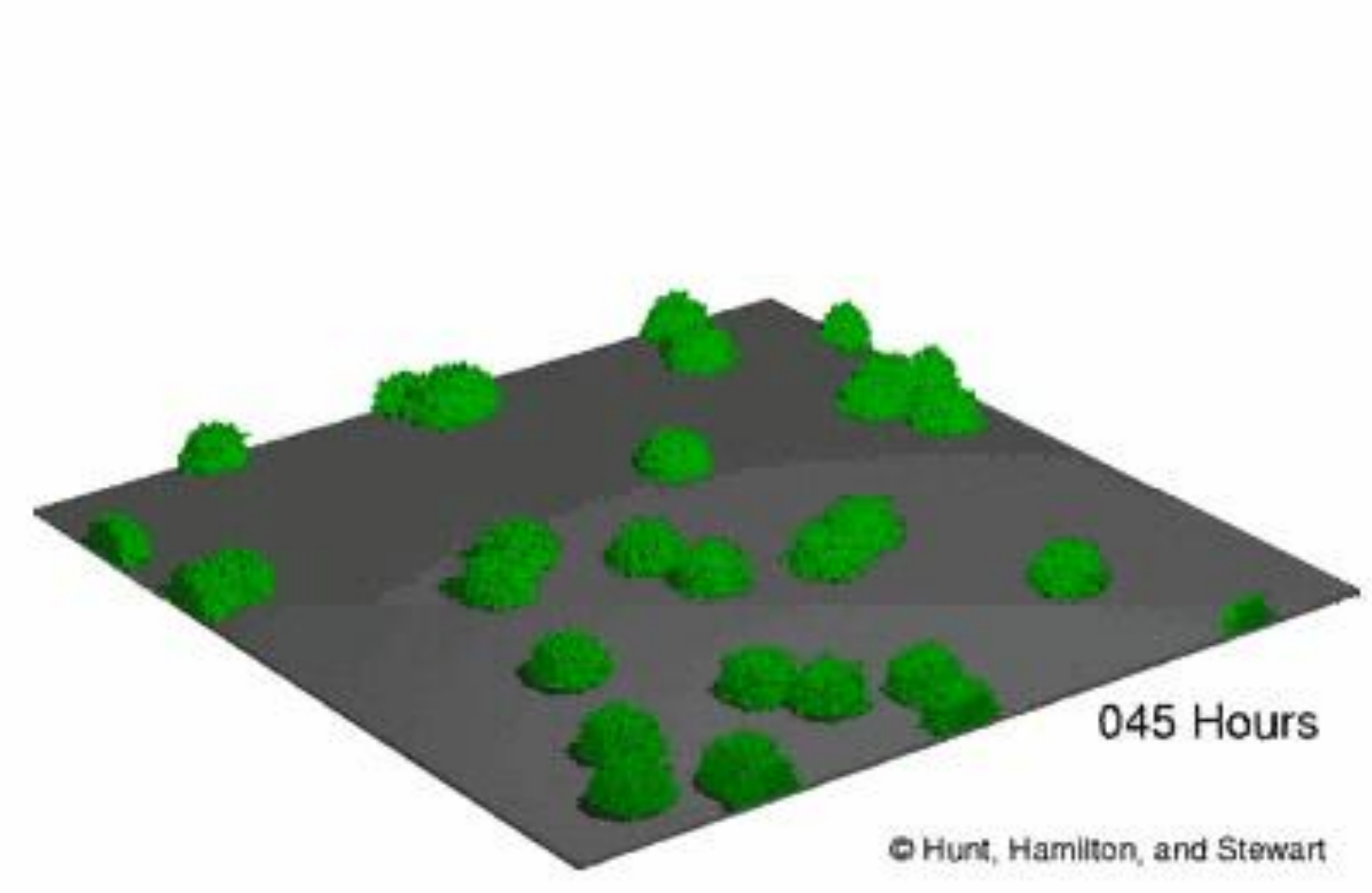

Regulation of Biofilms

- Biofilms are considered a “pest” by the EPA
- Biofilm is regulated under FIFRA
  - Federal Insecticide Fungicide Rodenticide Act
- Currently there are no validated methods for the disinfection efficacy of biofilms
- EPA has started the process to validate a biofilm efficacy test method

