Ozone Drinking Water Treatment Applications and Operational Improvements

Ohio Section
AWWA
18 September 2008

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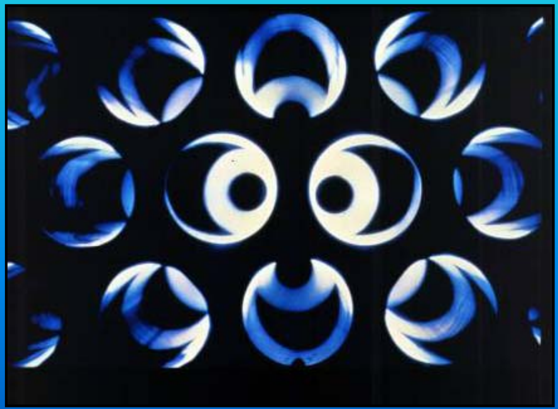
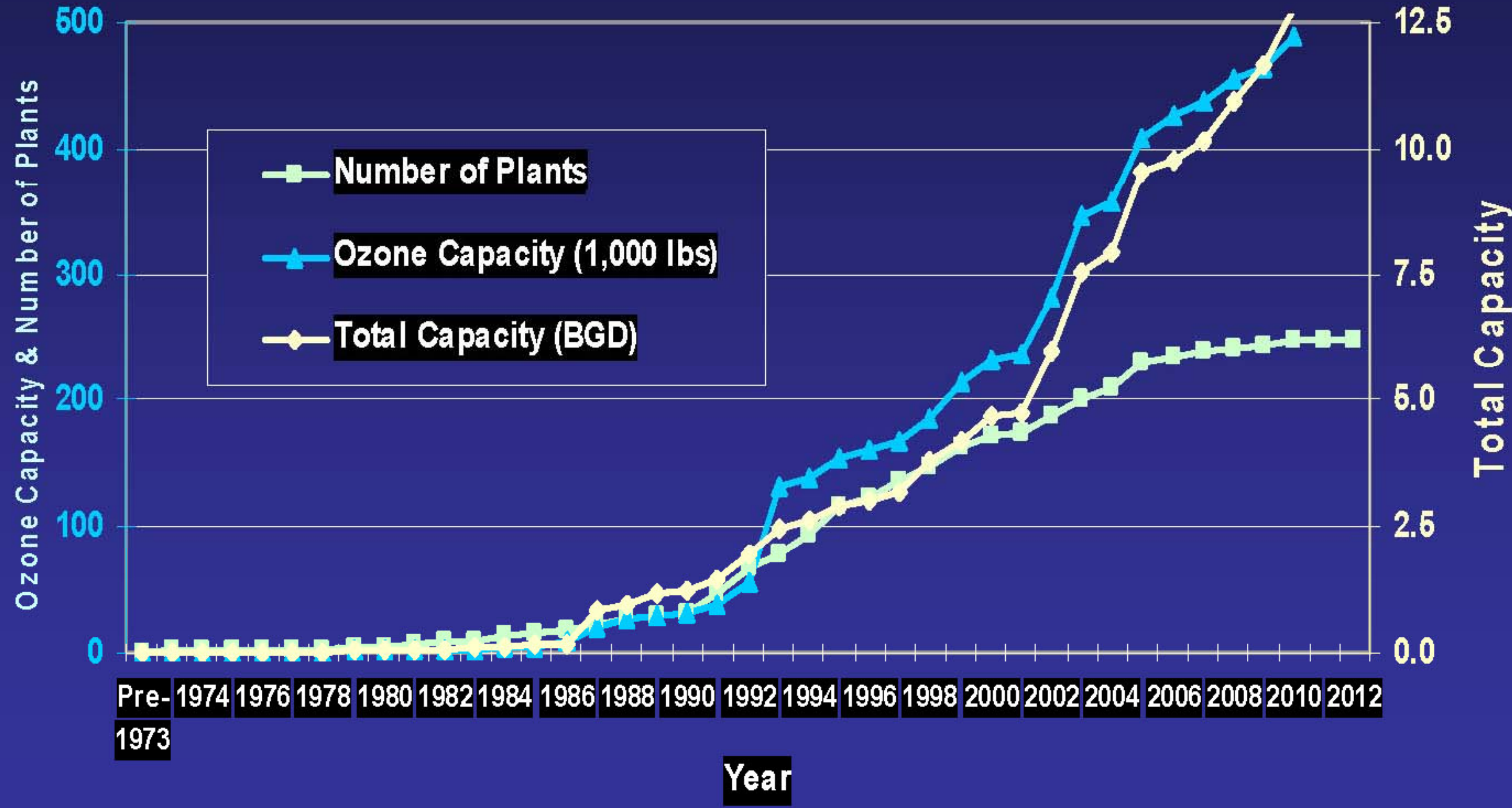
International Ozone Association



Ozone Use at WTPs in United States

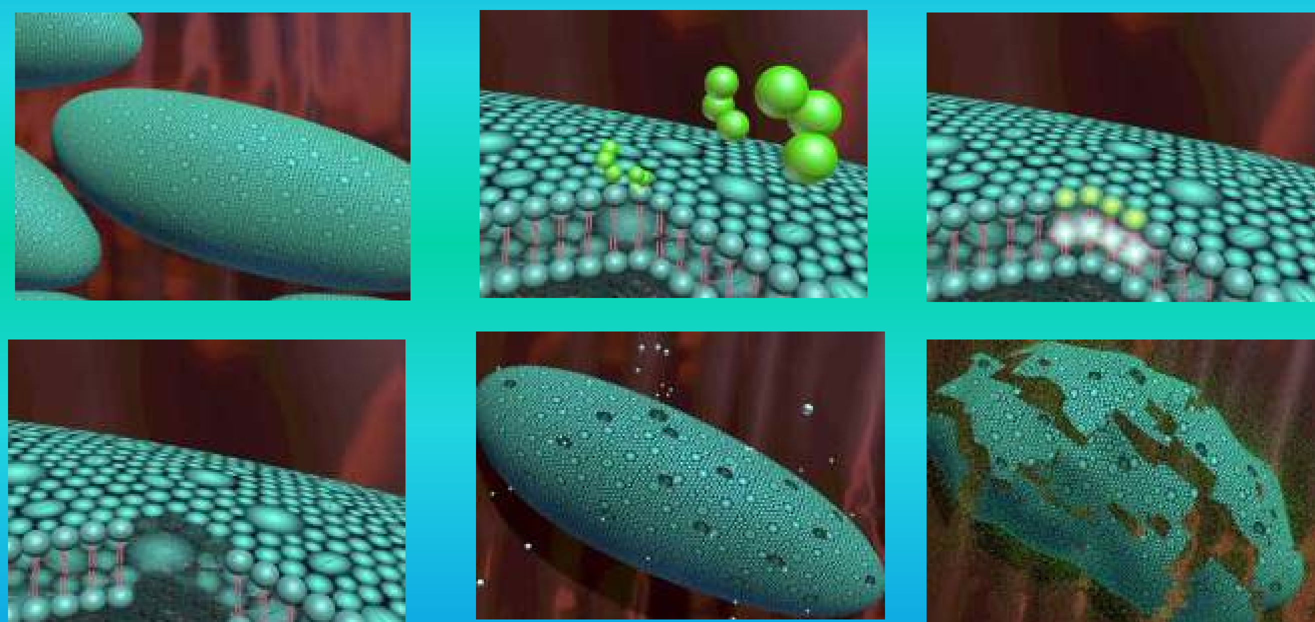


OZONE

- *Providing Multiple Benefits*
  - **Oxidation**
    - **TOC**
    - **Fe/Mn**
    - **Hydrogen Sulfide**
    - **Taste & Odor**
    - **Color**
    - **CL2-DBPs**
    - **EDC**
  - **Disinfection**
    - **Bacteria**
    - **Virus**
    - **Parasites**
  - **Flocculation**
    - **Less Chemical Coagulant**
    - **Lower solids Handling**
    - **Lower Turbidity & Particles**
    - **Longer Run time**
    - **Less Backwashing**

