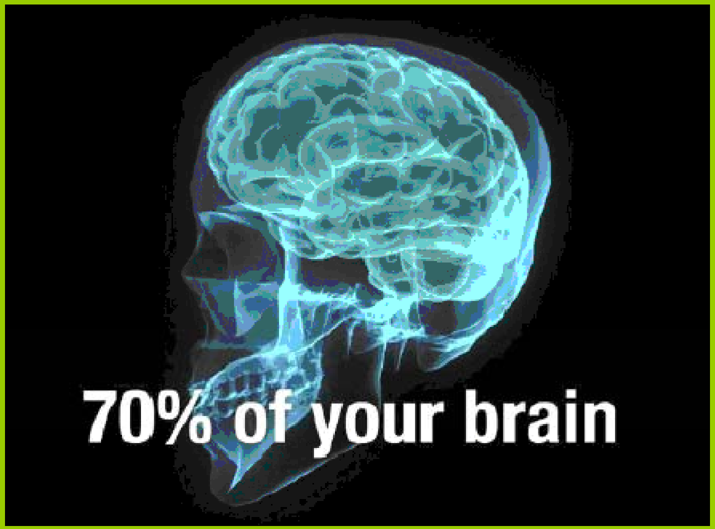
DEZINFEKCIJA VODE ZA PIĆE

Siniša L. Markov, Dragoljub D. Cvetković, Aleksandra S. Velićanski

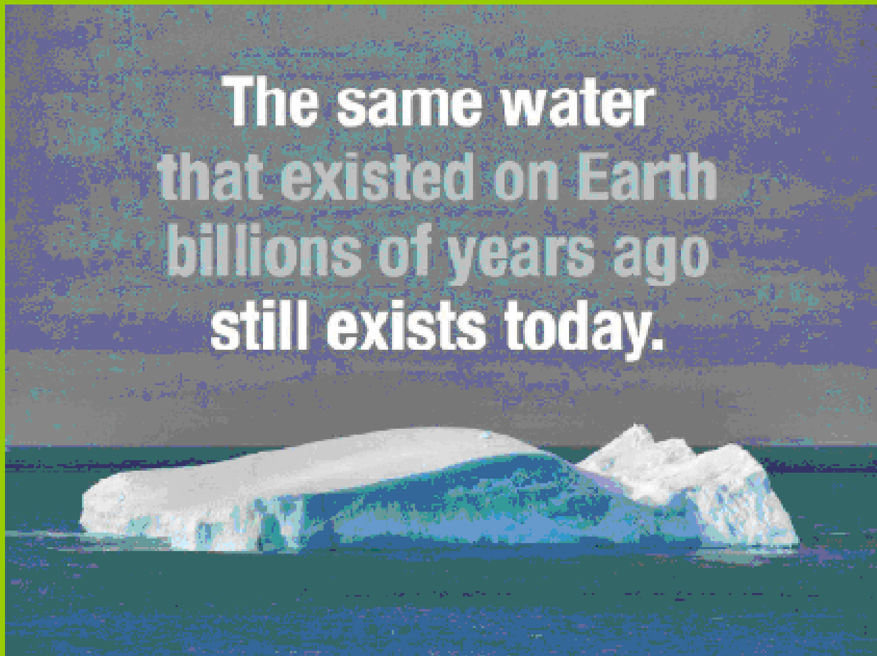
TEHNOLOŠKI FAKULTET NOVI SAD

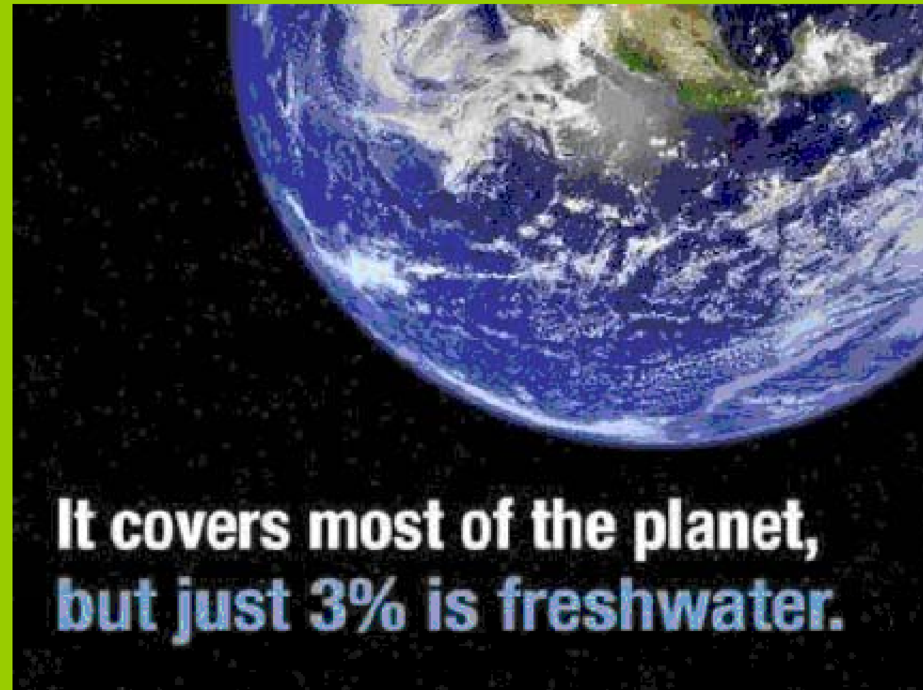

60% of your body


70% of your brain


While you can go almost
a month without food…


your body
can't survive
one week
without water.
One Week
S M T W T F S
1 2 3 4
5 6 7 8 9 10 11
12 13 14 15 16 17 18
19 20 21 22 23 24 25
26 27 28 29 30 31


The same water
that existed on Earth
billions of years ago
still exists today.


