Antoine Technical Consulting LLC

Biological Control of Water

Presented by **Keisha Antoine, PhD, PE** at AIChE
Southwest Process Technology Conference
Moody Gardens & Conference Center
October 2016

Overview

- About Me
- Use of water in industrial processes
- Biofilms and process issues
- Chemical treatment – disinfection & corrosion inhibition
- Summary

Keisha Antoine, PhD, PE
About Me

Education
B.S. Chemical Engineering, **M. Eng.** & **Ph.D.** Materials Science & Engineering, Lehigh University
Dissertation: "*In situ* investigation of photoinduced effects in arsenic-selenium glass films by x-ray photoelectron spectroscopy (XPS) and optical spectroscopy".

Career – 10 years in Industry
Antoine Technical Consulting, LLC, Principal/Process Engineer Consultant
Corning Incorporated, Senior Chemical Engineer, Chemical Process Engineer, Development Scientist

Other Qualifications

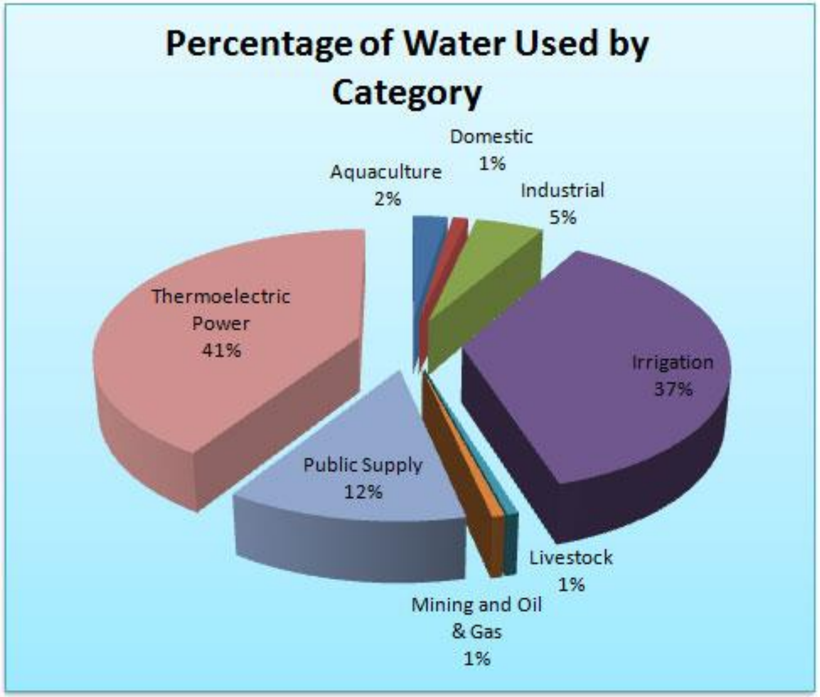
- Professional Engineer
- Peer reviewer, Journal of Non-Crystalline Solids
- National Science Foundation (NSF) Panel Reviewer
- 1 patent, 1 patent application
- Certified Green Belt
- 8 Publications, 11 presentations, 2 invited talks

Goal

- To provide an overview of chemical methods of control of biological contaminants in industrial process water
- We will discuss chemical and physical methods of biological control
- This is NOT a talk on waste water processing

Water in process use

- Water has a high heat capacity, i.e., it absorbs more heat for a given temperature rise than any other common inorganic substance. The steam is capable of carrying large quantities of heat ➔ heating and power generation
- What's in water? Dissolved gases, ions, suspended solids and other contaminants. Before process use, it must first be treated to an acceptable water quality standard appropriate for its final use
- Water impurities can cause problems with equipment leading to issues like reduced flow, high back pressure, reduced heat transfer, higher utility bills for pumping and heating, unexpected downtime from equipment failure



https://fracfocus.org/water-protection/hydraulic-fracturing-usage

Water Contaminants

Organic

Carbon-based – synthetic + natural organic matter (NOM). Synthetic: derived from petroleum e.g., dioxin, PCBs NOM: Humic acid, fulvic acid, amines, urea

Biological

Contact with the environment, air, humans and other animals
Microbes
Algae, Protozoa, Bacteria, Viruses