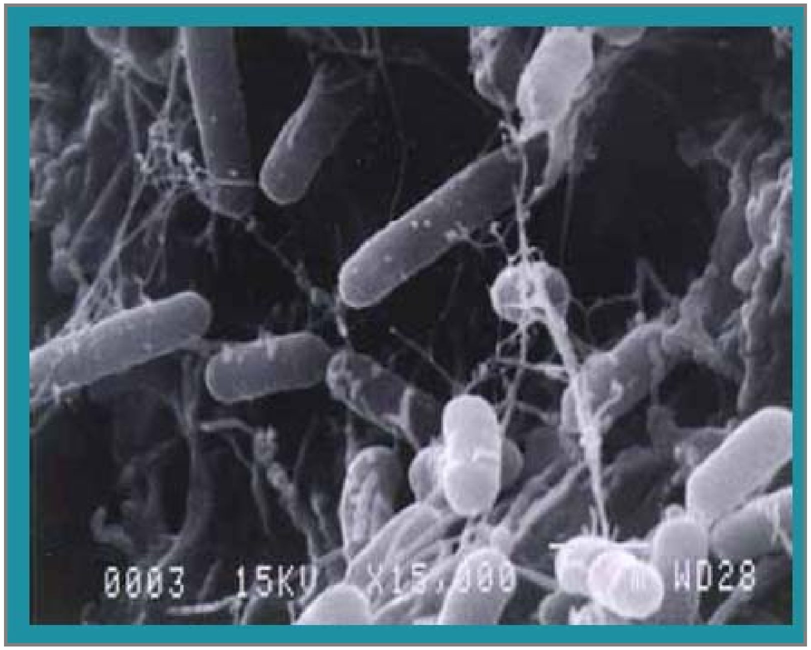
Photo Courtesy of SNWA

Ozone destroys bacteria, viruses, cysts and parasites



Ozone Biocidal Behavior

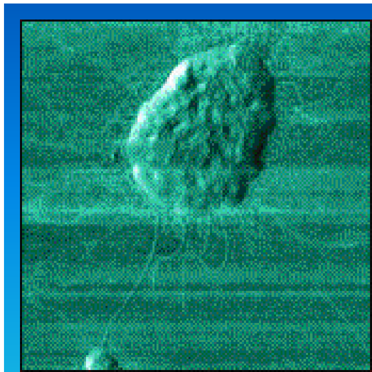
Before ozone treatment



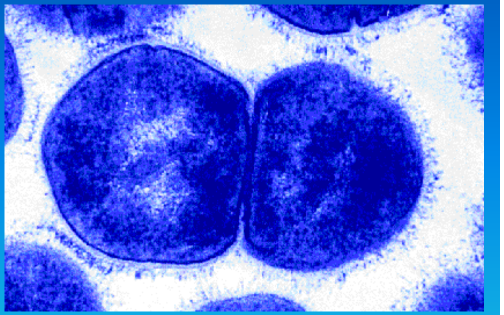
After ozone treatment

1. Ozone oxidizes cell membrane, causing osmotic bursting
2. Ozone continues to oxidize enzymes and DNA

Air Liquide America Corp., Chicago Research Center, James T.C. Yuan, Ph.D., year 2000

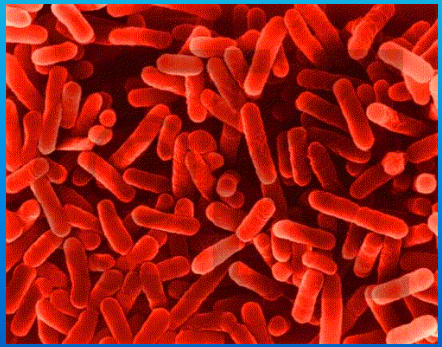


Bacteria Inactivation by Ozone



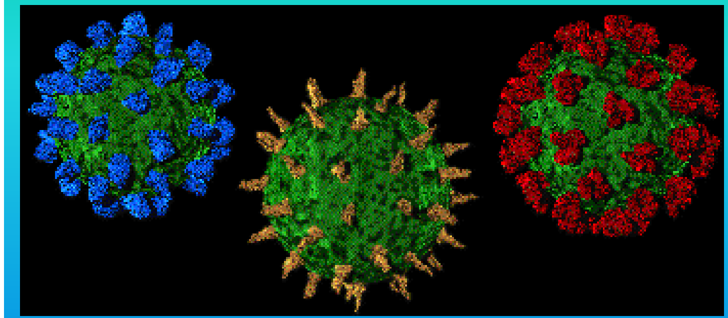
CT = residual concentration (mg/L) x time (min)

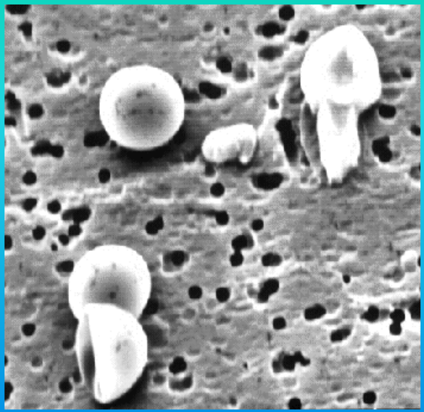
E. coli	0.02 - 0.06 mg-min/L	= **CT (2-log)AWWA**
Streptococcus faecalis	0.01 - 0.025 mg-min/L	= **CT (2-log)AWWA**
Legionella pneumophila	0.3 - 1.1 mg-min/L	= **CT (2-log)AWWA**
Total Coliform	0.19 mg-min/L	= **CT (6-log) LAAFP**
HPC	0.19 mg-min/L	= **CT (3-log) LAAFP**



Ct Values (mg x min./L) For 99.9 % Inactivation of Giardia and 99.99% Virus

				Data for 5°C	
	Free Chlorine	Chloramine	Chlorine Dioxide	Ozone	
	(pH 6 to 7)	(pH 8 to 9)	(pH 6 to 7)	(pH 6 to 7)	
Giardia	122	2200	26.0	1.9	
Virus	8	1988	33.4	1.2	





Taken from: "Optimizing Water Treatment Plant Performance Using Composite Correction Program." prepared by Process Applications, Inc., for the U.S. EPA, Office of Drinking Water, Cincinnati, Ohio.

US EPA *CT* Values for Virus Inactivation by Ozone

	Temperature °C					
Inactivation	<1	5	10	15	20	25
2-log	0.9	0.6	0.5	0.3	0.25	0.15
3-log	1.4	0.9	0.8	0.5	0.4	0.25
4-log	1.8	1.2	1.0	0.6	0.5	0.3

Table 2-2. CT Values for *Cryptosporidium* Inactivation by Ozone (40 CFR 141.730)[1]

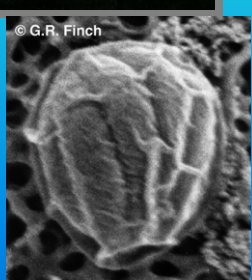
Log Credit	Water Temperature, °C[2]									
	0.5	**1**	**2**	**3**	**5**	**7**	**10**	**15**	**20**	**25**
0.5	12	12	10	9.5	7.9	6.5	4.9	3.1	2.0	1.2
1.0	24	23	21	19	16	13	9 6	2 3	9 2	2.5
1.5	36	35	31	29	24	20	15	9.3	5.9	3.7
2.0	48	46	42	38	32	26	20	12	7.8	4.9
2.5	60	58	52	48	40	33	25	16	9.8	6.2
3.0	72	69	63	57	47	39	30	19	12	7.4

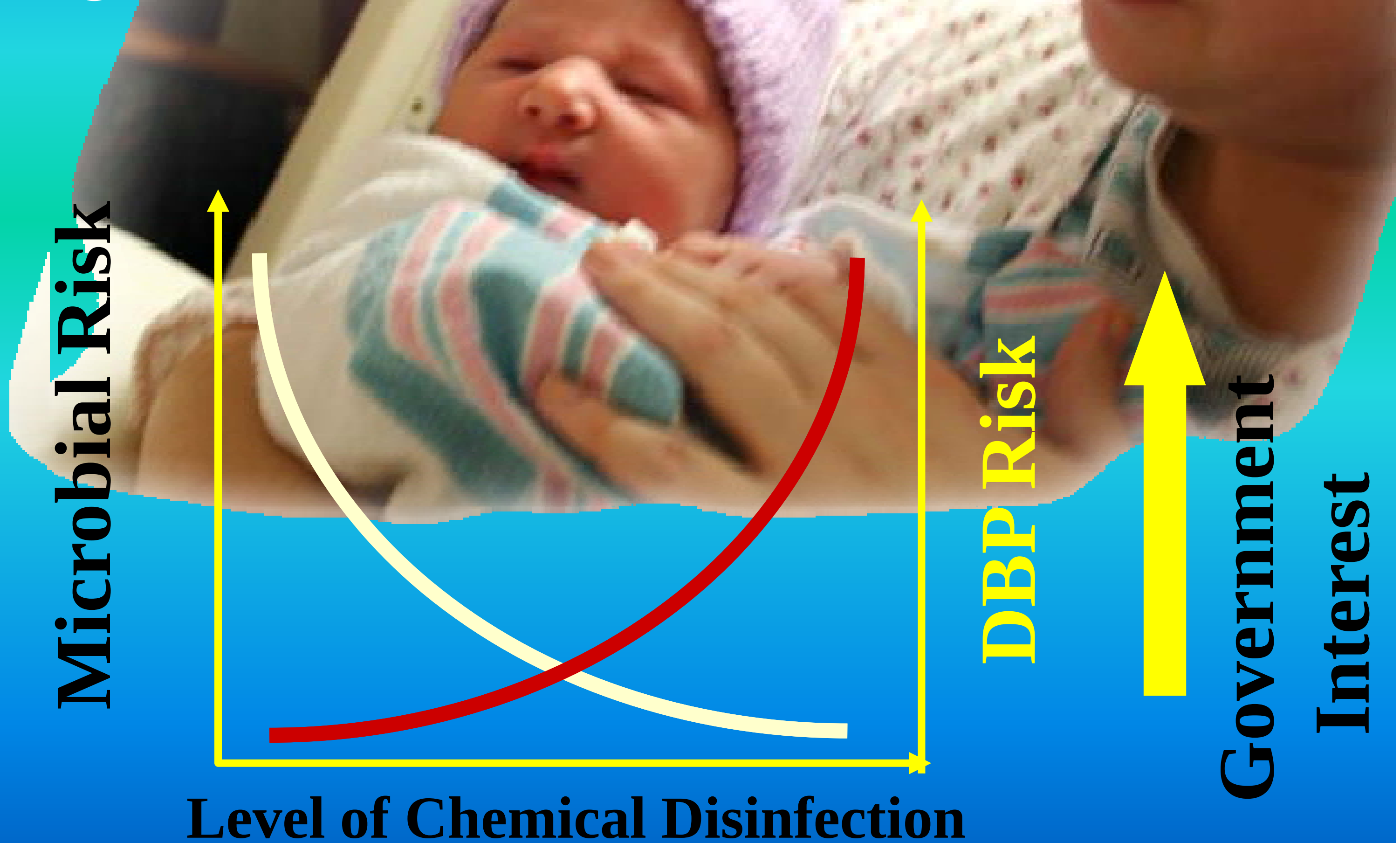
1. LT2ESWTR Toolbox Guidance Manual Chapter 11 (draft June 2003)
2. CT values between the indicated temperatures may be determined by interpolation.