It covers most of the planet,
but just 3% is freshwater.


Less than 1% of all freshwater
is readily accessible
for human use.


Less than 0.007%
of all the water on Earth
is available
to drink.

Nature **452**, 301-310 (20 March 2008) | **doi:10.1038/nature06599**; Received 14July2007; Accepted 14Dec.2007

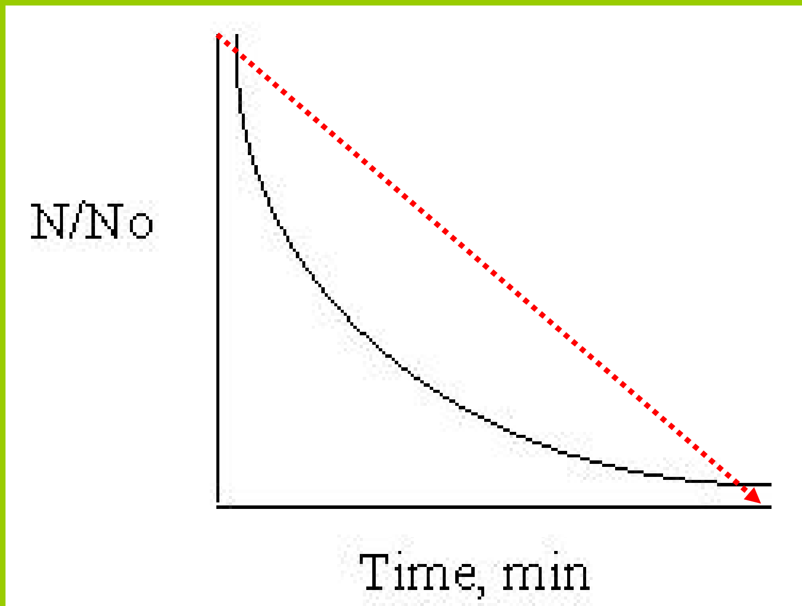
Science and technology for water purification in the coming decades

Mark A. Shannon, Paul W. Bohn, Menachem Elimelech, John G. Georgiadis, Benito J. Mariñas & Anne M. Mayes

Abstract

One of the most pervasive problems afflicting people throughout the world is inadequate access to clean water and sanitation. Problems with water are expected to grow worse in the coming decades, with water scarcity occurring globally, even in regions currently considered water-rich. Addressing these problems calls out for a tremendous amount of research to be conducted to identify robust new methods of purifying water at lower cost and with less energy, while at the same time minimizing the use of chemicals and impact on the environment. Here we highlight some of the science and technology being developed to improve the disinfection and decontamination of water, as well as efforts to increase water supplies through the safe re-use of wastewater and efficient desalination of sea and brackish water.

kome još – pa poželjno je .....



$$\ln\left(\frac{N_t}{N_0}\right) = -\lambda c^n t$$

where,

N_o = initial number of organisms

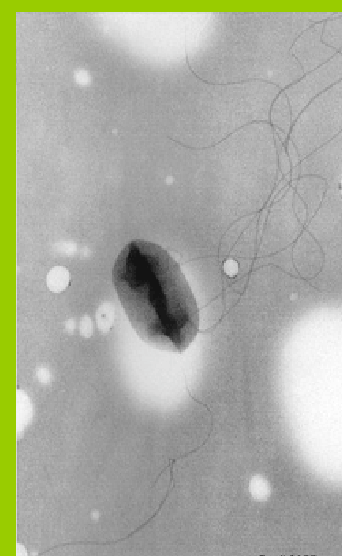
N_t = number of organisms at time t

C = concentration of disinfectant (mg/l)

t = contact time (min)

λ = coefficient of specific lethality

n = coefficient depending on disinfectant type and pH



TEM mikrografija

CT-values for the inactivation of *Giardia* cysts by various disinfectants

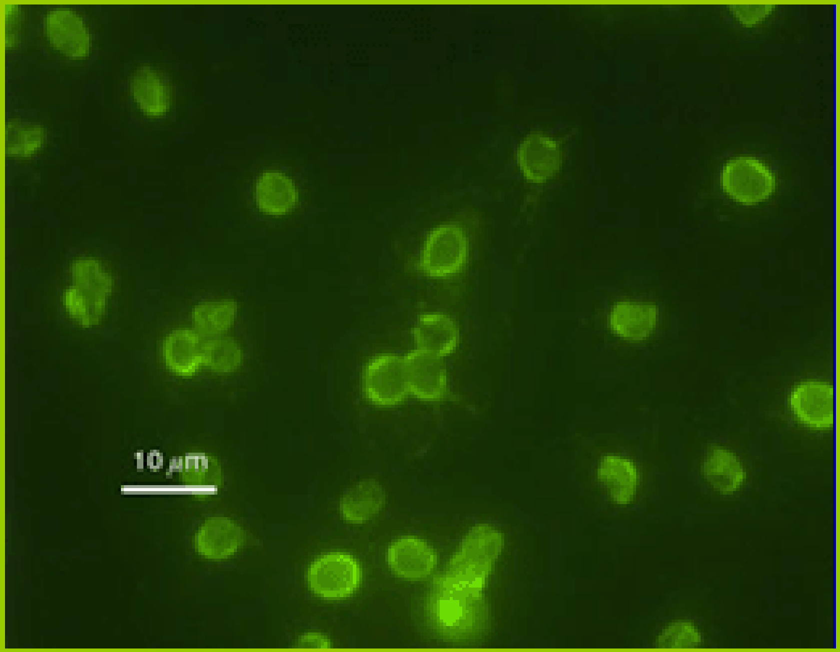
Disinfectant	Inactivation (mg · min/L)					
	0.5-log	1-log	1.5-log	2-log	2.5-log	3-log
Chlorine[1]	17	35	52	69	87	104
Chloramine[2]	310	615	930	1,230	1,540	1,850
Chlorine Dioxide[3]	4	7.7	12	15	19	23
Ozone[3]	0.23	0.48	0.72	0.95	1.2	1.43

CT values were obtained from AWWA, 1991.