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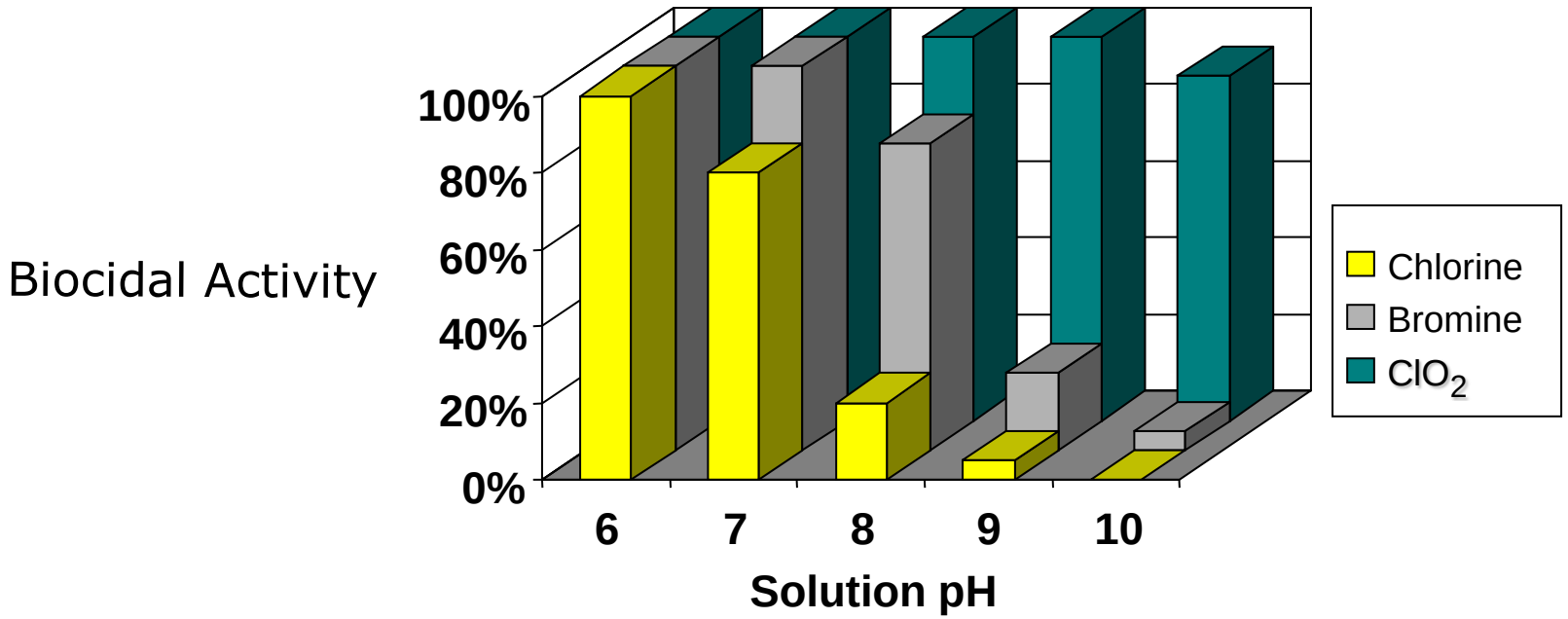
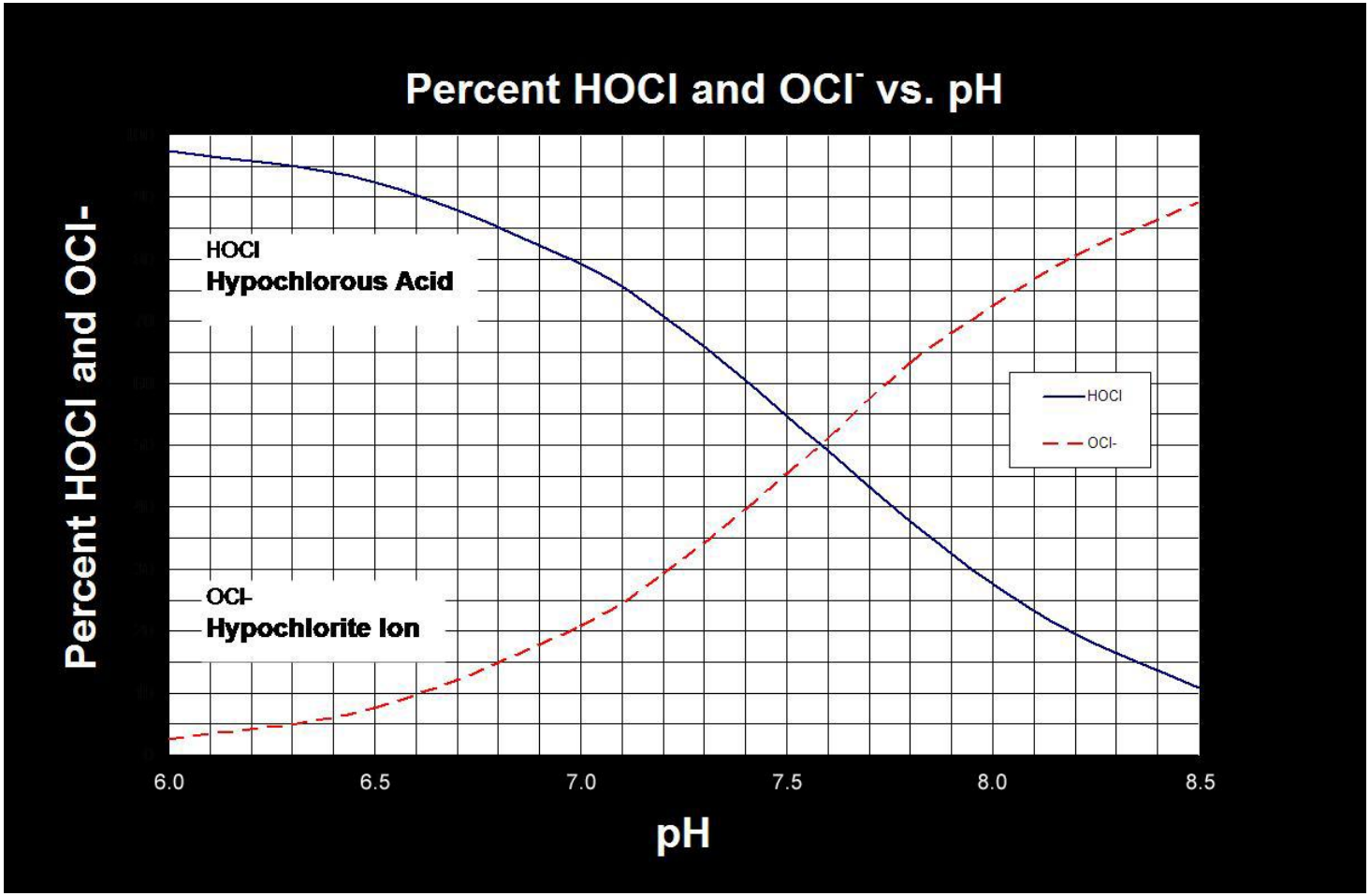
Chlorine Dioxide is not pH Dependent