Drinking Water

Regulatory Backdrop

Longstanding Dilemma





Disinfection By-Products

Chlorine

-Trihalomethanes (THM)

-Haloacetic Acids ($THAA_5$)

-Bromate

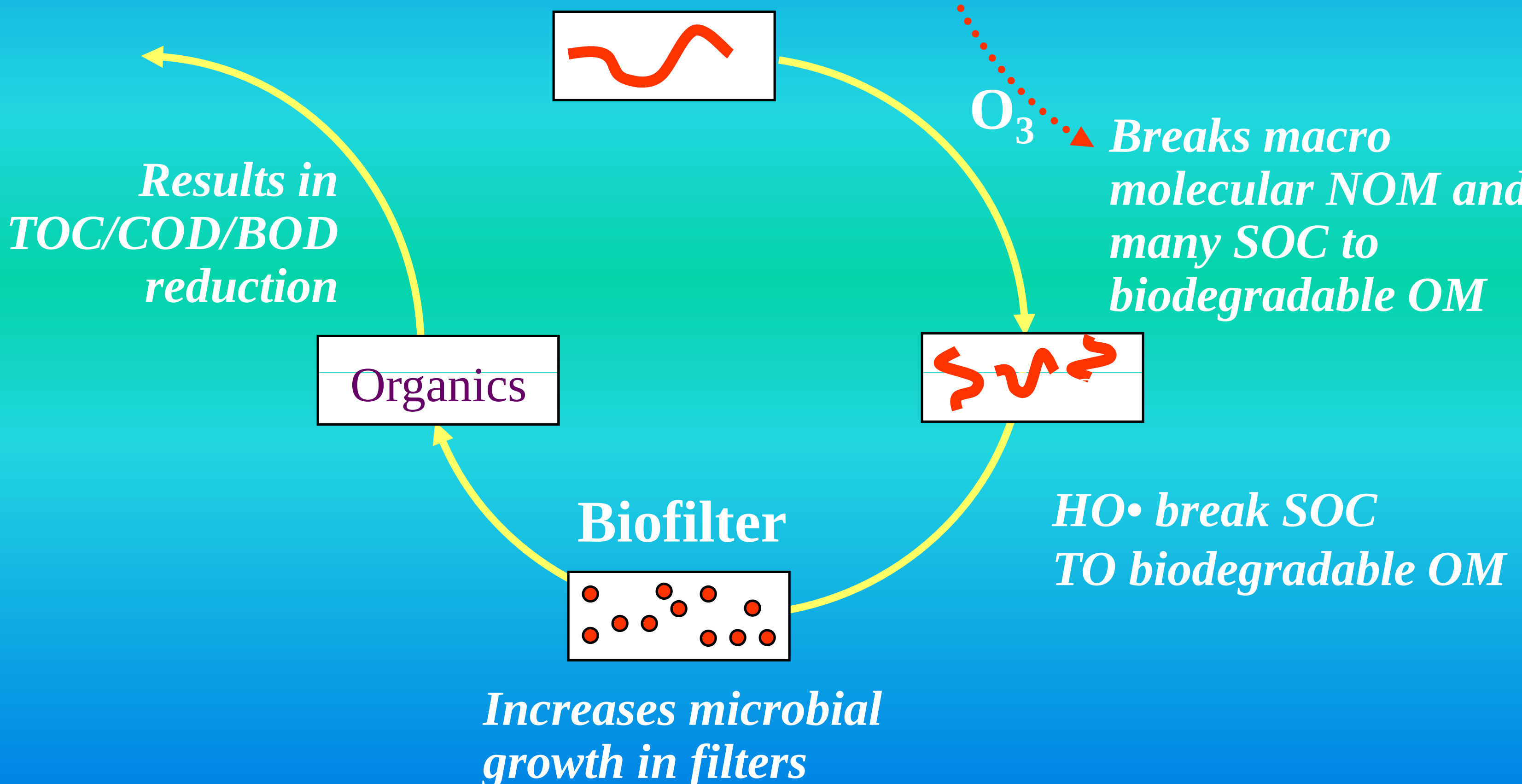
Ozone

-Bromate

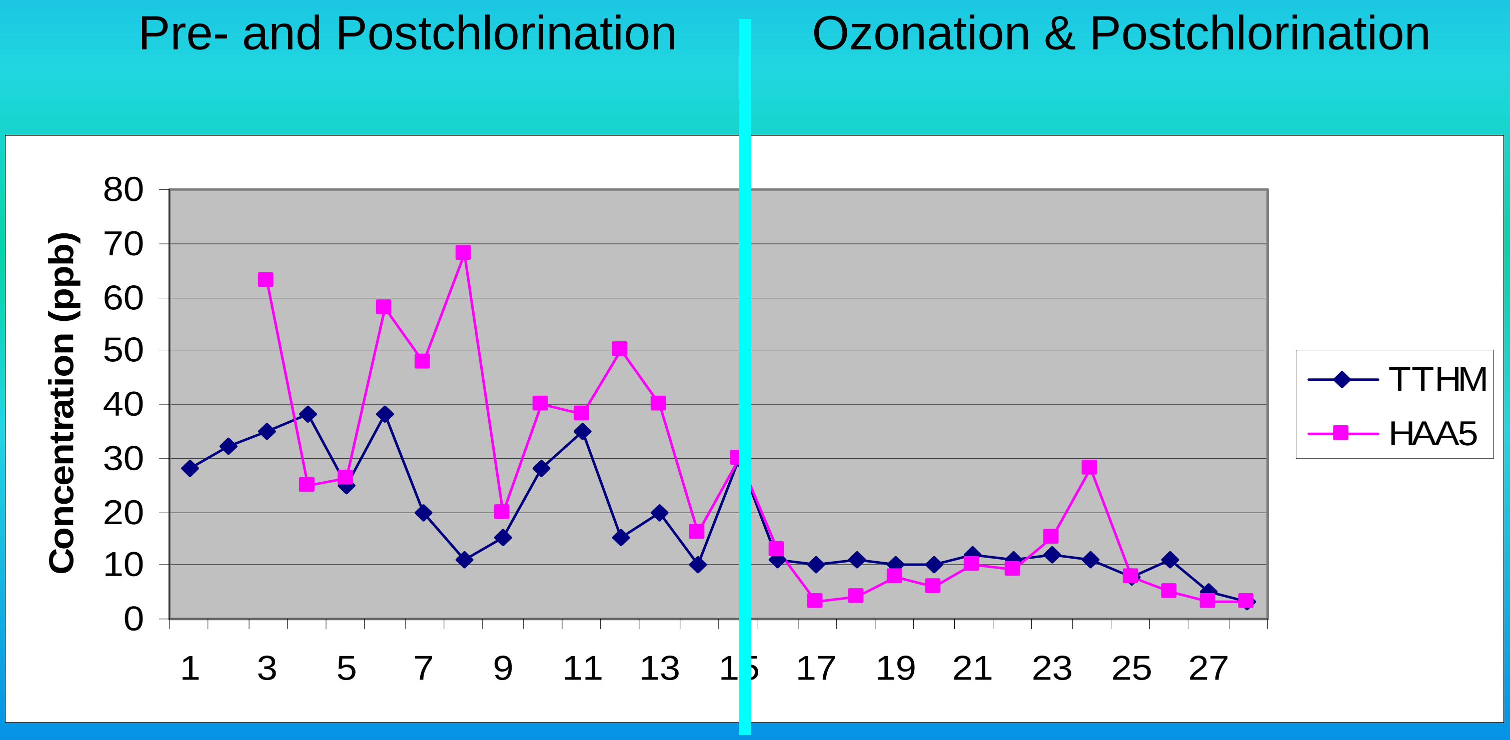
-Assimilable Organic Carbon (AOC)

How does ozone/biofiltration work?