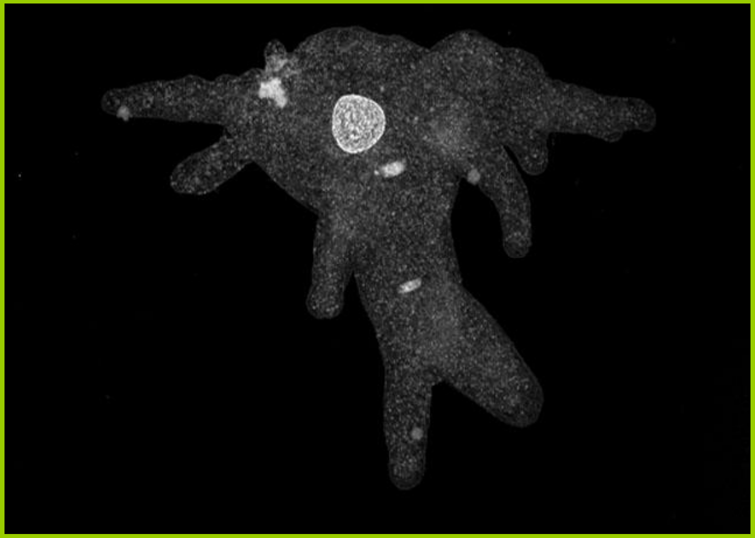
[1]Values are based on a free chlorine residual less than or equal to 0.4 mg/L, temperature of 10°C, and a pH of 7.

[2]Values are based on a temperature of 10°C and a pH in the range of 6 to 9.

[3]Values are based on a temperature of 10°C and a pH of 6 to 9.



Imunofluorescentna slika oocista *Cryptosporidium parvum*



CT-values for the inactivation of viruses by various disinfectants

Disinfectant	Units	Inactivation		
		2-log	3-log	4-log
Chlorine[1]	mg · min/L	3	4	6
Chloramine[2]	mg · min/L	643	1,067	1,491
Chlorine Dioxide[3]	mg · min/L	4.2	12.8	25.1
Ozone	mg · min/L	0.5	0.8	1.0
UV	$mW \cdot s/cm^2$	21	36	not available

CT values were obtained from AWWA, 1991.

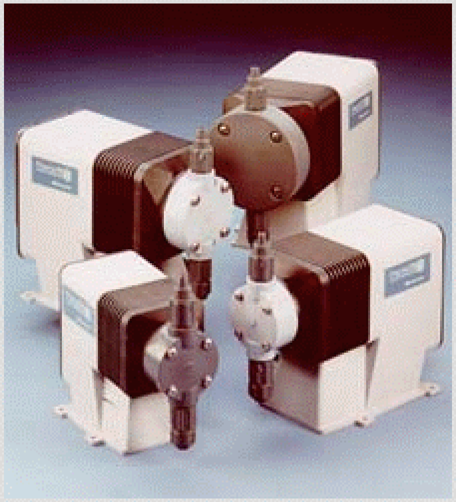
[1]Values are based on a temperature of 10°C, pH range of 6 to 9, and a free chlorine residual of 0.2 to 0.5 mg/L.

[2]Values are based on a temperature of 10°C, pH of 8.

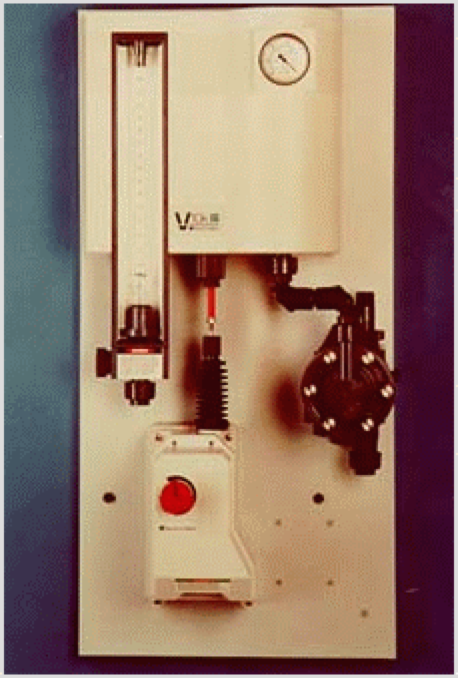
[3]Values are based on a temperature of 10°C, pH range of 6 to 9.

