Chloramines and the Distribution System

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Outline

Effectiveness of Chloramines versus Chlorine

Control of Positive Total Coliform

Persistence of Distribution System Residuals

Chloramine Breakdown and Ammonia Release

Nitrification: Adverse Effects on Water Quality

H2O'C ENGINEERING

Chloramination

$Cl_2 + H_2O \Rightarrow HOCl + H^+ + Cl^-$

Chlorine normally added first to establish C x t credit

$NH_3 + HOCl \Rightarrow NH_2Cl + H_2O$

Ammonia added with mixing to accelerate kinetics,
Primarily, monochloramine formed at pH > 7

$NH_2Cl + HOCL \Rightarrow NHCl_2 + H_2O$

Dichloramine formation is significant at pH < 7 and when chlorine addition is near the breakpoint

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Chloramine Decay

$$NH_2Cl + H_2O \Rightarrow NH_4^+ + OCl^-$$

Depletion of disinfectant residual

Increase in food for nitrifying organisms

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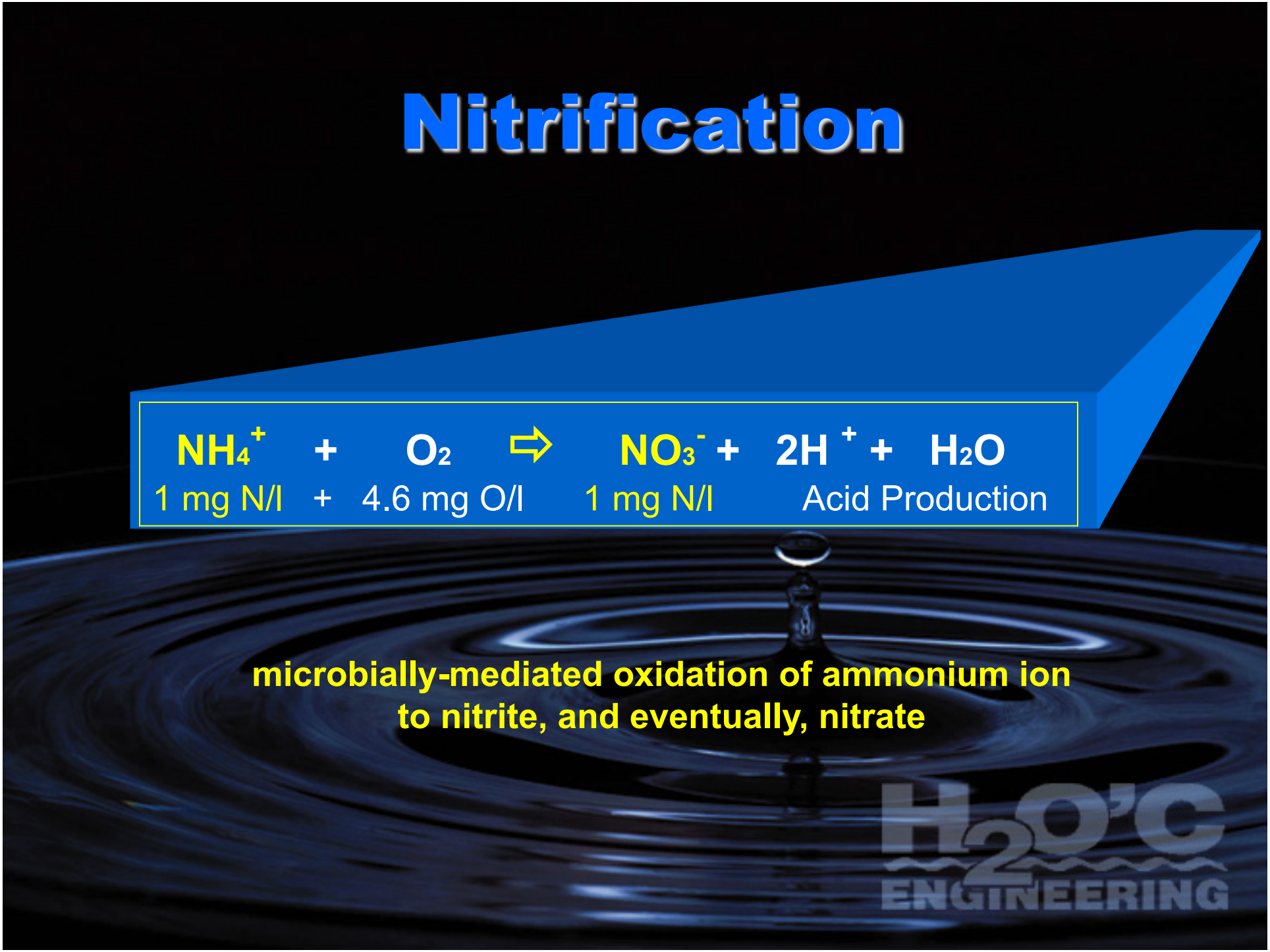
Nitrification