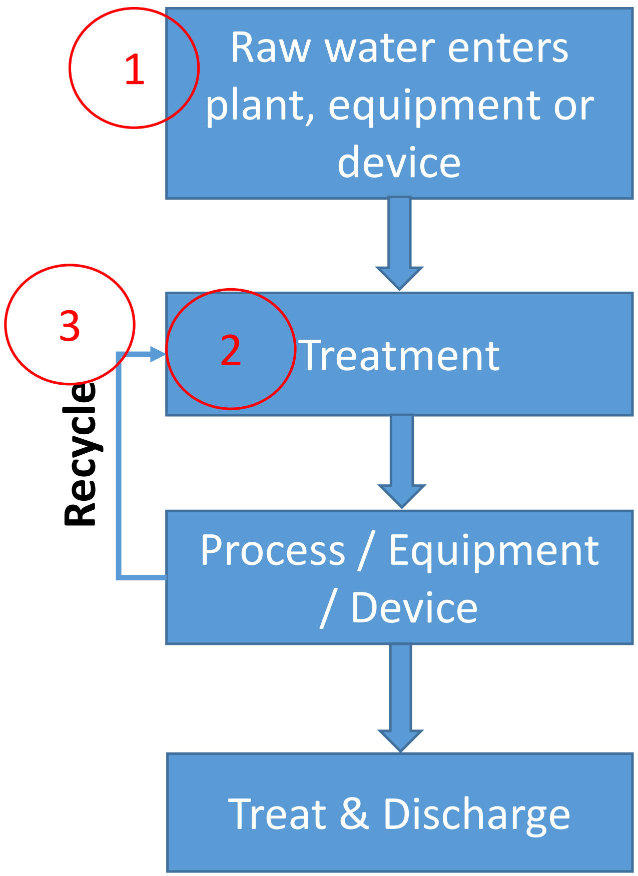
Inorganic minerals

Minerals and toxic metals. Nutrients from Agriculture runoff
From water source: Calcium, magnesium, iron
From piping networks: copper, lead, arsenic, iron

Radioactive minerals

Uranium, plutonium, radium
A concern of produced water from fracking

High Level Process of Water Flow

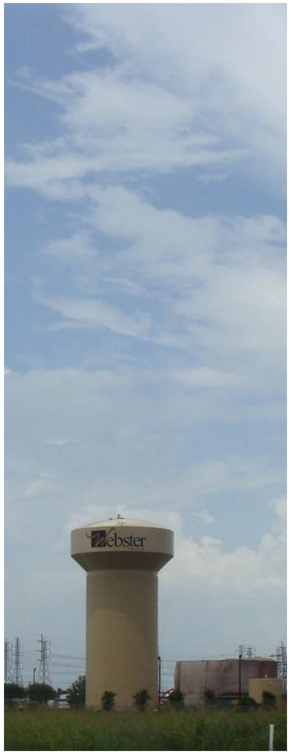


Process Flow	Microbes path of entry
Water source: River, Lake, Groundwater, Seawater, Municipal	✓
Provide water of a given spec eliminating or reducing: Suspended solids, Dissolved ions, Organic contaminants, Biological contaminants	✓
Water used for: Cooling, Boilers/power generation, Washing, rinsing, Incorporated in food/beverage	✓
After process use, a portion of the water is recycled and the rest is treated and discharged	

The goal of Industrial water treatment:
make efficient or optimize industrial water use

Heating & cooling

The goal of Industrial water treatment:
make efficient or optimize industrial water use



Storage

The goal of Industrial water treatment:
make efficient or optimize industrial water use

Processing

Fire suppression

We will focus on Biological contaminants in process water – not wastewater treatment

- Biological contaminants can lead to formation of biofilms
  - Reduced hydraulic diameter, Reduced flow, Reduced heat transfer, overheating of pipes and/or increased fuel usage. **BOILERS**
  - Provision of nutrients and protection for breeding of microorganisms that can be harmful to human health, e.g. Legionnaire's disease. **COOLING TOWERS.**
  - Sites for microbiological induced corrosion, leading to leaks and tuberculation and therefore shortened equipment lifespan. **ALL PROCESS EQUIPMENT.**