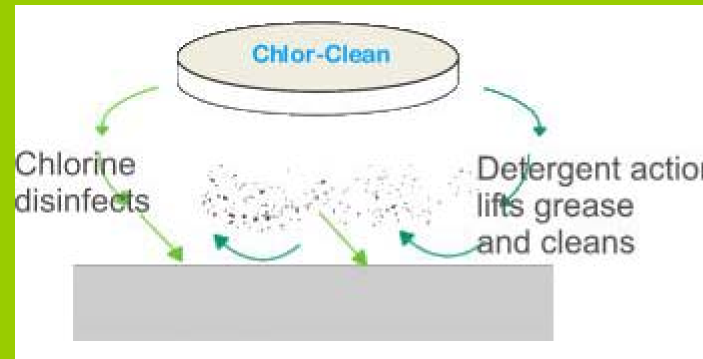
Chlorine Storage Tank

Hypochlorite Dosing Pumps



Gas Chlorinator





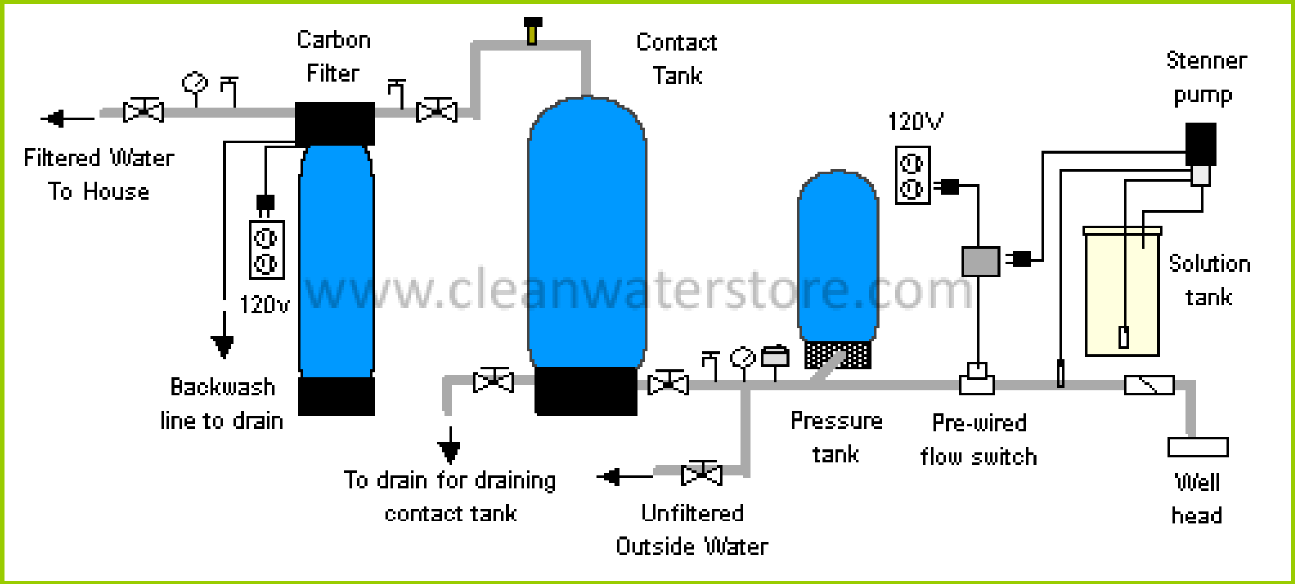
pH	Percent of active HOCl (%)	Percent of inactive OCl (%)
5.0	100	0
6.0	96	4
7.0	75	25
7.2	66	34
7.5	48	52
7.8	33	67
8.0	22	78

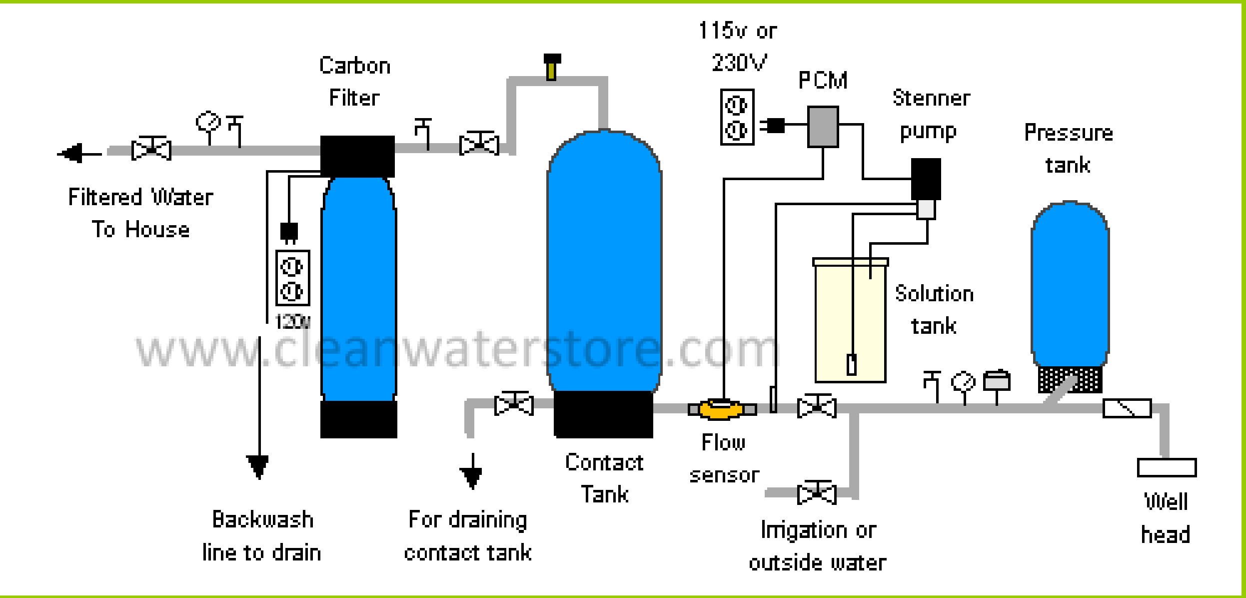
Uporedna efikasnost dezinfektanata za 99%-nu bakterijsku inaktivaciju