$$NH_4^+ + O_2 \Rightarrow NO_3^- + 2H^+ + H_2O$$

1 mg N/l + 4.6 mg O/l → 1 mg N/l + Acid Production

microbially-mediated oxidation of ammonium ion to nitrite, and eventually, nitrate

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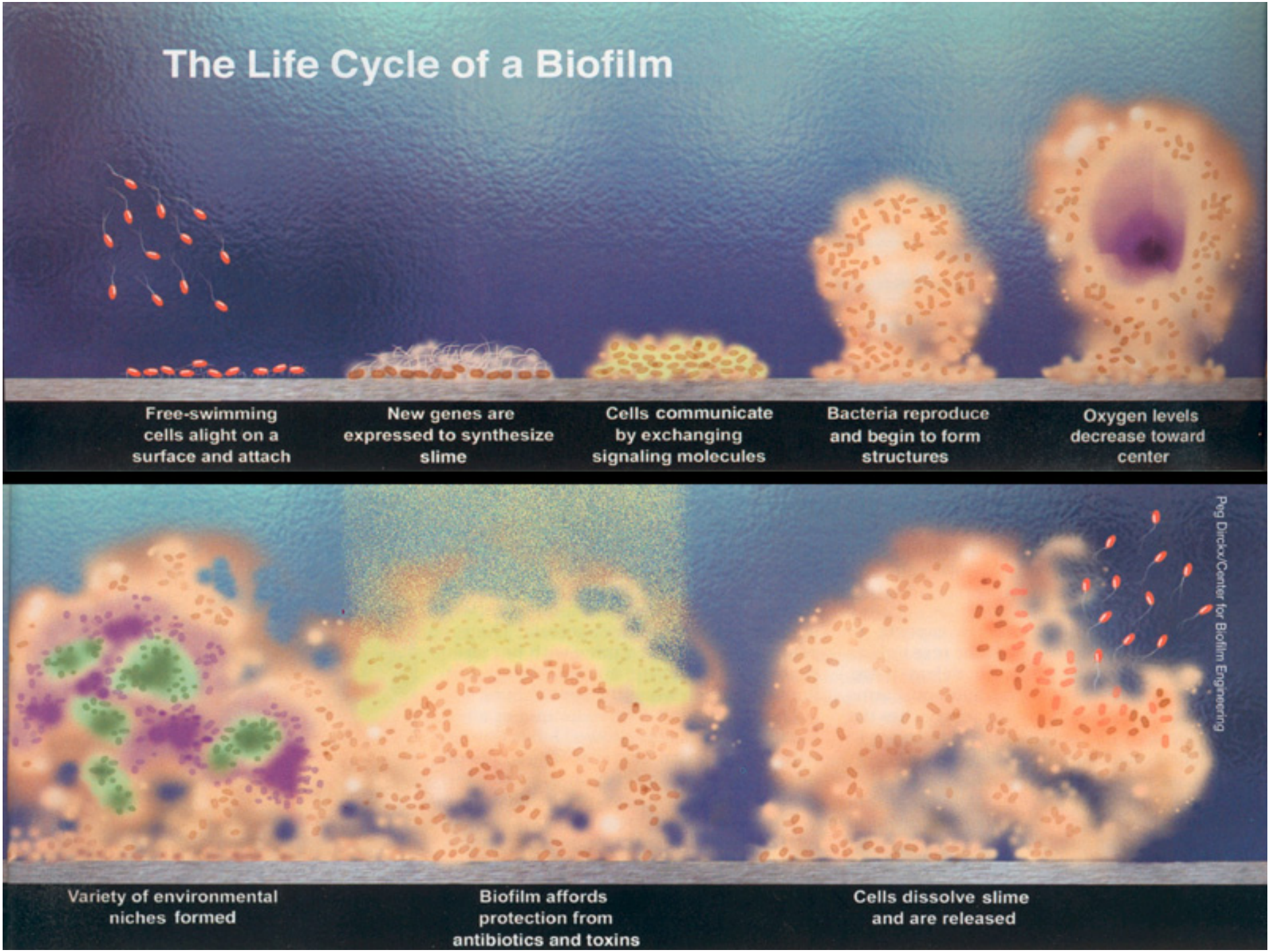
The Life Cycle of a Biofilm
Free-swimming cells alight on a surface and attach
New genes are expressed to synthesize slime
Cells communicate by exchanging signaling molecules
Bacteria reproduce and begin to form structures
Oxygen levels decrease toward center
Variety of environmental niches formed
Biofilm affords protection from antibiotics and toxins
Cells dissolve slime and are released
Peg Dirckx/Center for Biofilm Engineering