✓ Synergy between ozone and biofiltration

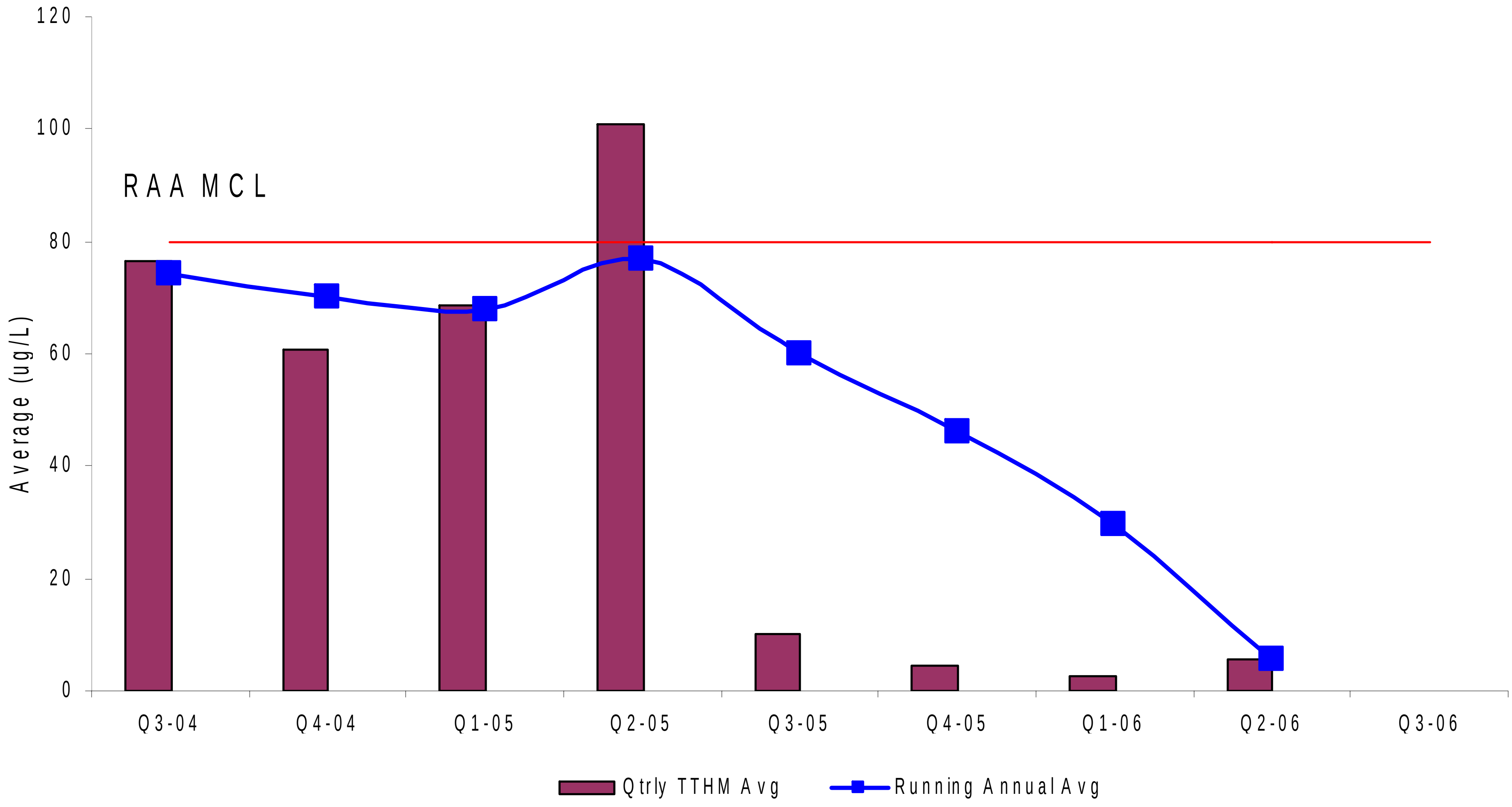


By-Product Formation – THM/HAA



Courtesy of Gwinnett County, Georgia

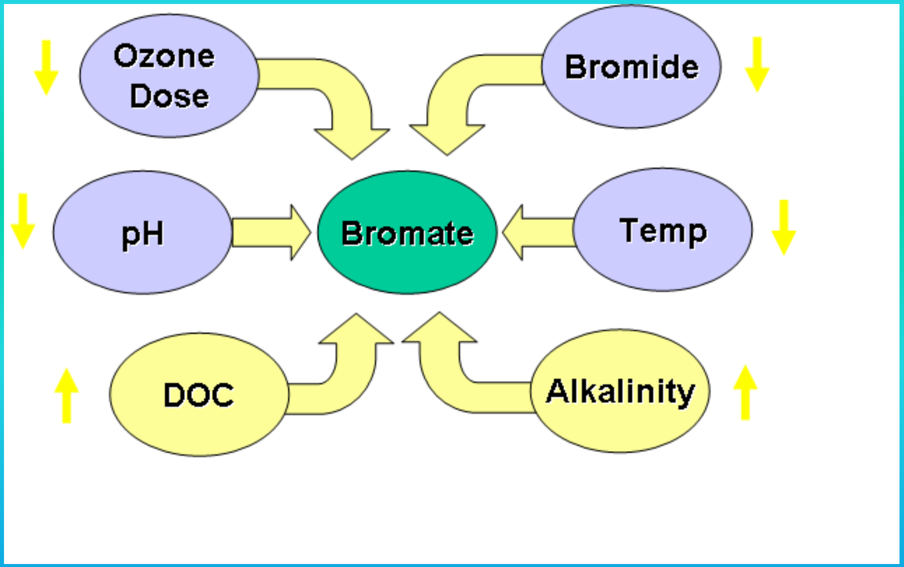
Dramatic disinfection-by-product reductions

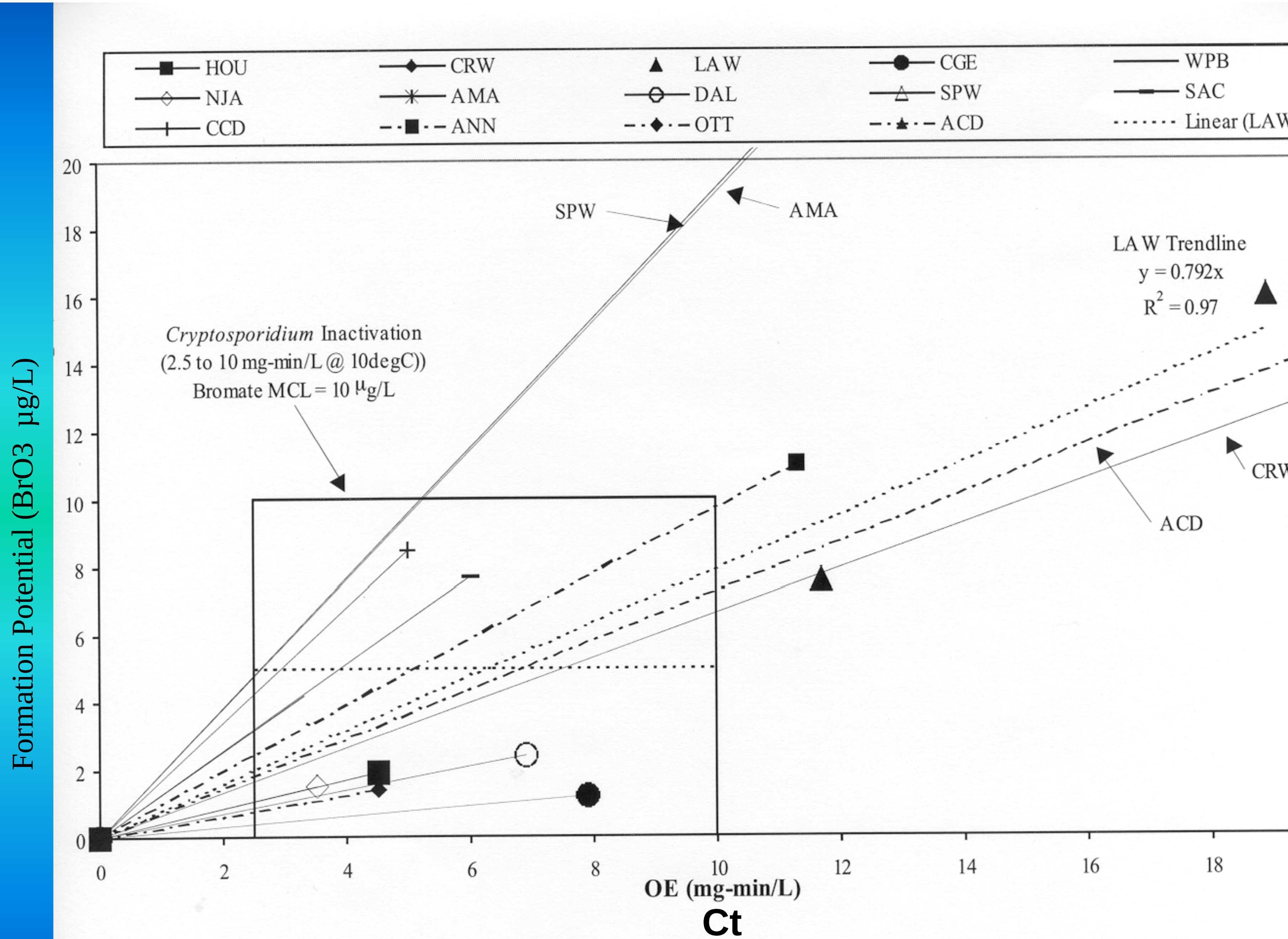


MWRA

Summary
Bromate Formation Control

- **Chemical Addition Options**
  - ***Chlorine***
  - ***Ammonia***
  - *Alkalinity*
  - *Organic Matter*
  - **pH Adjustment**
- Temperature Control
- **Lower O3 Applied Dose & Reaction Time**





B. Daw, et.al. 2001

Microflocculation

- Improved Floc/Clarification & Filtration
- TOC Reduction
- Dosage Influenced by pH, TOC
- Extends Filter Runs
- Reduces Solid Handling