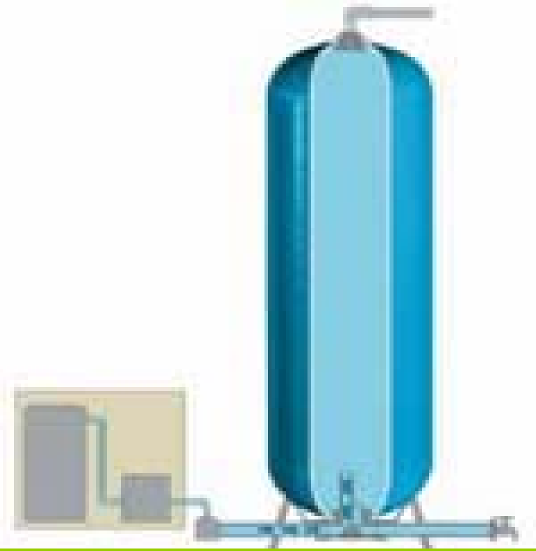
dezinfektant	*Escherichia coli*				Heterotrofne bakterije		
	pH	temperatura (°C)	CT (mg/min L^{-1})		pH	tempera-tura (°C)	CT (mg/min L^{-1})
Hipohlorasta kiselina	6,0	5	0,04		7,0	1-2	0,08±0,02
Hipohoritni jon	10,0	5	0,92		8,5	1-2	3,3±1,0
Hlor-dioksid	6,5	20	0,18		7,0	1-2	0,13±0,02
Monohloramin	9,0	15	64		7,0	1-2	9,4±7,0

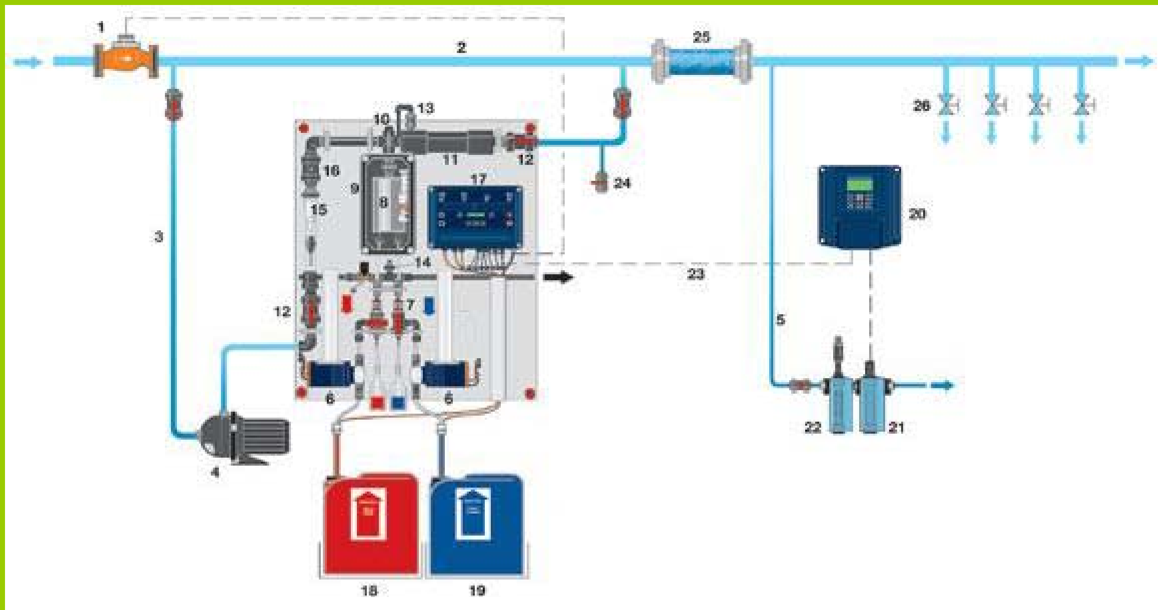
Procenjene CT vrednosti za inaktivaciju *Giardia* oocista slobodnim hlorom na 25°C

Hlor (mg/L)	pH 7			pH 8		
	Log inaktivacija			Log inaktivacija		
	1	2	3	1	2	3
1	12	25	37	18	36	54
1,6	13	27	40	19	39	58
2	14	27	41	20	41	61
2,6	15	29	44	22	43	65

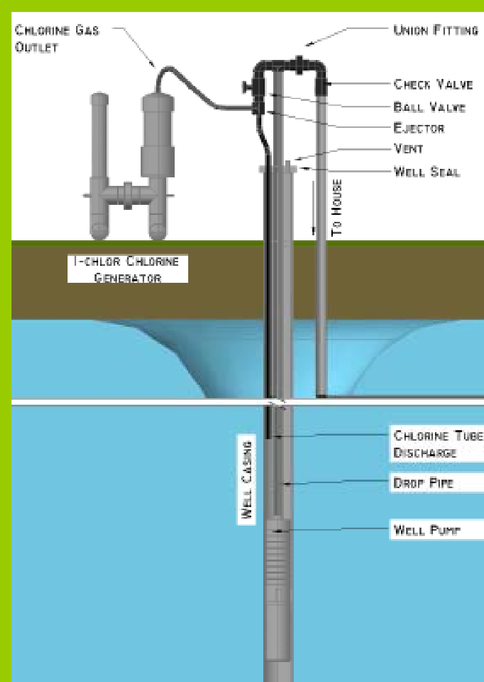

Carbon Filter
Contact Tank
Stenner pump
120V
Filtered Water To House
120v
www.cleanwaterstore.com
Solution tank
Backwash line to drain
Pressure tank
Pre-wired flow switch
To drain for draining contact tank
Unfiltered Outside Water
Well head


115v or 230V
PCM
Carbon Filter
Stenner pump
Pressure tank
Filtered Water To House
120v
Solution tank
www.cleanwaterstore.com
Flow sensor
Contact Tank
Backwash line to drain
For draining contact tank
Irrigation or outside water
Well head