Effects of Nitrification on a Distribution (Closed) System

Ammonium Ion consumed = Nitrate produced

Oxygen depleted (4.6 O: 1 N) ⇨ anoxia

Acid produced = Alkalinity consumed
pH lowered in distribution system

Nitrite Ion (NO_2^-), a reducing agent formed as an intermediate, reacts to consume disinfectant residuals (chlorine, chloramine)

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Distribution System Monitoring

Look for: loss of oxygen (field DO probe)

pH, alkalinity decrease

free and total chlorine depletion

Heterotrophic Plate Count increase

Monitor Nitrogen Series:

nitrite (MCL: 1 mg N /l),

nitrate (MCL: 10 mg N /l),

ammonium ion

$\sum N$ = (ammonium + nitrite + nitrate) as N = constant

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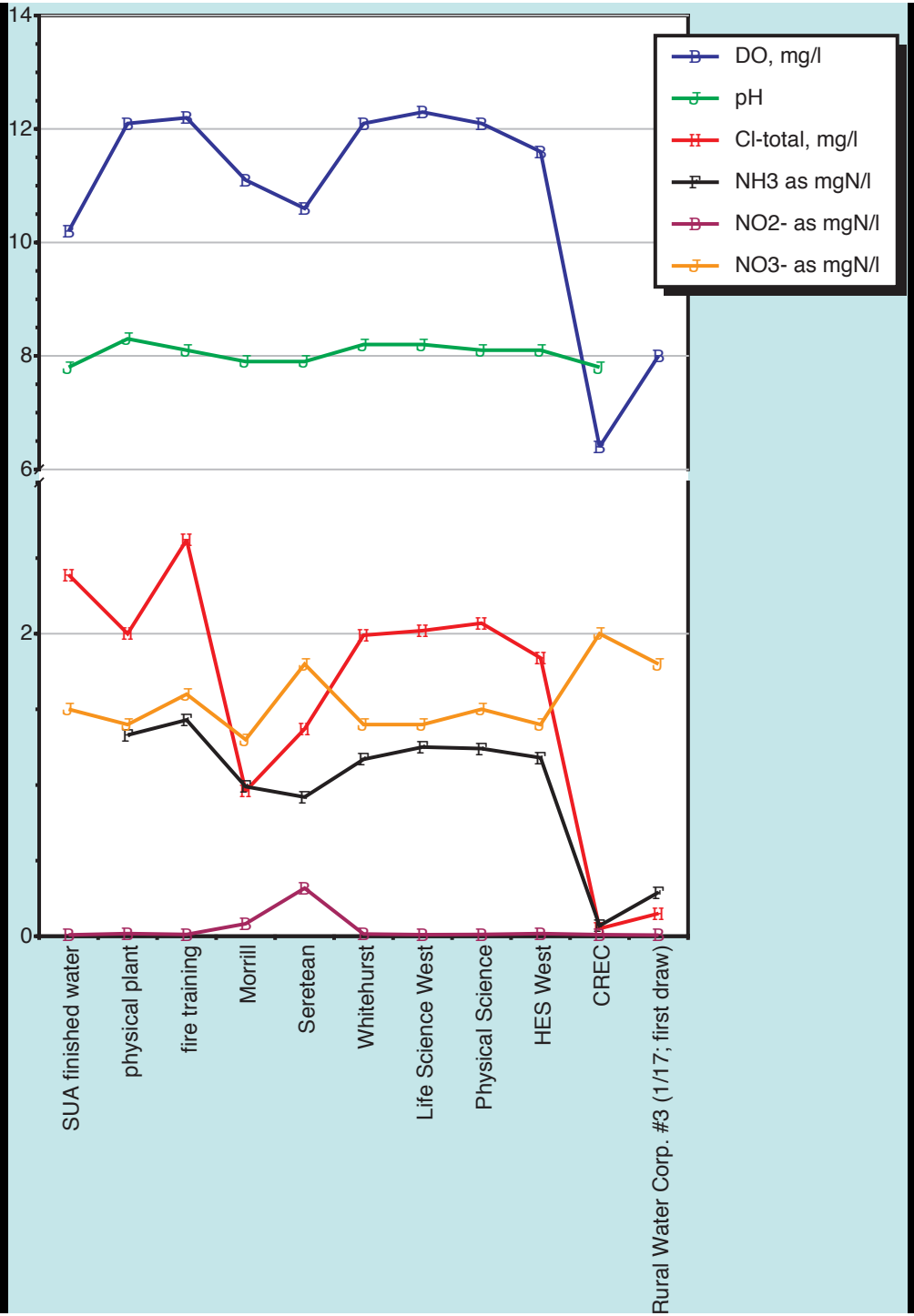
Distribution System Monitoring

Oklahoma State Univ. - Jan. 2002



Water Utility	*% Positive Total Coliform,*	*Residual*
New Haven, CT	6.6	Chlorine
Los Angeles, CA	3.2	Chlorine
Boston, MA	2.2	Unfiltered
Louisville, KY	2.2	Chloramine
Oakland, CA	0.41	Chlorine
Phoenix, AZ	0.3	Chlorine
Baltimore, MD	0.22	Chlorine
New Orleans, LA	0.19	Chloramine
St. Louis, MO	0.17	Chloramine
MWD So. CA	0.1	Chloramine
Cleveland, OH	0.1	Chlorine
Kansas City, MO	0.1	Chloramine
St. Louis County	0.04	Chloramine
Dallas, TX	0.006	Chloramine

Chlorine vs. Chloramine

Utilities employing *chloramine*
as a distribution system residual recovered
8.6 times *fewer* positive total coliform
samples than utilities using chlorine.