http://www.waterandhealth.org/battling-biofilms-aging-water-infrastructure/

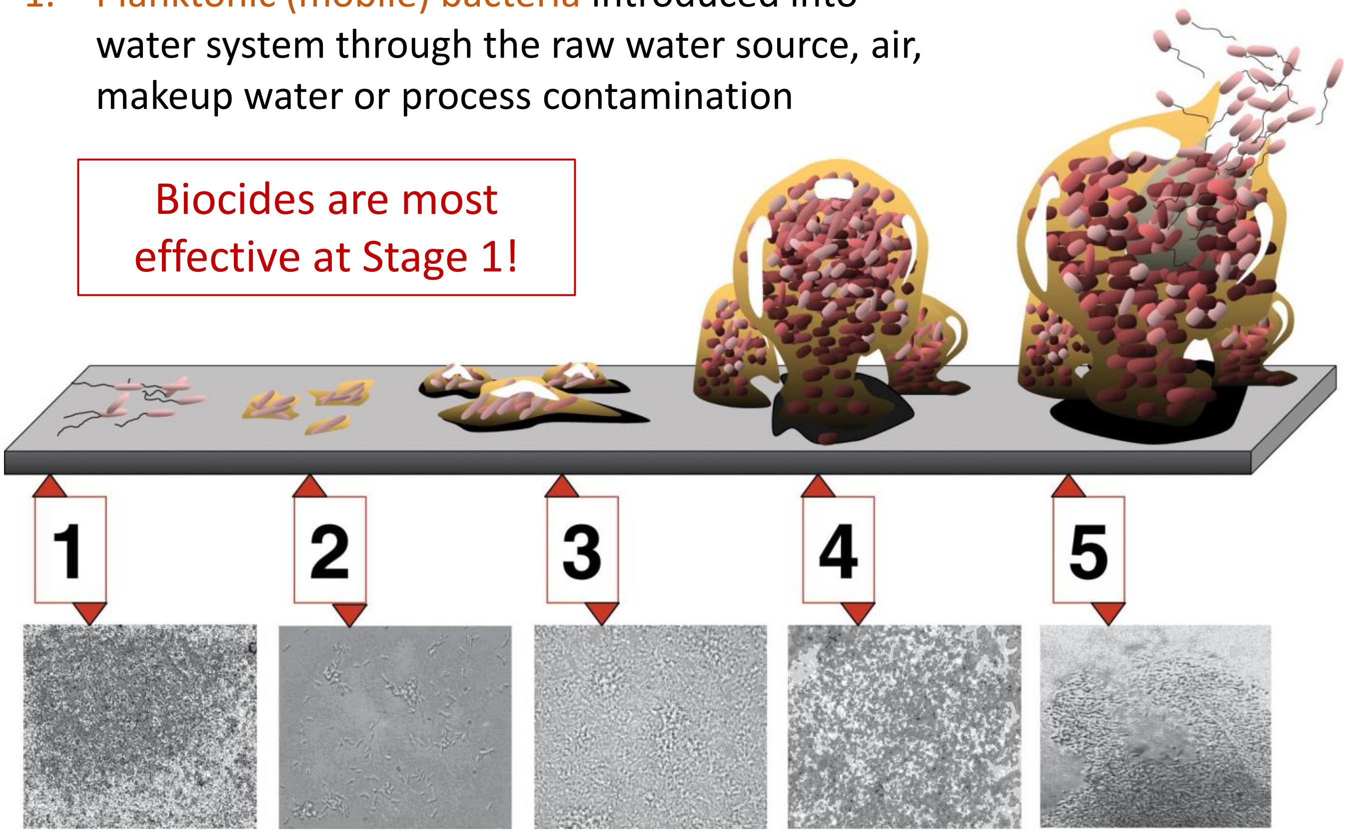
EXHIBIT S3.5 Interior Tubercle.

From Automatic Sprinkler Systems Handbook 2007, Supplement 3, Microbiologically Influenced Corrosion in Fire Sprinkler Systems, Bruce H. Clarke, Anthony M. Aguilera, p. 955

Biofilm formation

1. Planktonic (mobile) bacteria introduced into water system through the raw water source, air, makeup water or process contamination

Biocides are most effective at Stage 1!



2 - 4. The bacteria become sessile (fixed to a surface) where they can grow and multiply, creating a biofilm.

5. Dispersion. The biofilm continues to grow until some of it disperses to colonize new surfaces. The process is then repeated.

By D. Davis - From: Looking for Chinks in the Armor of Bacterial Biofilms Monroe D PLoS Biology Vol. 5, No. 11, e307 doi:10.1371/journal.pbio.0050307 http://biology.plosjournals.org/perlserv/?request=slideshow&type=figure&doi=10.1371/journal.pbio.0050307&id=89595, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=3364284

Mitigate biofilm formation by **Disinfection**

Disinfection – Keep the System Clean!