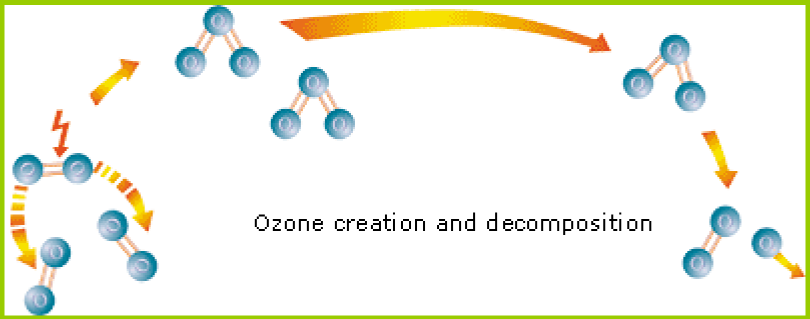
dezinfekcija hlordioksidom

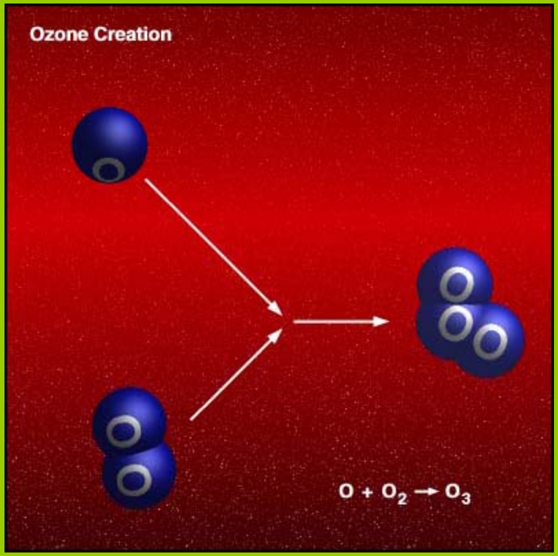


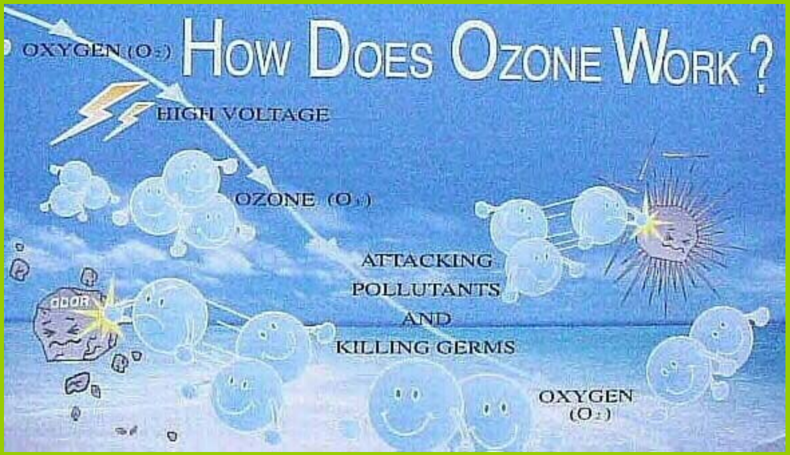
UV for drinking water

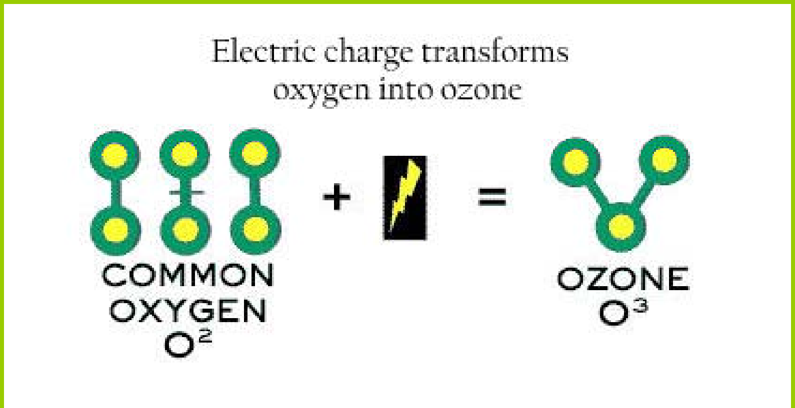
Tipične UV doze za četiri log inaktivaciju različitih mikroorganizama

bakterije	doza zračenja mW-s/cm^2		virusi	doza zračenja mW-s/cm^2
spore *Bacillus subtilis*	31		koksaki AZ	30
Escherichia coli	20		Hepatitis A	6 - 15
Salmonella typhi	30		Poliovirus	23 - 29
Vibrio cholera	0,65		Rotavirus SA11	40
			adenovirus	186


Ozone creation and decomposition


Ozone Creation
$O + O_2 \rightarrow O_3$


How Does Ozone Work ?
OXYGEN (O2)
HIGH VOLTAGE
OZONE (O3)
ATTACKING
POLLUTANTS
AND
KILLING GERMS
ODOR
OXYGEN
(O2)