Microflocculation

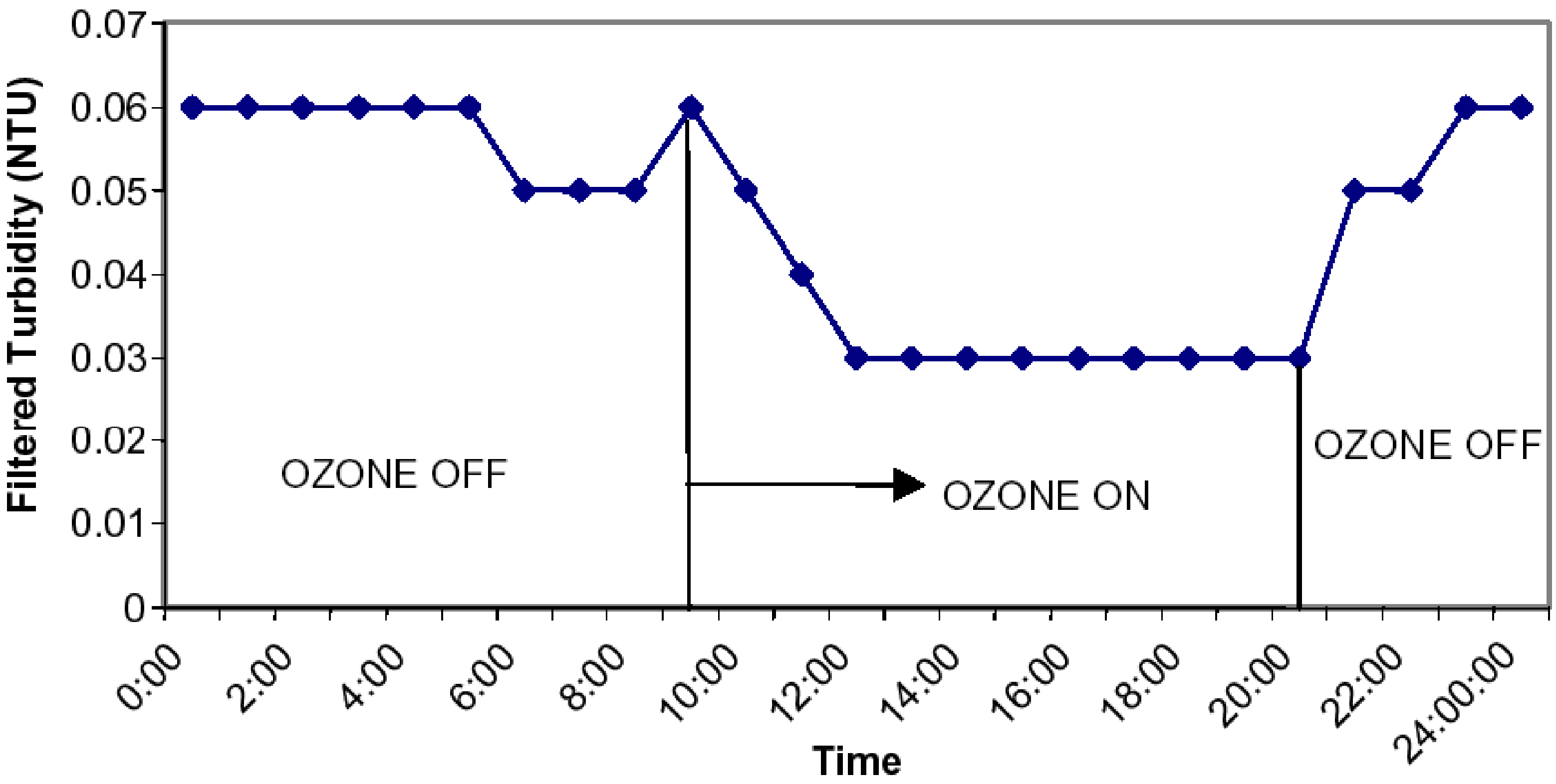
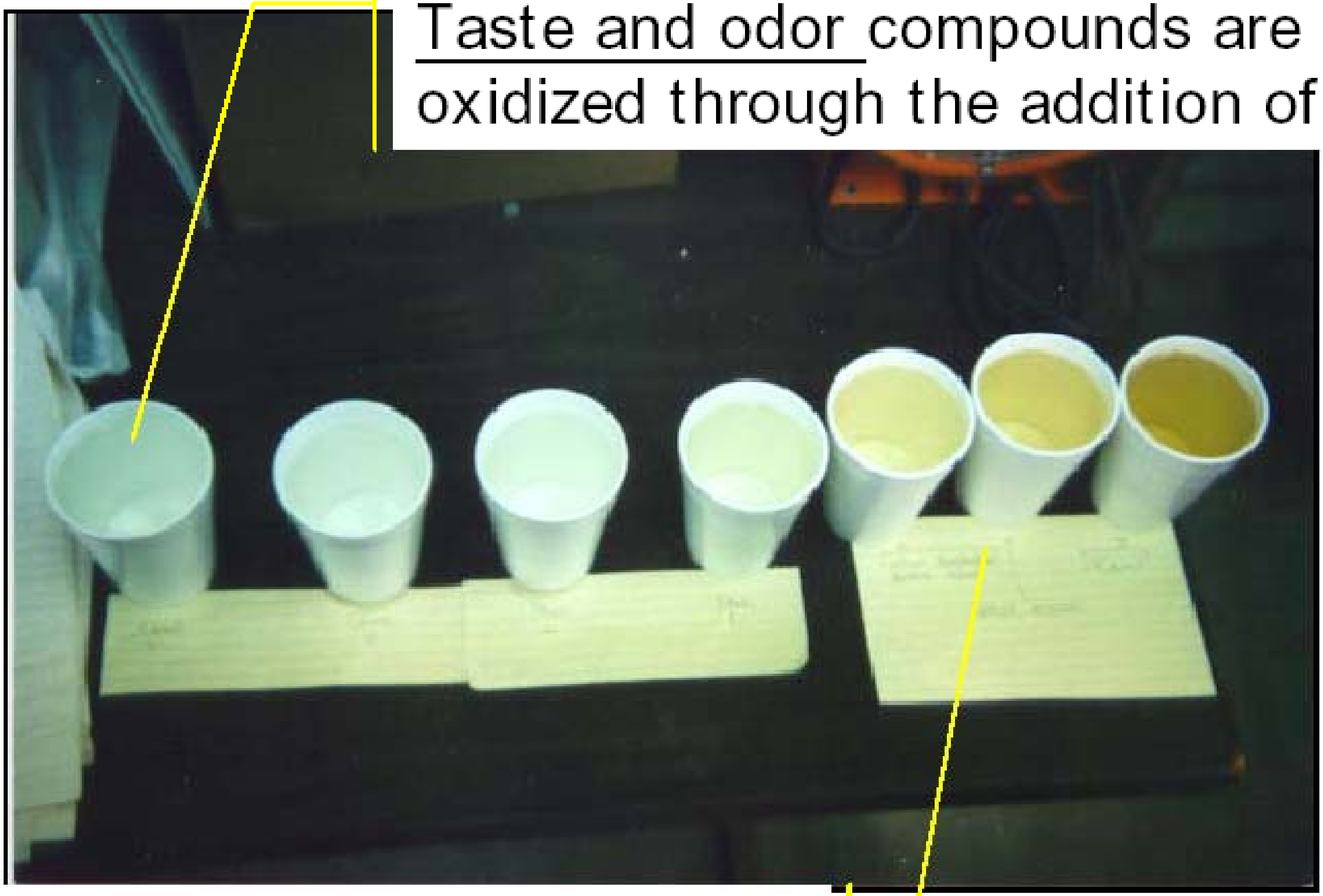


Figure 2-11. Pre-coagulation ozonation effect on turbidity during startup (Mazloum, 2004)

Organic Color Reduction

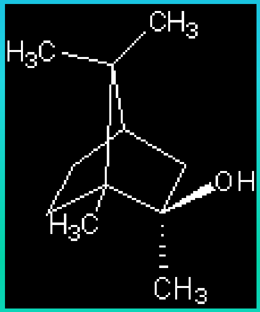
Taste and odor compounds are also oxidized through the addition of ozone.



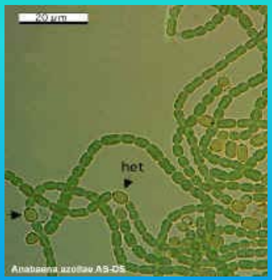
Ozone performs its work through oxidation reactions.

Taste & Odor

- Oxidation
  - Ozone Alone
  - Advanced Oxidation Processes



- Algal Sources
  - methyl isoborneal (MIB)
  - Geosmin



- Other Organic Matter

Use of Ozone for Taste and Odor Control has been Successful:

Star-Telegram.com

Tastes great, less chlorine

May 14, 1994

The Dallas Morning News

Wednesday, August 18, 2004

Safer Water

Substituting ozone for chlorine is good policy

DallasNews.com

The Dallas Morning News

Yucky water? Not in Dallas

Ozone treatment removes foul flavor of algae found elsewhere

09:20 PM CDT on Saturday, July 29, 2006

Star-Telegram.com

Ozone treatment makes water safer, taste better

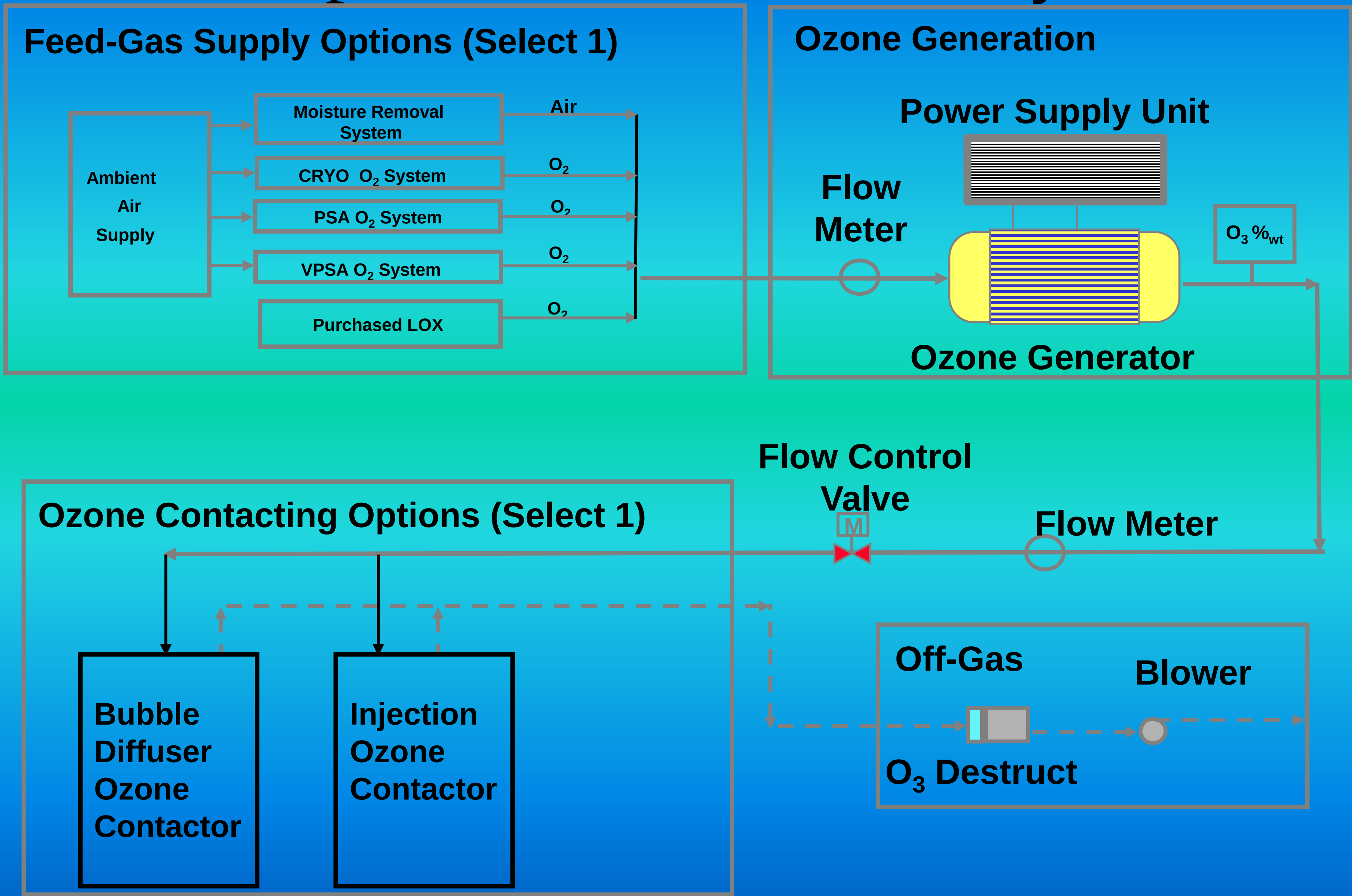
July 25, 1995

Water Treatment Performance
Emerging Contaminants

EDC Removal						
<50%	50-59%	60-69%	70-79%	80-89%	90-99%	
Monylphenol		Atrazine	Meprobromate	Acenaphtylene	Trimethoprim	Diazepam
BHC		Naphtalene	Iopromide	Phenolythrene	Acetaminophen	Oxybenzone
Musk Ketone		Heptachlor	Aldrine	Anthracene	Caffeine	Progesterone
Dieldrin		DDE		Galaxolide	Erythromyein-H_2O	Ethynylestradin
Endrin				Metolachlorine	Sulfamethozazone	Testroterone
				Benzo (a) pyrene	Fluoxetine	Andeostenedione
				Chrysene	Pentoxifylline	Naproxen
				Methoxychlor	Pilantin	Ibuprofen
					Carbcamazepine	Diclofenae
					DEET	Triclosan
					Fluorene	Gernfibrozil
					Pyrene	Octylphenol
					Fluoraythene	

Courtesy of SNWA

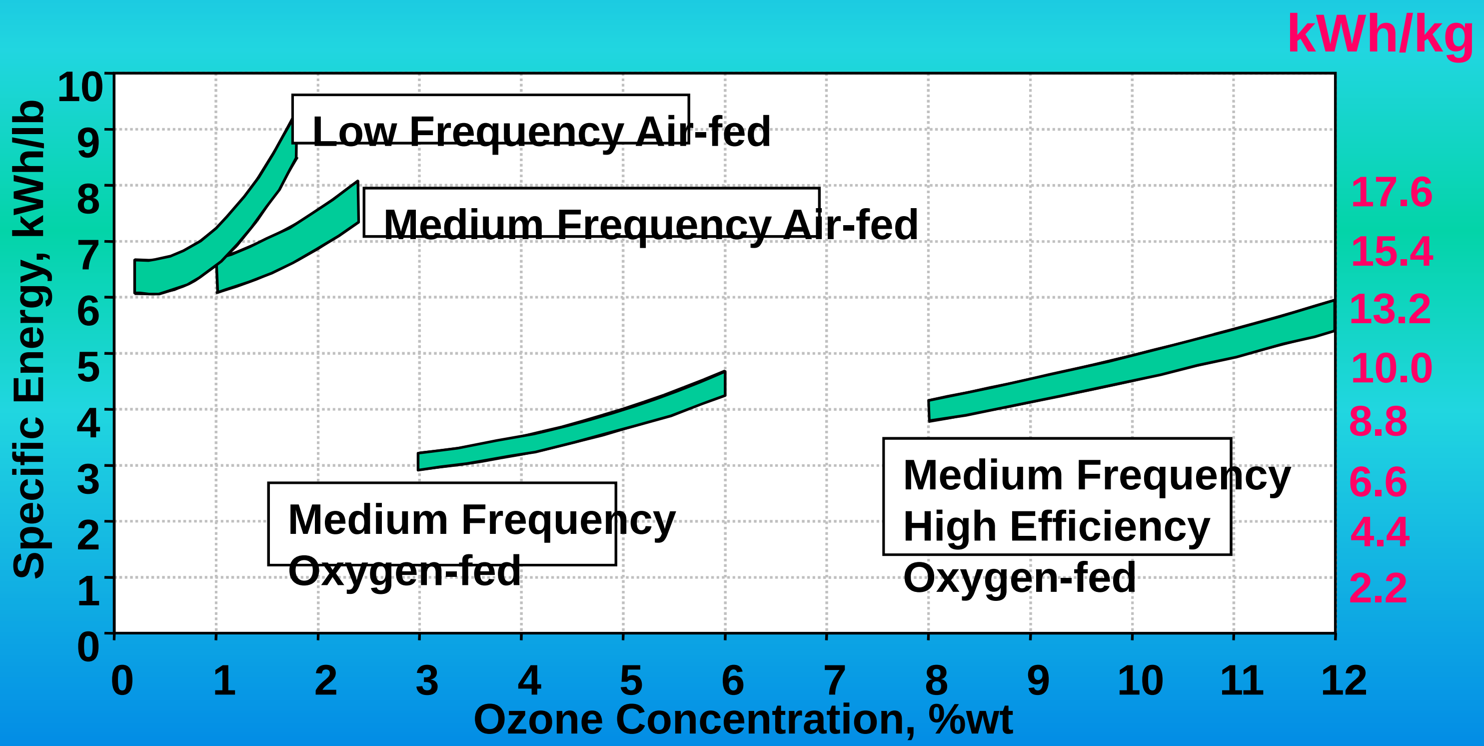
Components of an Ozone System



Important Advancements in Ozone System Design and Operation

- Lowered capital and O&M cost by switching to oxygen feed-gas (LOX and VPSA) and improvements in ozone generator design
- Developed/implemented robust process monitoring and control
- Improved fine bubble diffusion & side stream dissolution