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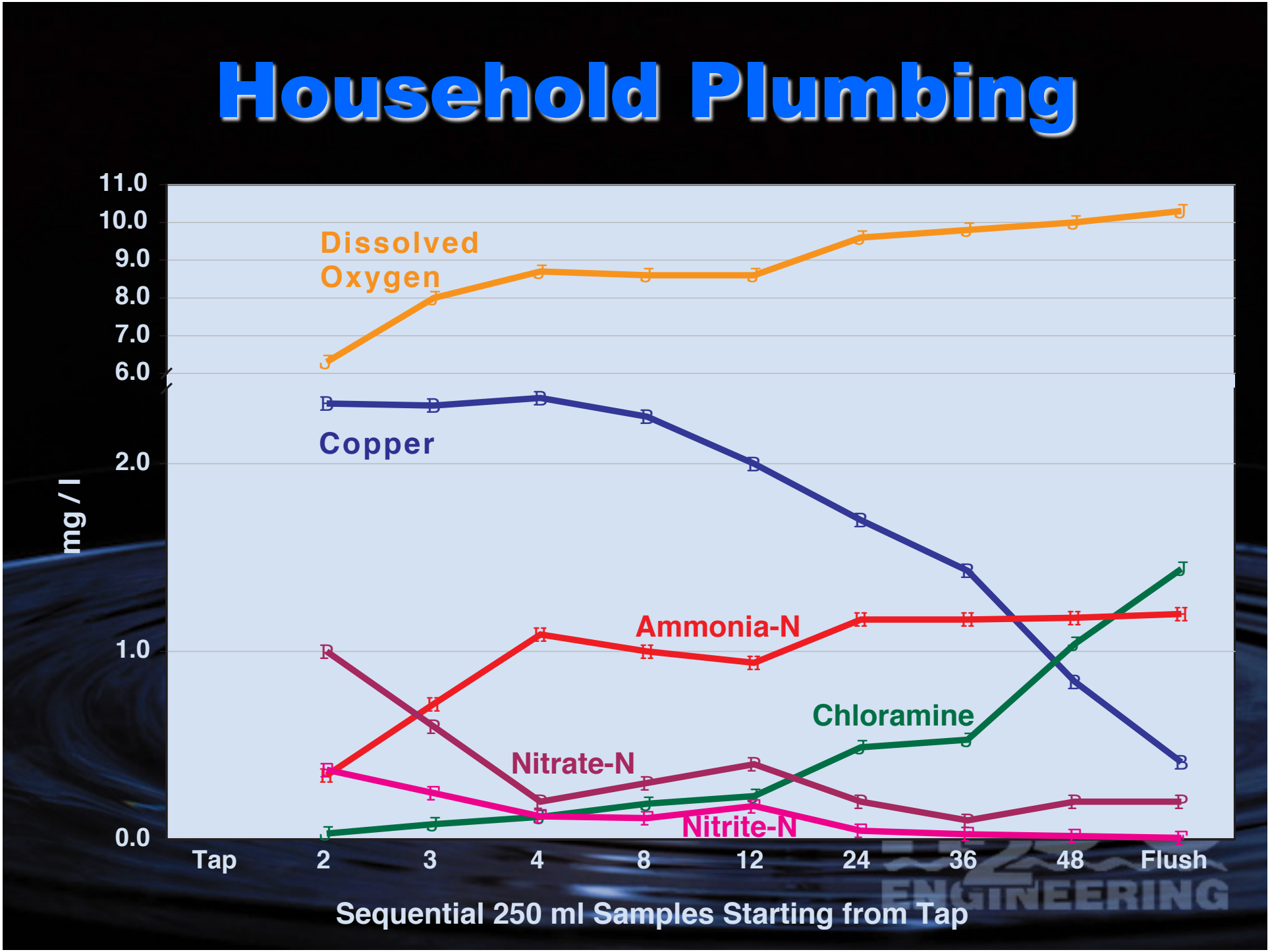
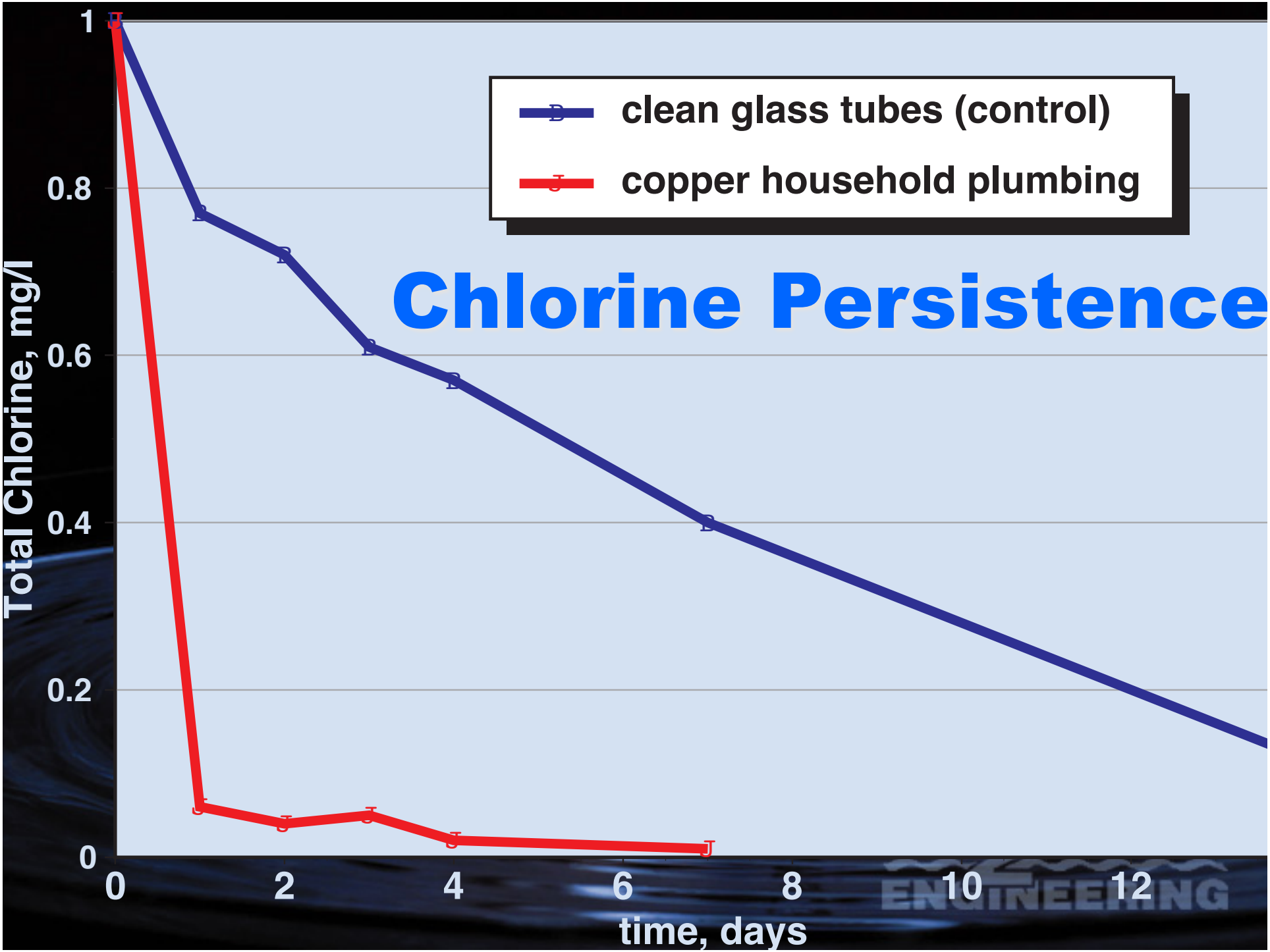
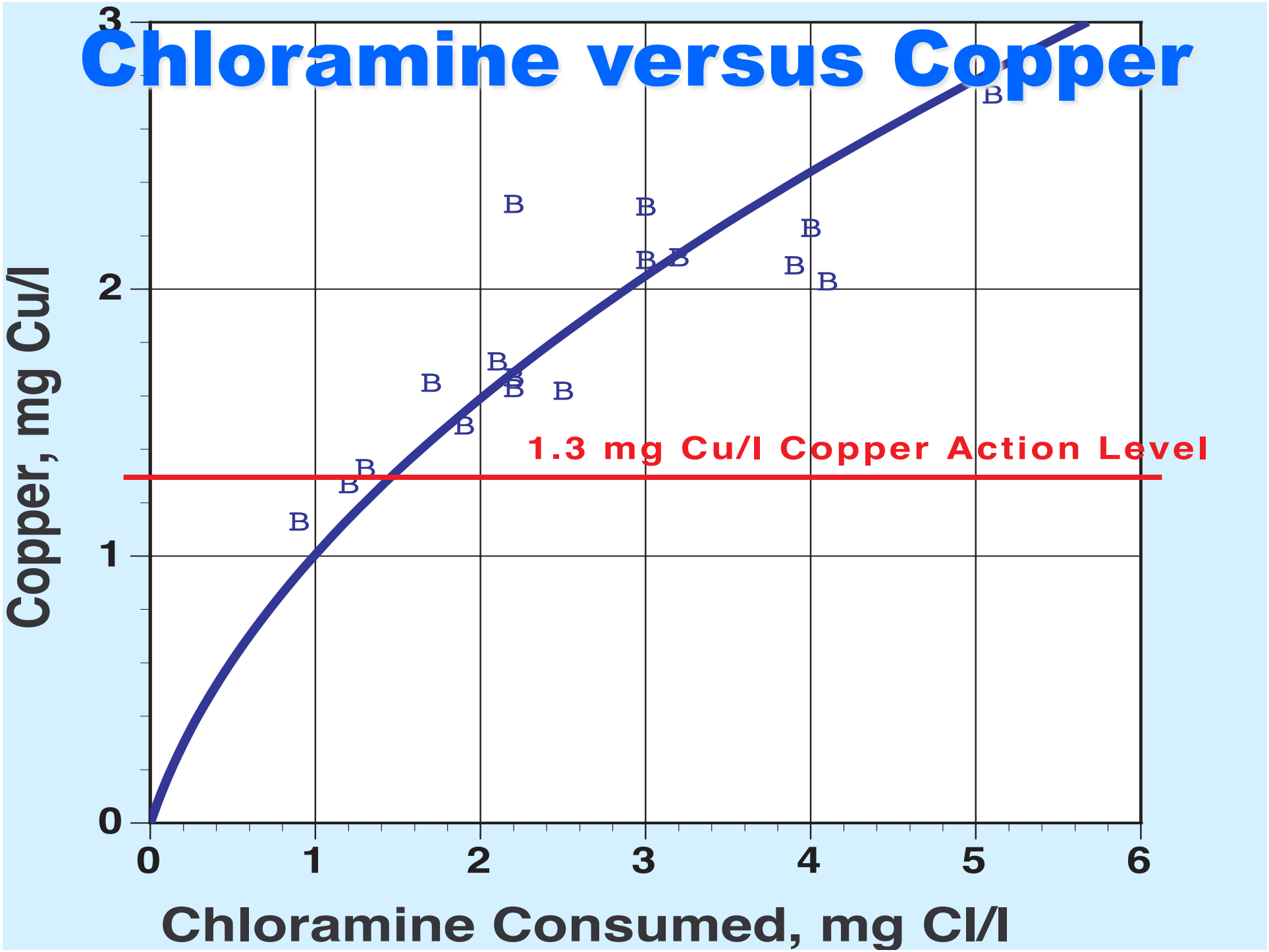