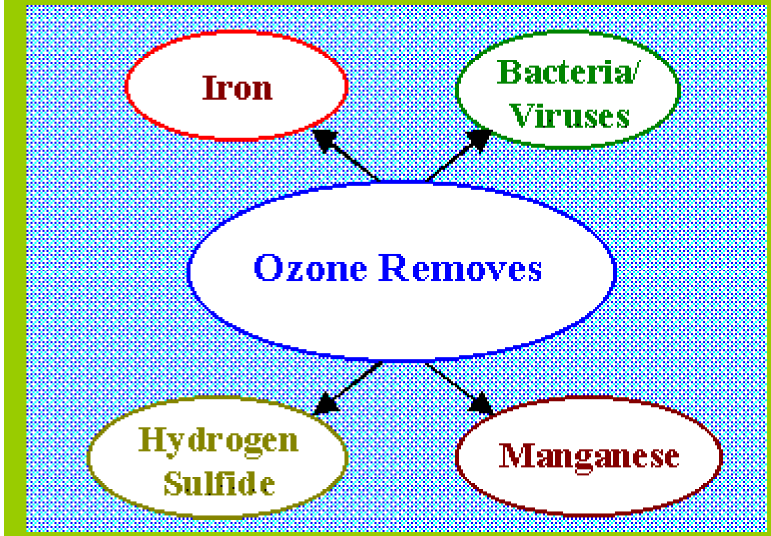

Electric charge transforms
oxygen into ozone
+
=
COMMON
OXYGEN
O2
OZONE
O3

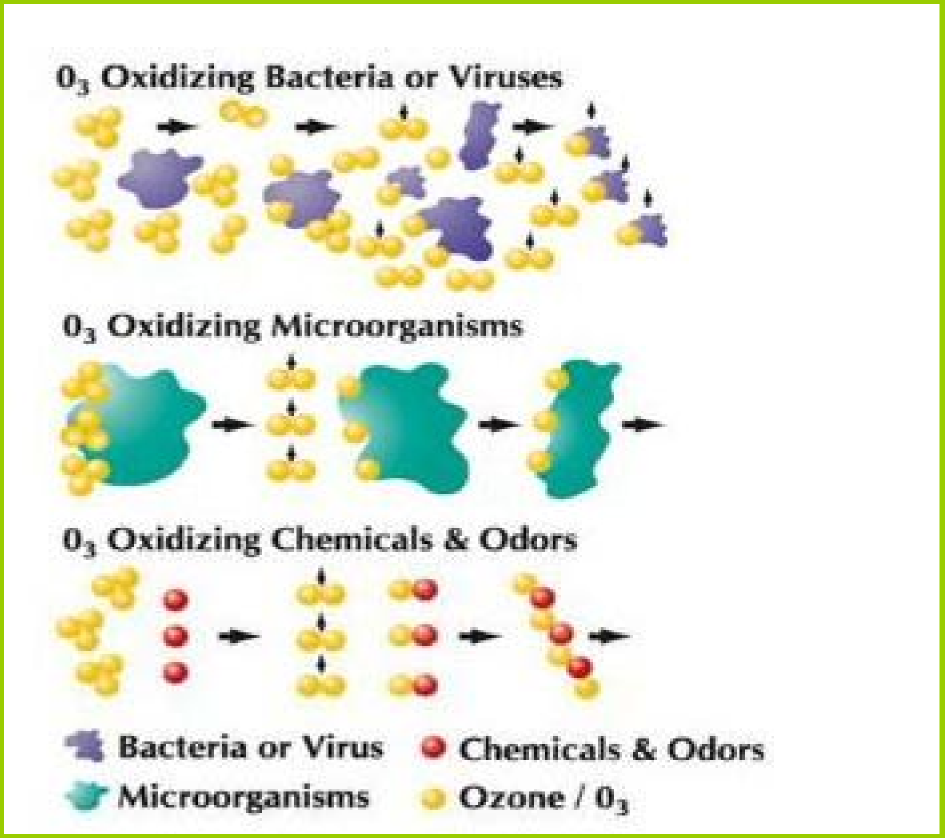
History of GRAS Status of Ozone

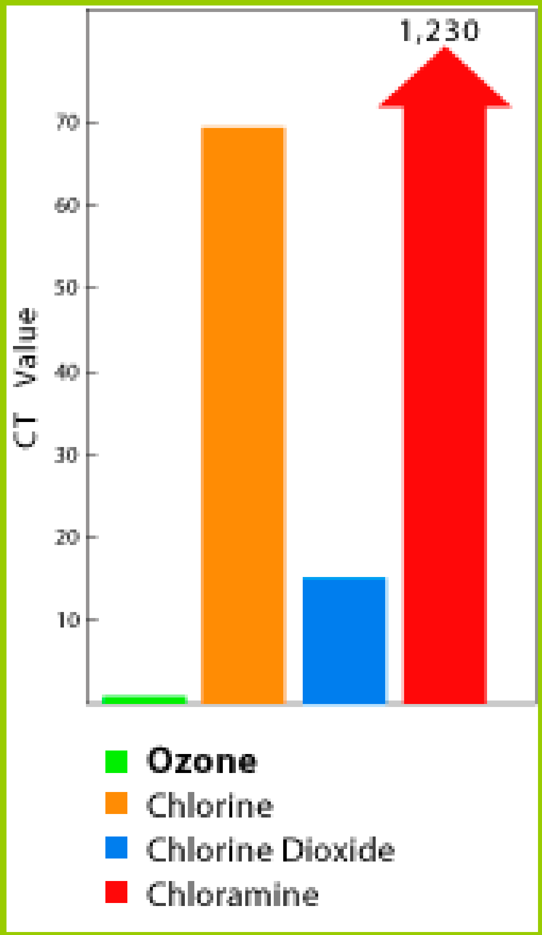
Date	Event
1840	Discovered by Schönbein
1893	**Used as a disinfectant in drinking water**
1909	Used as a food preservative for cold storage of meats
1939	Was found to prevent the growth of yeast & mold during the storage of fruits
1982	**FDA GRAS declaration for ozone use in bottled water**
1995	**FDA GRAS for ozone use in bottled water renewed without change**
1997	**Industry Expert Panel declares ozone GRAS and meets FDA requirements. Regulators have the option to later add control on ozone use.**
1999	USDA rejects an ozone use protocol for meats, cites 1982 GRAS declaration for water where FDA stated "any other use must be regulated by a Food Additive Petition."
2000	Food Additive Petition, that addresses both water and air use of ozone, under preparation. FDA estimates approval will occur within six months of submission of the Petition