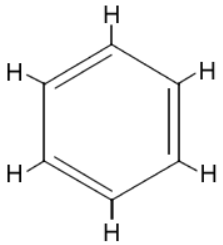
AQUAPULSE SYSTEMS

pH Effects on Active Chlorine

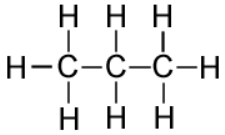


Chlorine Harmful Byproducts

- Tri Halo Methane (THMs)
  - Chlorine, Bromine, Iodine

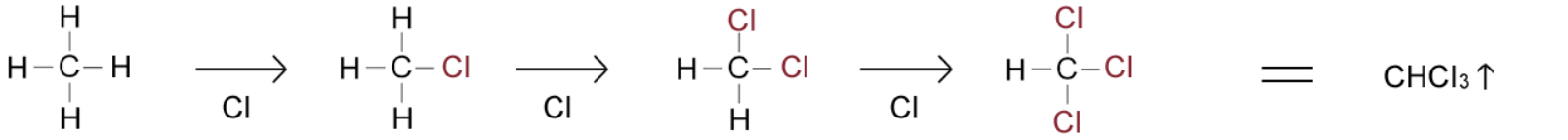


Aromatics



Chain

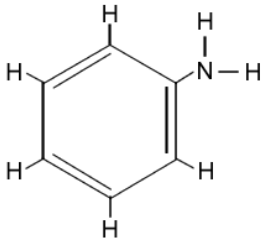
Chlorine Substitution Reaction
Harmful by products
Trihalomethane - THMs



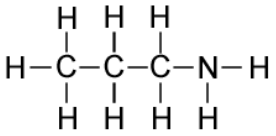
Methane — Mono- — Di- — Trichloromethane — Chloroform (gas)