From Air to Oxygen: Pre-1987, 1987 to 1993 and Post 1993



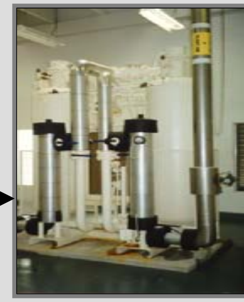
Ozone Equipment is Simplified

Earlier air-fed ozone systems

Air Compressor

Refrigerant Dryer

Desiccant Dryer



Ozone Generator

Less equipment = Lower maintenance, capital cost, and operating cost

Liquid Oxygen Storage & Ambient Vaporizers

Ozone Generator

Current oxygen-fed ozone systems

Ozone Residual Monitoring has Improved

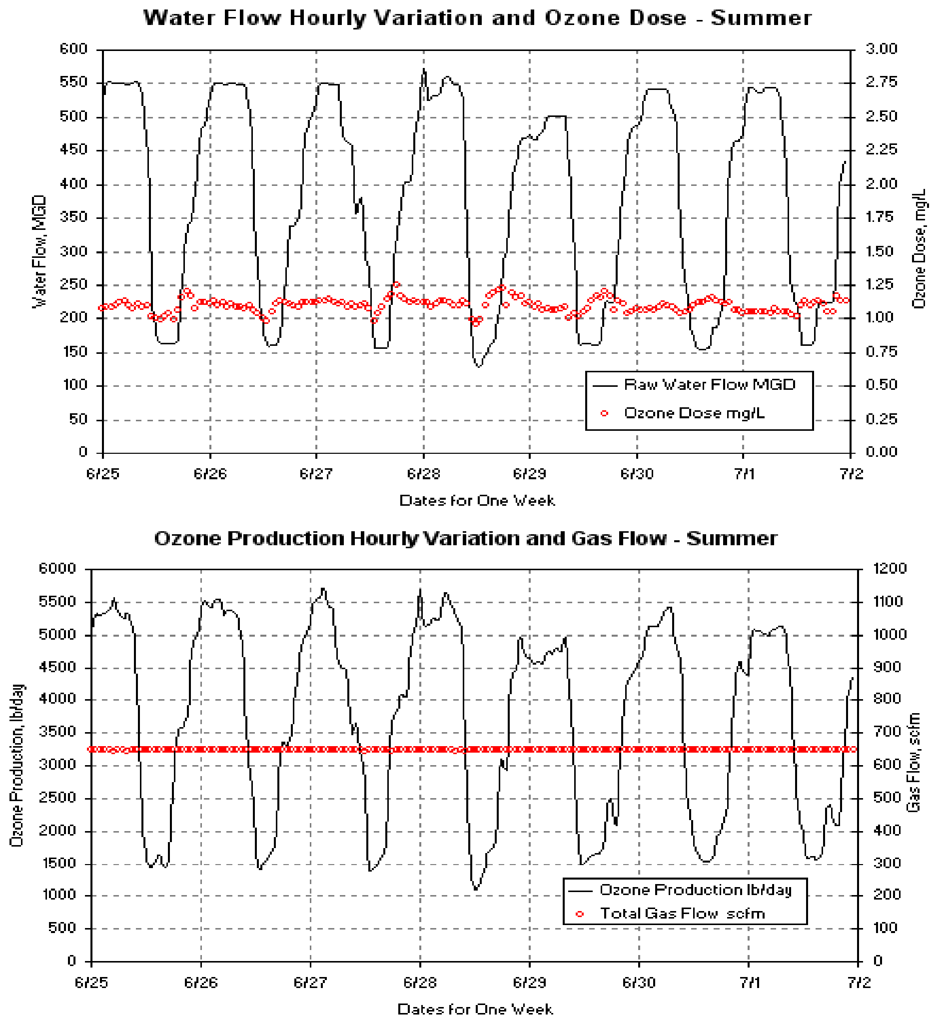
- "Indigo Trisulfonate" Standard Method ozone residual test
- Trustworthy on-line residual analyzers and robust sampling systems

Display Range: 0-200.0 PPB, 0-2.000 PPM
Accuracy: ± 0.02 PPM or 0.5% of F.S.
Repeatability: ± 0.01 PPM or 0.3% of F.S.
Linearity: 0.1% of F.S.
Zero Drift: < 0.01 PPM per month

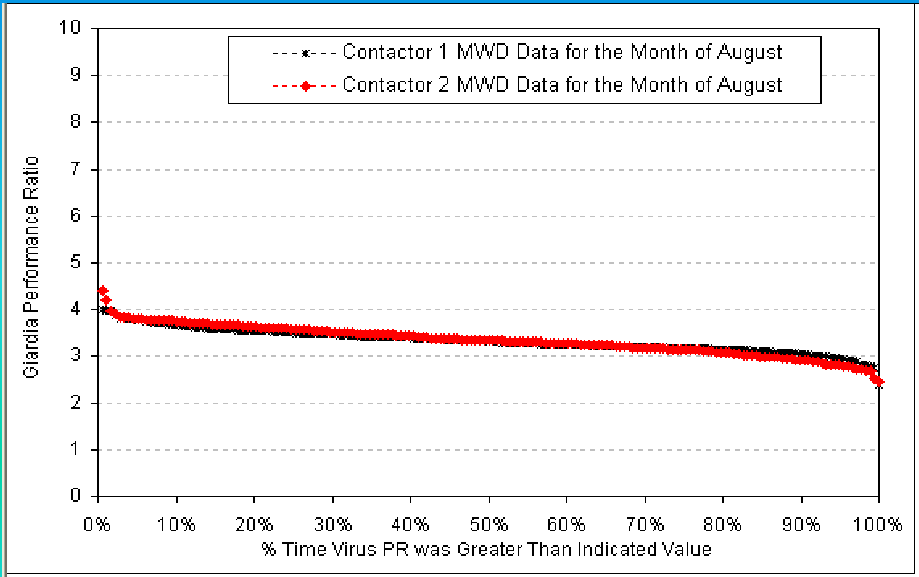
Las Vegas, AMS Water Treatment Plant

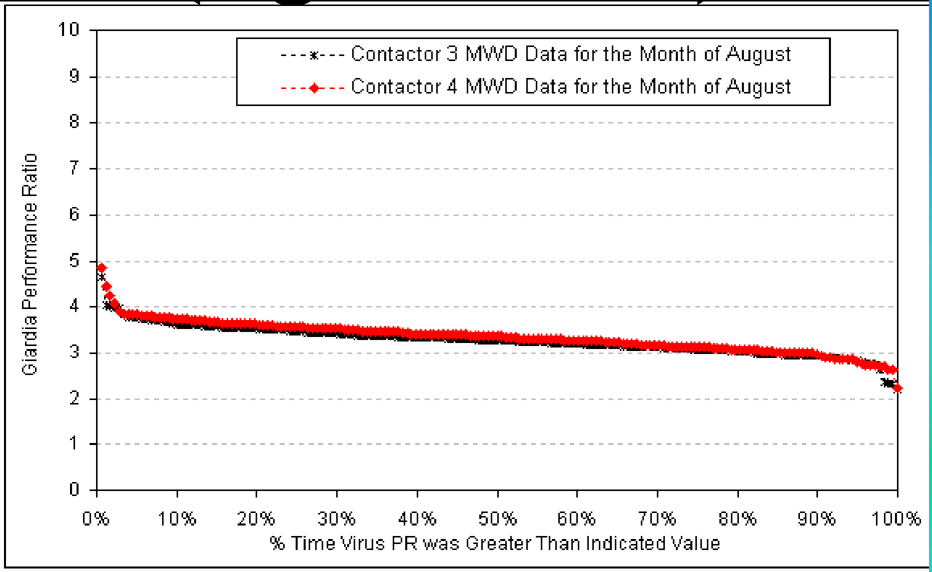
7 days of hourly data

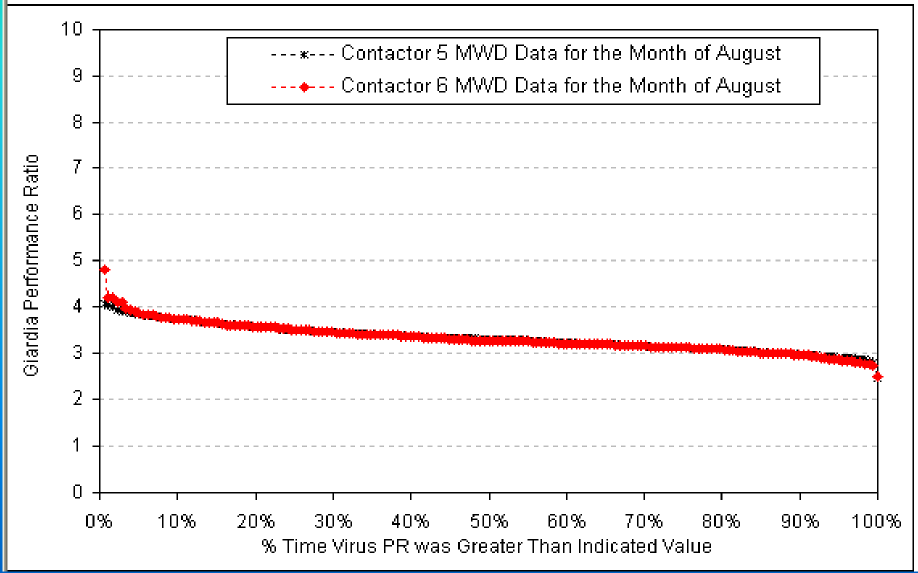
- Water flow varies from 150 to 550 MGD twice per day
- Dose target = 1.1 mg/L Range = 1.0 to 1.2
- Gas flow is constant
- Ozone production range is 1500 to 5500 lb/day



Controlling Disinfection is the Performance GOAL (e.g., *Giardia*)







MWD Jensen – August 2007

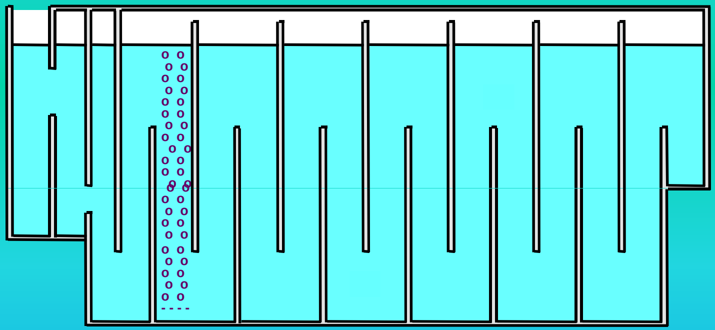
100% of time PR>2 (1-log)

1% of time PR>4 (2-log)