- Specialized cleaning techniques that destroy and prevent growth or organisms capable of infection.
- Expose microorganisms to chemical or physical agents

The effectiveness of disinfection is determined by testing for an indicator organism (total coliform bacteria). Although this organism is considered harmless, its presence indicates that pathogens may also have survived.

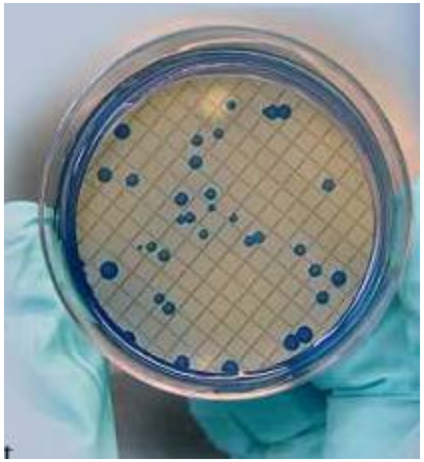
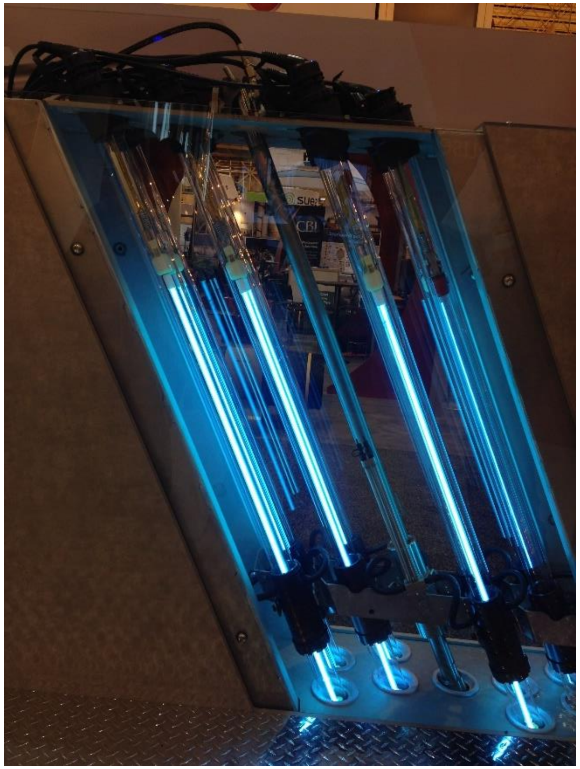


Image: *"Bacteria and Private Wells, Information Every Well Owner Should Know",* Cliff Tyrens, Director of Public Awareness, National Ground Water Association

Disinfection Methods



UV Disinfection system by TrojanUV

On-site sodium hypochlorite generation (chlorination) by De Nora

Primary

- Chlorination
- Chloramines
- Ozone
- Ultraviolet light (UV)

Other

- Chlorine dioxide,
- Potassium permanganate
- Nanofiltration.

Considerations for picking a biocide

- Water chemistry (dissolved solids, particles of organic matter other non-pathogenic microorganisms)
- pH
- Type of microbes present and efficacy against those microbes
- Compatibility with corrosion inhibitors
- Retention time (length of time it remains active in the system)
- Contact time (CT) = disinfectant residual concentration [mg/L] x minimum contact time [minutes] of disinfectant with microorganism
- System volume
- Temperature
- Discharge points and permitting requirements
- Compatibility with materials of construction
- Cost

Types of Biocides

Oxidizing biocides – for maintenance

Chemicals that kill microorganisms by the electrochemical process of oxidation. The microorganism is oxidized by the oxidizing agent which is itself reduced by gaining electrons. Can create disinfectant byproducts, unwanted and oftentimes harmful if above defined thresholds. Continuous or shot-fed application.

Non-oxidizing biocides

They work through various processes, e.g., interfering with reproduction, stopping respiration, lysis. Generally shot fed to achieve a high enough concentration for a sufficient period of time (several hours up to a day) to kill the bacteria, algae or fungi.