Chlorine Harmful Byproducts

- Chloramines – Chlorine, Bromine, Iodine
  - Ammonia, Nitrates, Proteins

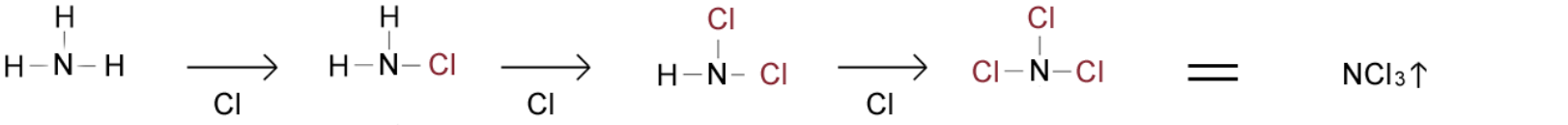


Aromatics



Chain

Chlorine Substitution Reaction
Harmful by products
Chloramines

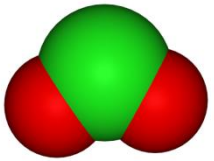


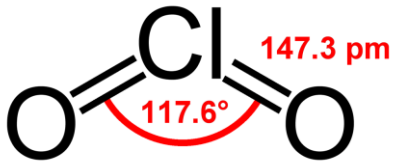
Ammonia

Chloramine

Nitrogen Trichloride (gas)

Chlorine Dioxide





- Powerful Water Sanitizer
- Oxidizer 2.5x more effective than Chlorine
- 10x more soluble in water than chlorine
- Low Sodium, Low Chlorite
- No hydrophilic substitution reactions
- Does not form THMs
- Does not form Chloramines
- Effective at wide pH ranges

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Biofilm Removal by ClO2

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- Chlorine Dioxide penetrates biofilm

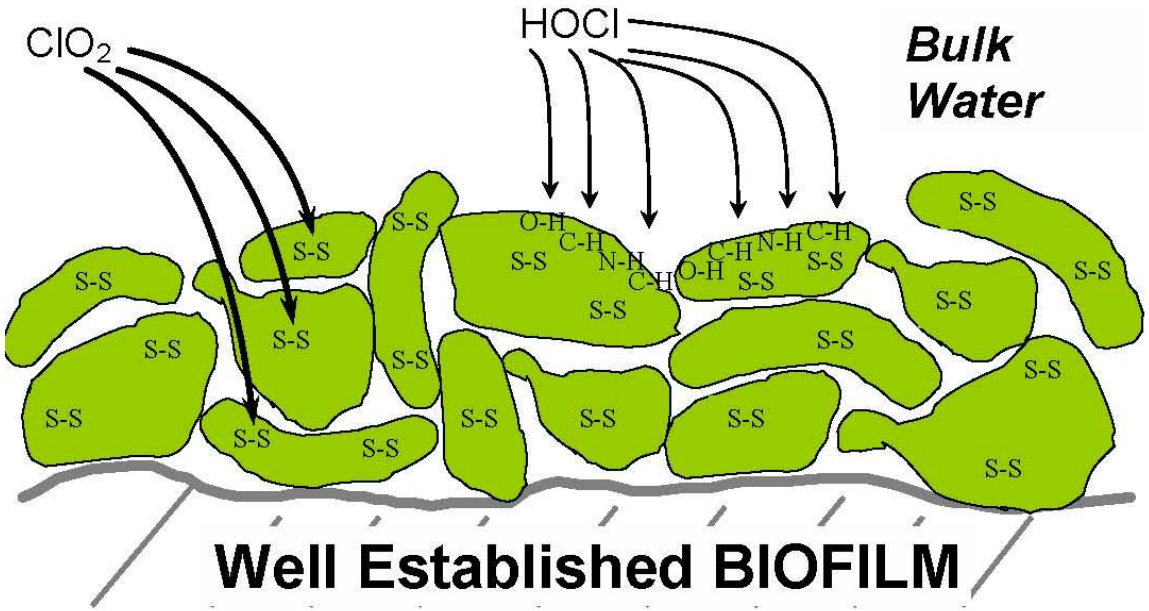

Figure 1. Effect of chlorine and chlorine dioxide at biofilm penetration.

http://postharvest.tfrec.wsu.edu/PC2004B.pdf
Douglas G. Kelley, Ph. D. Technical Director