Average PR = 3 or 1.5-logs

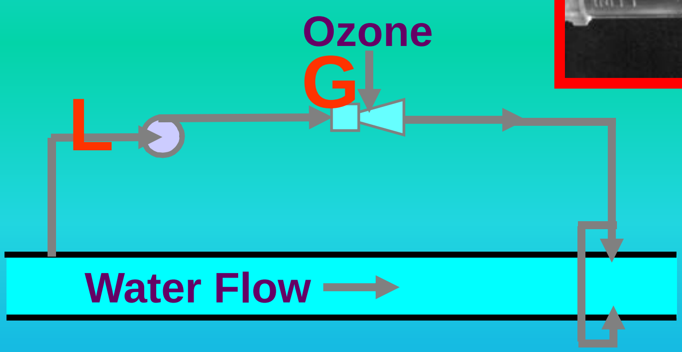
Ozone Dissolution Options

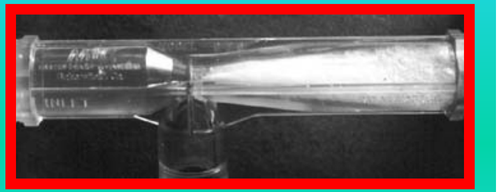
Bubble Diffuser



Historically, the most common ozone contacting option

Side Stream



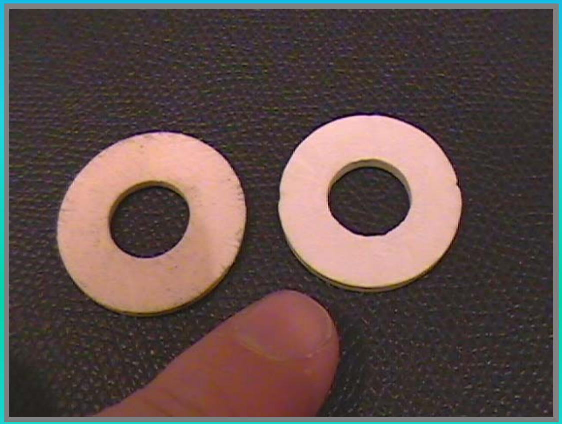


High Efficiency Venturi Injectors

For many reasons, the side stream option is becoming more popular today

Fine Bubble Diffuser Material Improvements

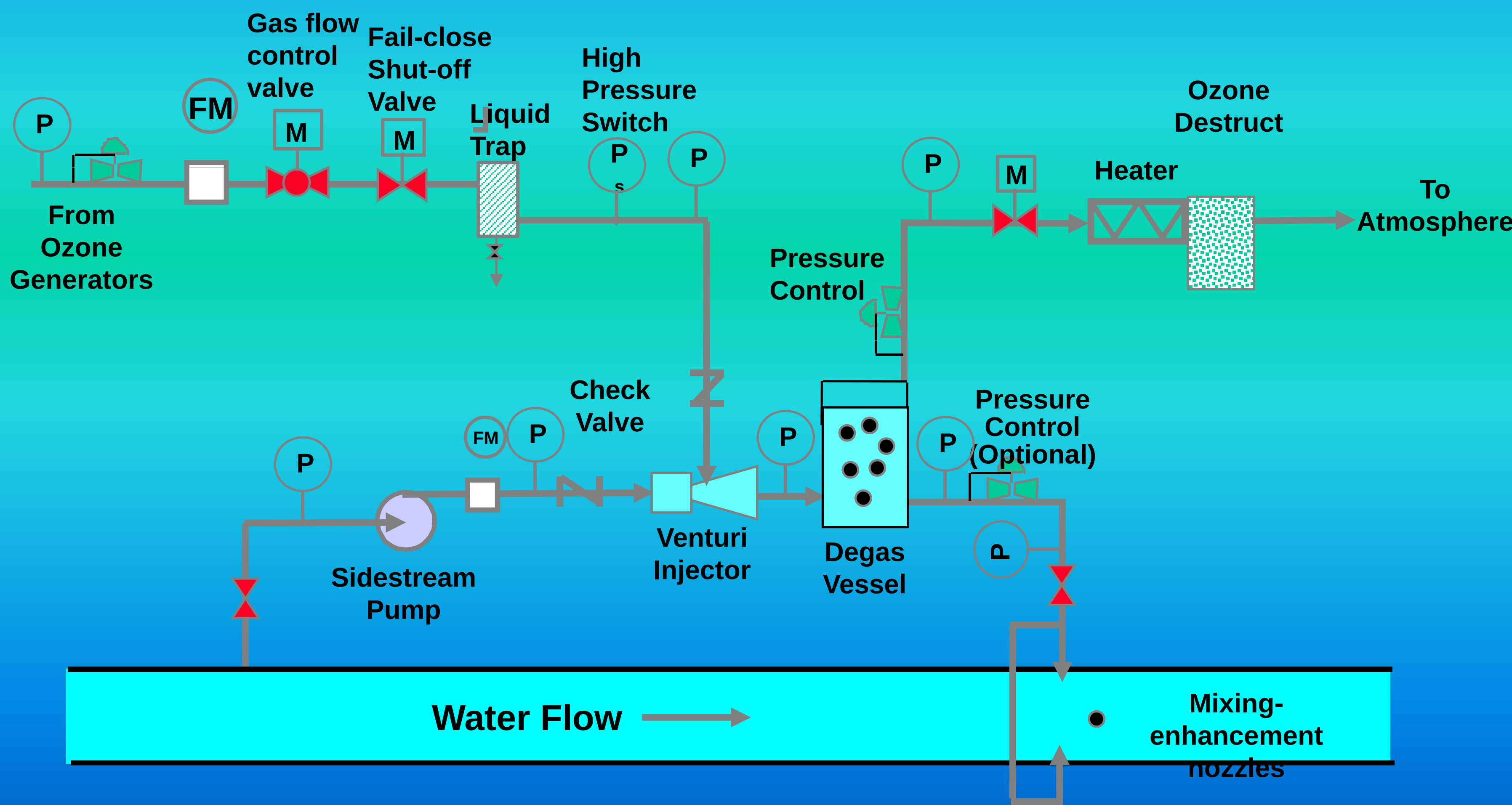
Hypalon diffuser gaskets after 2-yr service in a high-ozone-concentration (8%wt) oxygen-fed ozone application



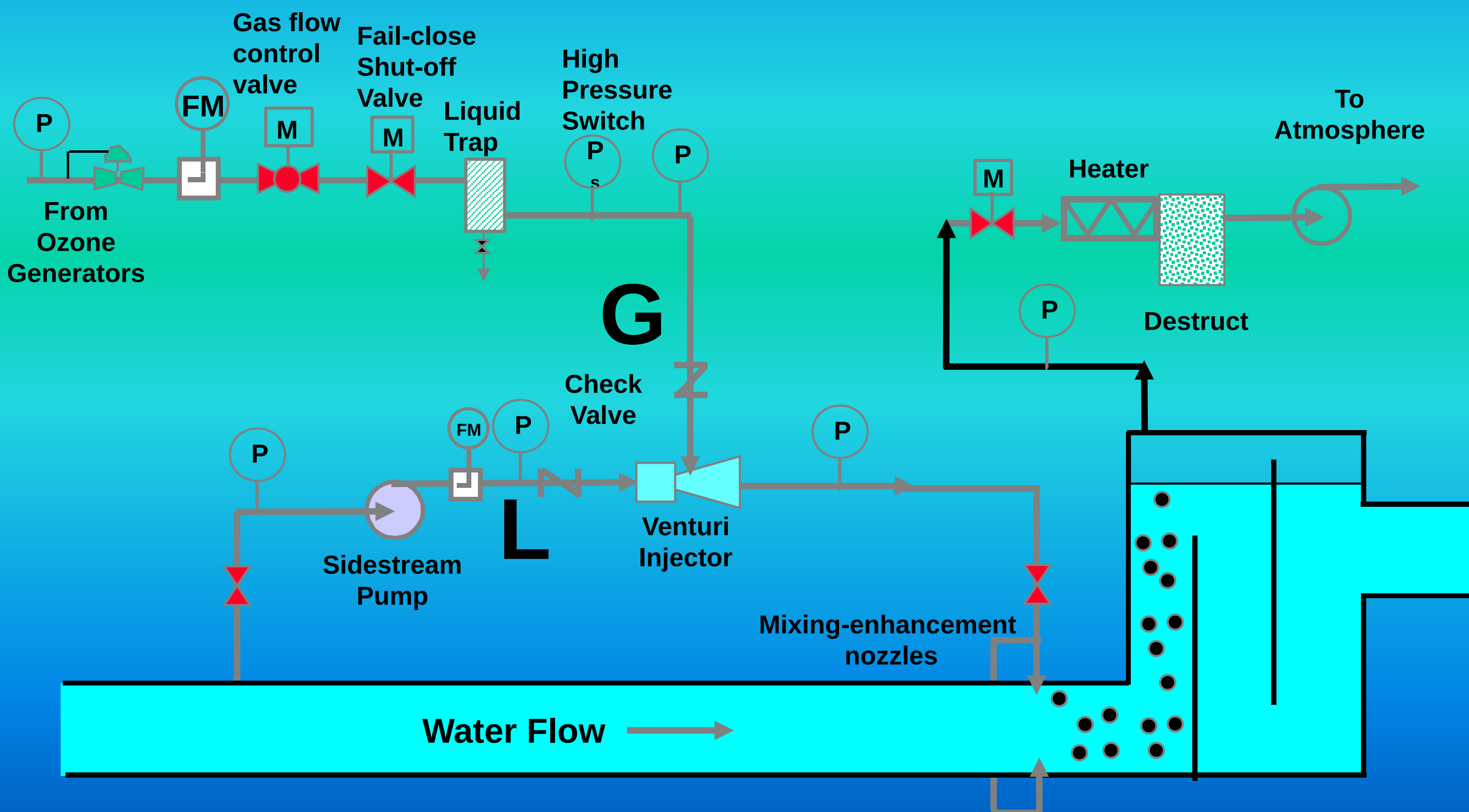
Alternative expanded-Teflon gaskets that are gaining popularity for use in oxygen-fed ozone applications

One-piece design is formed of a gas permeable porous alumina diffuser ceramic bonded at high temperature yielding a corrosion resistant product. Stainless steel components, polymer gaskets and cements of any kind have been eliminated.

Option 1 - Designed to maximize ozone transfer within the side stream flow



Option 2 - Designed to utilize ozone contactor for ozone transfer assistance



International Ozone Association

www.io3a.org

Joint IOA & IUVA Conference
04 – 06 May 2009
Boston, MA

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