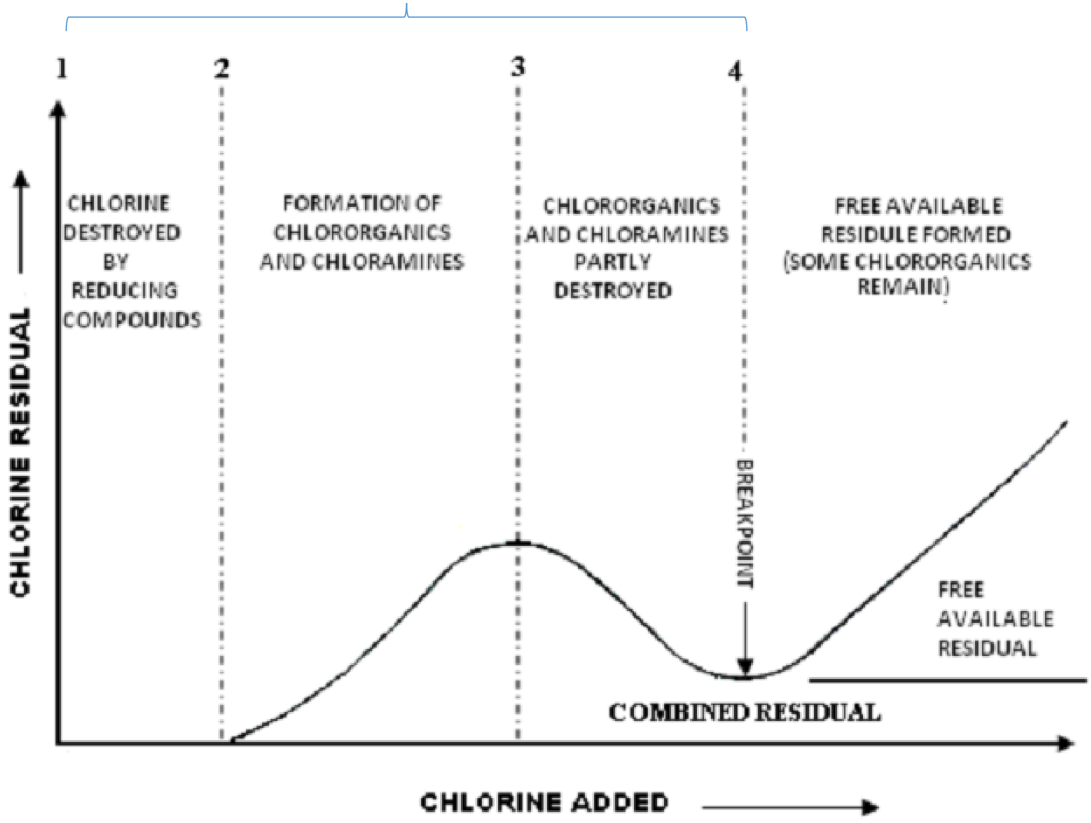
Surfactants, biodispersants, biopenetrants

Chemicals that can penetrate and loosen the complex matrix of biofilms allow biocides to reach the organisms for more effective kill and control. Usually shot fed at dosages that break down polysaccharides, emulsify oils, release minerals and foulants or disperse the bipolymers

Be aware of **Disinfectant Demand**

Disinfectant demand

reactions of the disinfectant with substances other than pathogenic microorganisms



- Disinfectant demand consumes the disinfectant.
- Therefore, excess disinfectant must be added to provide a sufficient concentration of residual disinfectant to effectively kill pathogenic organisms.

Corrosion Inhibitors reduce Disinfectant Demand

https://www.nachi.org/forum/f22/copper-pipe-flux-corrosion-89835/

- Corrosion inhibition is especially important for unlined cast iron and unlined ductile iron pipes (old infrastructure). Ferrous compounds provide nutrients for microbial contaminants.

- Although corrosion inhibitors are phosphorous-based, which itself may be a nutrient source, these inhibitors:
  - ↓ the leaching of lead and copper ➔ ↓ disinfectant load and ↑ residual disinfectant

Effective corrosion control + disinfection = ↓biofilm growth + ↓microbiological contamination

Summary

- **Keep system clean! Reduce available nutrients & disinfectant demand**
  1. At design stage, incorporate use of alternative piping materials to unlined cast iron
  2. If older system using unlined cast iron, ensure an effective anti-corrosion program using phosphate-based inhibitors.
  3. Maintain high residual chlorine (within permitted limits) or other oxidizer for secondary disinfection. High residuals can be a deterrent to biofilm formation
- **Choice of treatment plan depends on system**
  - New vs. in-service and fouled
  - pH and other process conditions
  - Permitting requirements/limits