Simple Chemical Injection

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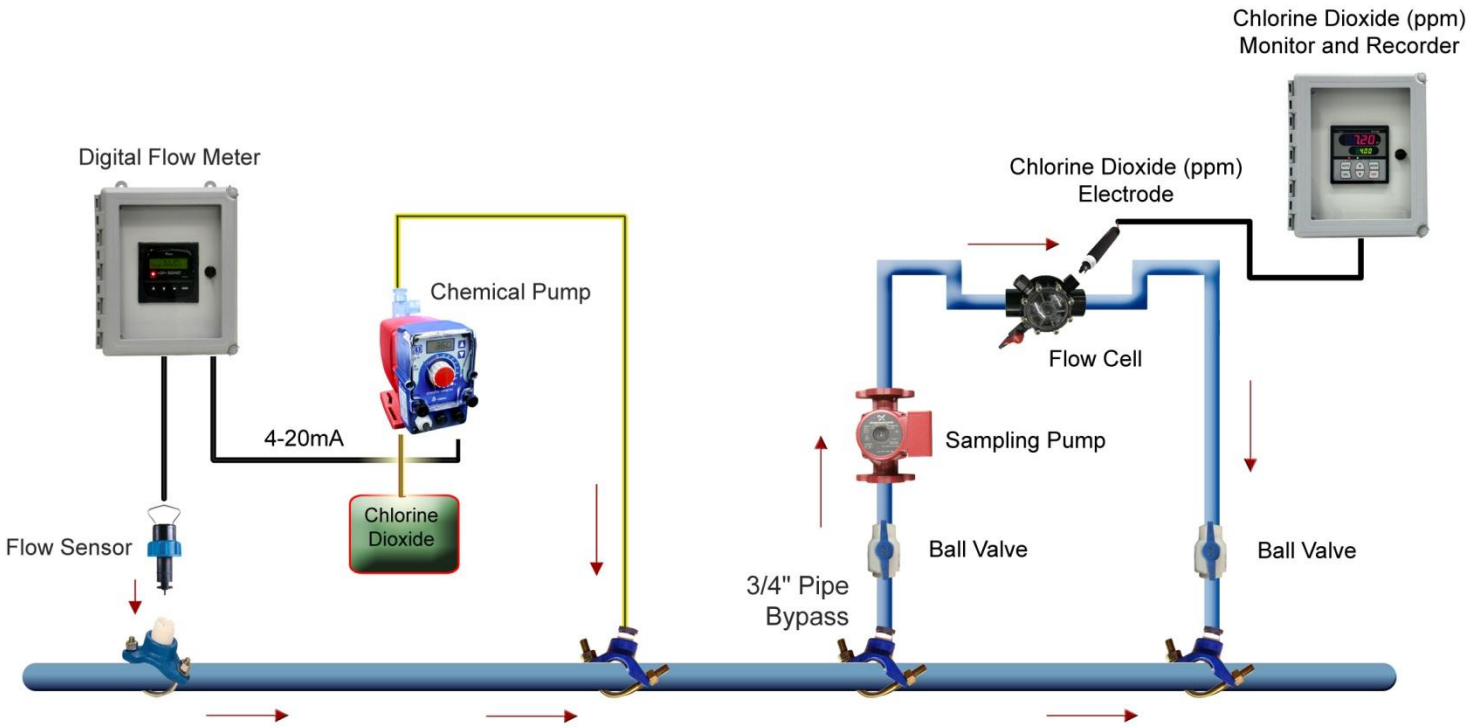

Chlorine Dioxide Generators

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Generation Process

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2 Chemical Process – 80% efficient