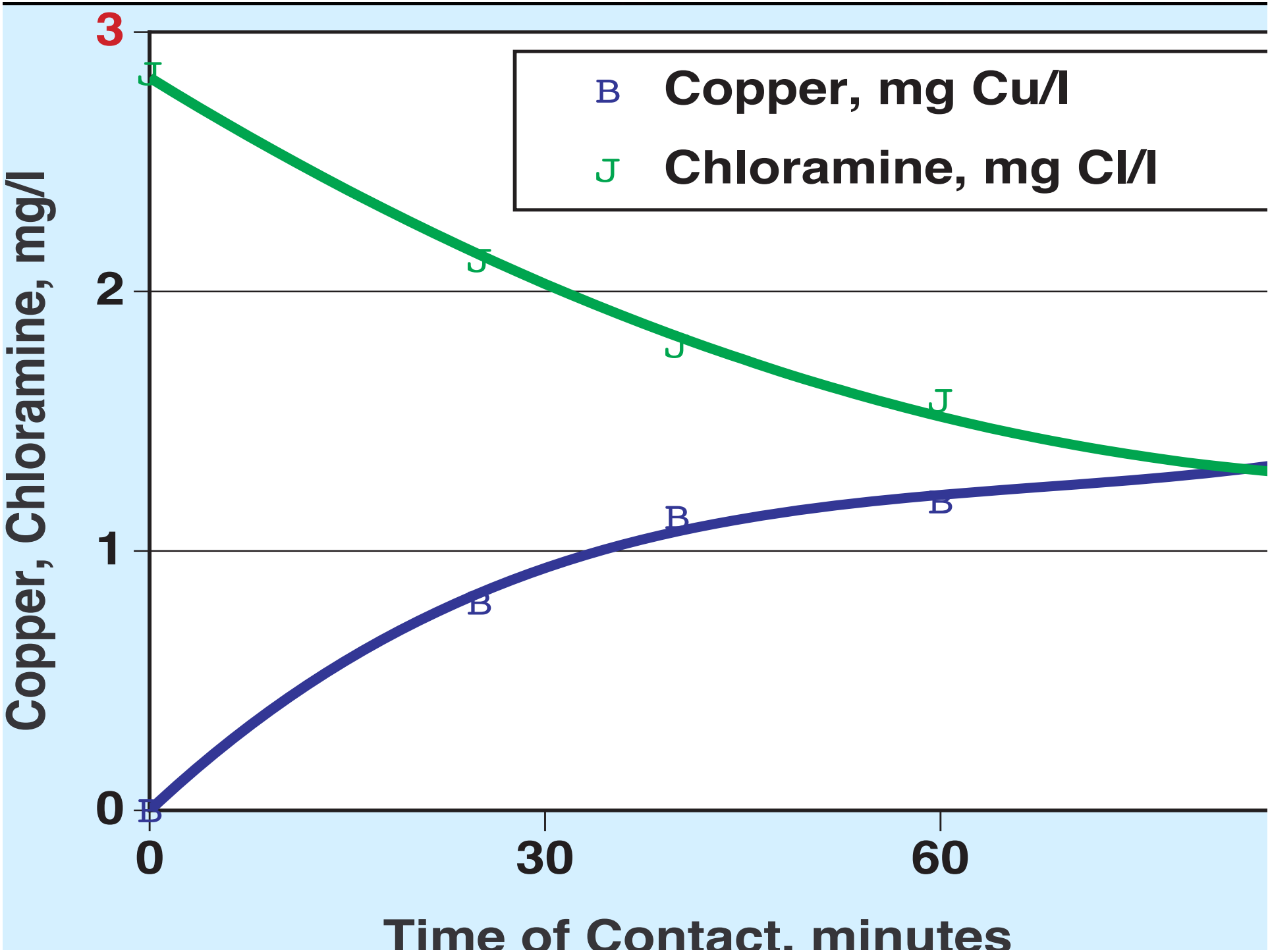
Household Plumbing




Chlorine Persistence
clean glass tubes (control)
copper household plumbing
Total Chlorine, mg/l
time, days
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
12


Chloramine versus Copper
Copper, mg Cu/l
Chloramine Consumed, mg Cl/l
1.3 mg Cu/l Copper Action Level
0
1
2
3
4
5
6


3
2
1
0
Copper, Chloramine, mg/l
B Copper, mg Cu/l
J Chloramine, mg Cl/l
0
30
60
Time of Contact, minutes

Copper Monitoring - Willmar, MN