$$5NaClO_2 + 4HCl = 4ClO_2 + 2H_2O + 5NaCl$$

3 Chemical Process – 100% efficient

$$2NaClO_2 + NaOCl + 2HCl = 2ClO_2 + 3NaCl + H_2O$$

Chlorine Dioxide Oxidation

$$ClO_2 + 4H^+ + 5e^- = Cl^- + 2H_2O$$

Chlorine Dioxide System

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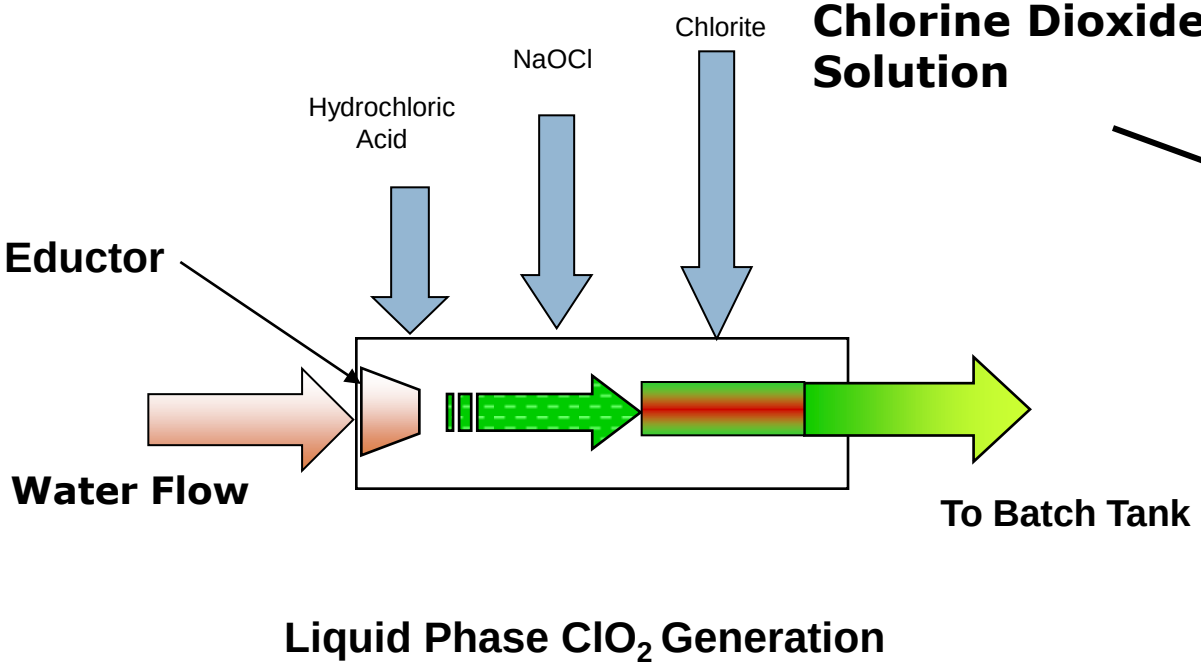
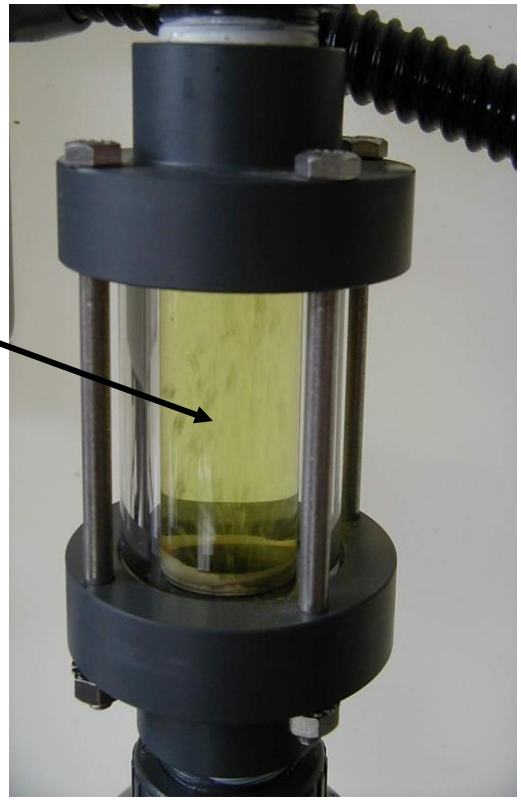
Production of Chlorine Dioxide





Liquid Phase ClO_2 Generation

Monitoring Treatment

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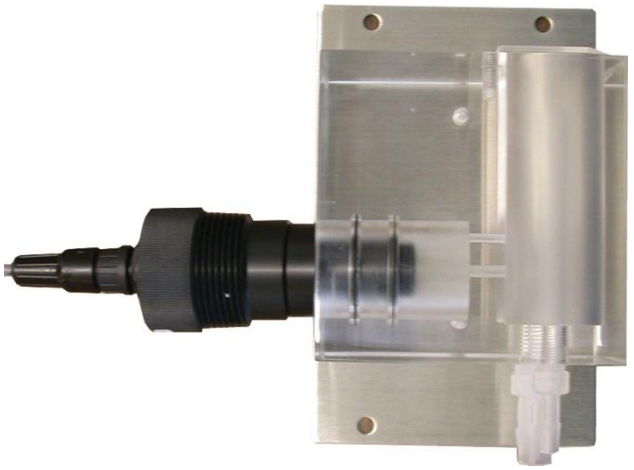
- Chlorine Dioxide Monitoring (ppm)
- Membrane Sensor
- Amperometric Measurement



APS Treatment Program

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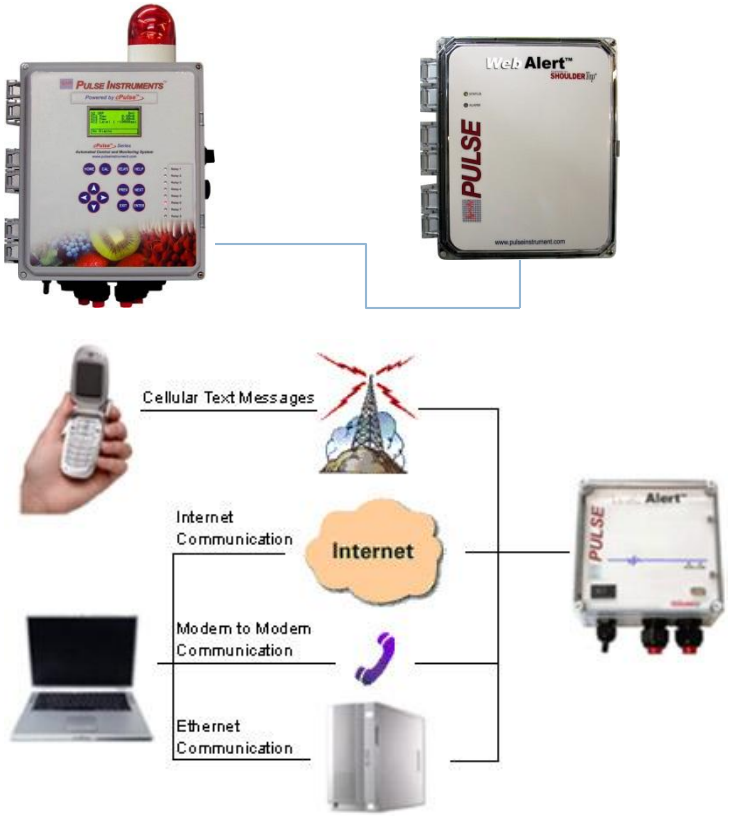
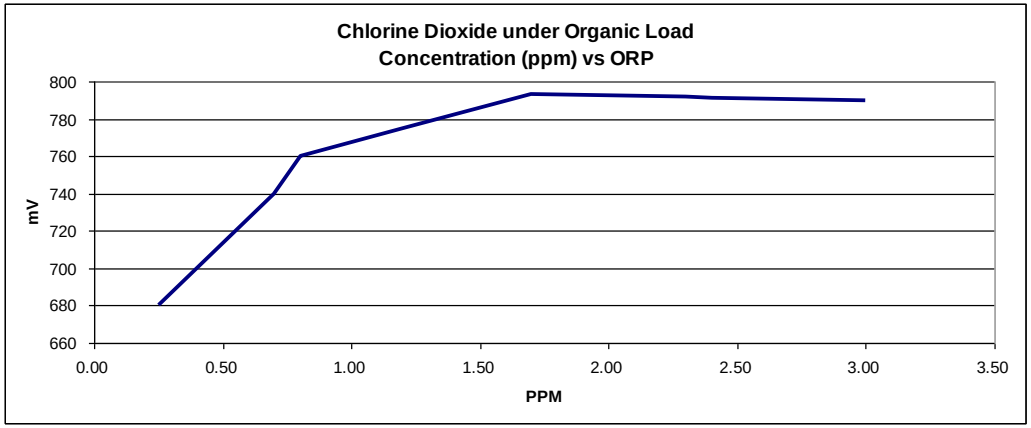
APS Full Service Program

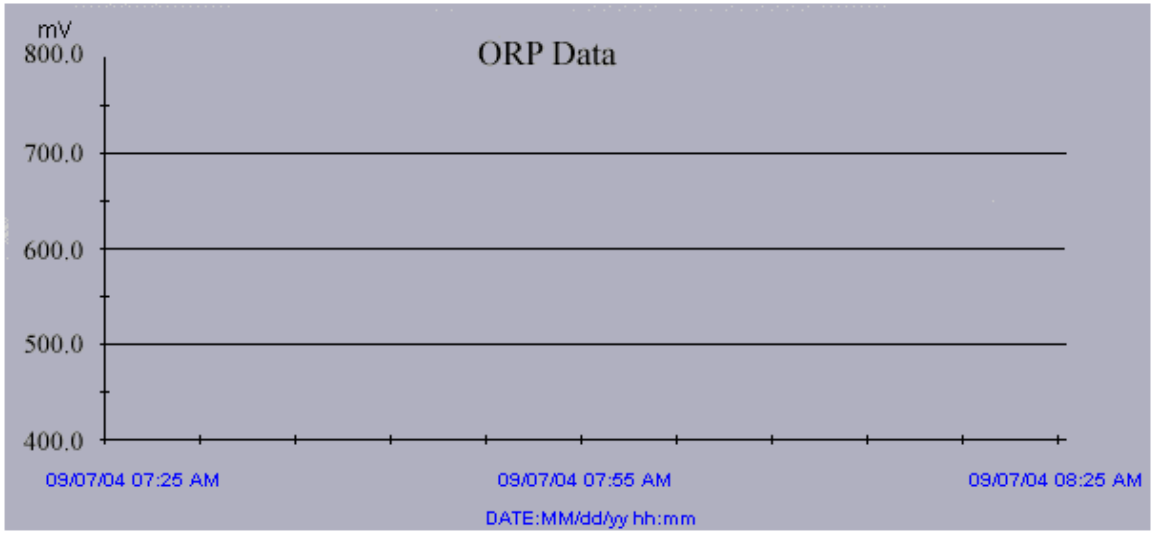
- Full Service Program
- APS Generator
- Maintenance and Service
- Includes Chemicals
- Includes Freight
- Process Monitoring
- Real Time Access
- Data Recording and Reports
- Data Management

Data Recording and Management



Chlorine Dioxide ORP





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Microsoft Excel - log_User

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Draw AutoShapes

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Formula Bar

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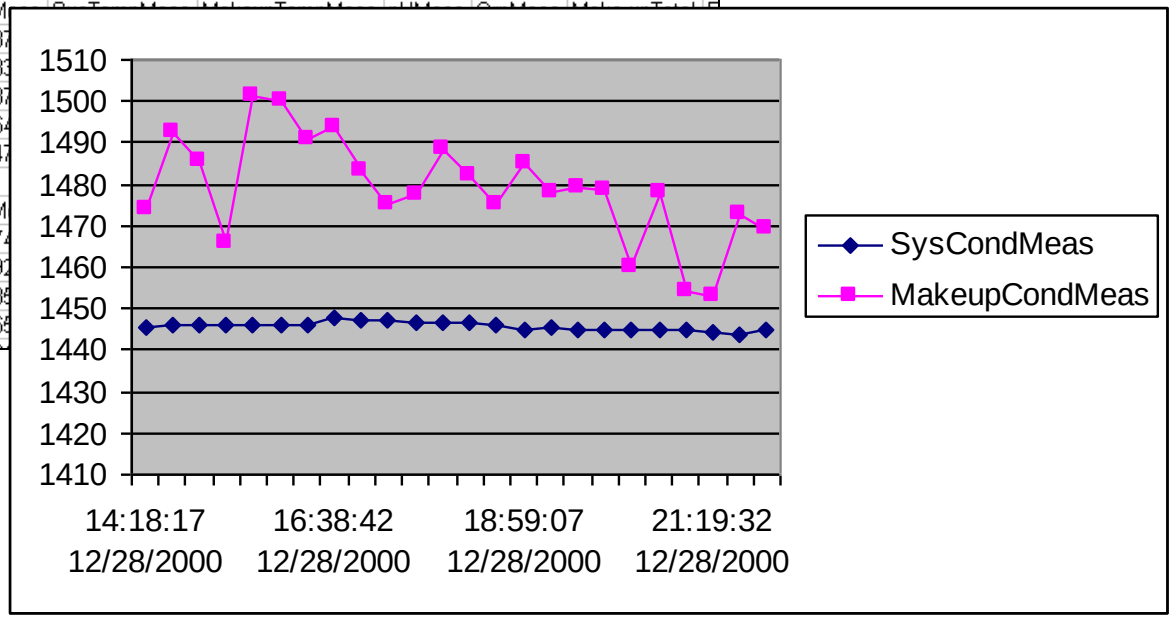
Datalogs allow user to easily create charts using Excel!



Manual download of user data log direct to USB flash without a PC!

Ongoing Research Affiliation

AQUAPULSE SYSTEMS

- University of Florida – Dr. Paul Fisher
  - Water Education Alliance Member
  - Young Plant Research Center
- Konjoian Research and Education
  - Dr. Peter Konjoian
- UC Davis – At "The Bubble" and Greenhouse Production
  - Dr. Michael Parrella
- UC Davis – Fresh Produce
  - Dr. Trevor Suslow
- Washington State University – Tree Fruit Research
  - Dr. Karen Killinger
- Montana State University – Biofilm Engineering
  - Dr. Phil Stewart

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