Oxidizing Potential of Various Reagents

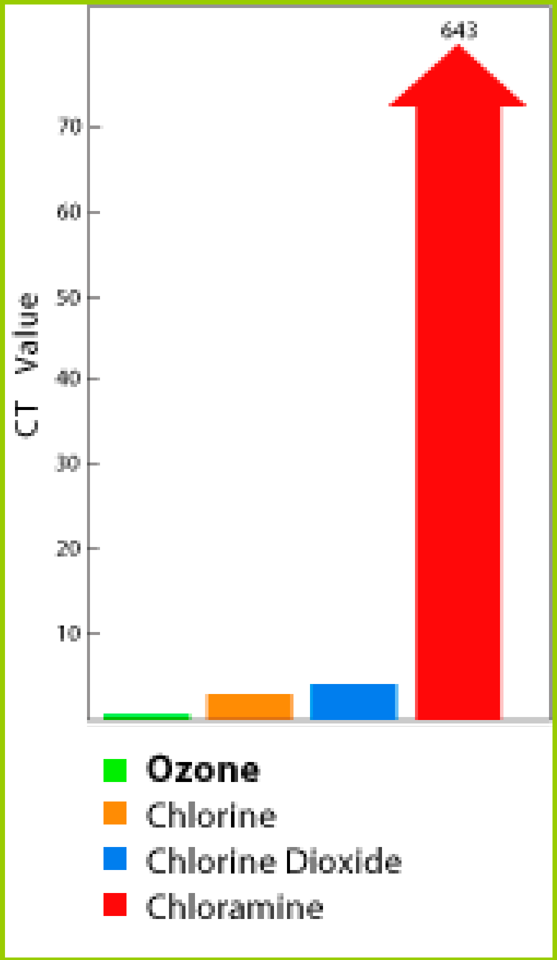
Oxidizing Reagent	Oxidizing Potential
Ozone	2.07
Hydrogen Peroxide	1.77
Permanganate	1.67
Chlorine Dioxide	1.57
Hypochlorous Acid	1.49
Chlorine Gas	1.36
Hypobromous Acid	1.33
Oxygen	1.23
Bromine	1.09
Hypoiodous Acid	0.99
Hypochlorite	0.94
Chlorite	0.76
Iodine	0.54


Iron
Bacteria/ Viruses
Ozone Removes
Hydrogen Sulfide
Manganese


O_3 Oxidizing Bacteria or Viruses
O_3 Oxidizing Microorganisms
O_3 Oxidizing Chemicals & Odors
Bacteria or Virus
Chemicals & Odors
Microorganisms
Ozone / O_3



Inaktivacija virusa
(2 log jedinice)



Inaktivacija cista *Giardia*
(2 log jedinice)

*Aspergillus niger (*Black Mount)	Destroyed by 1.5 to 2 mg/l
Bacillus Bacteria	Destroyed by 0.2 m/l within 30 seconds
Bacillus cereus	99% destruction after 5-min at 0.12 mg/l in water
B. cereus (spores)	99% destruction after 5-min at 2.3 mg/l in water
Bacillus subtilis	90% reduction at 0.10-PPM for 33 minutes
Bacteriophage f2	99.99% destruction at 0.41 mg/l for 10-seconds in water
Botrytis cinerea	3.8 mg/l for 2 minutes
Cladosporium	90% reduction at 0.10-PPM for 12.1 minutes
Clostridium Bacteria	Ozone susceptible

Disinfection Efficacy of Gaseous Ozone against Selected Microorganisms on a Wet Surface over 8 hours.

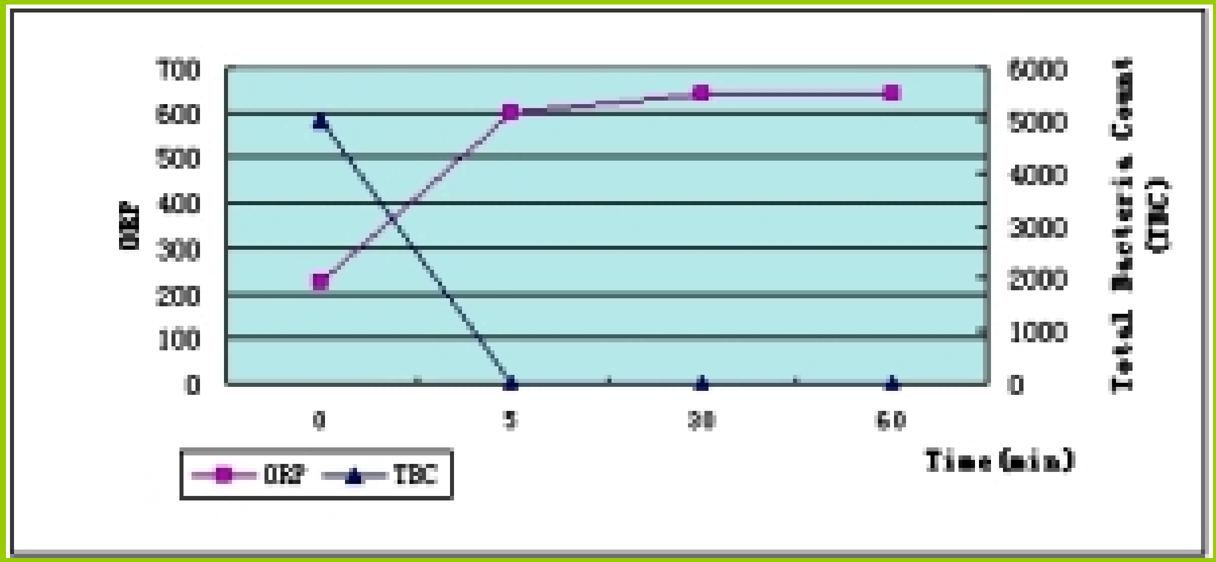
Exposure Time (hours)		E. coli		Salmonella typhimurium		Listeria monocytogenes		Staphylococcus aureus		Streptococcus pyogenes	
		CFU/cm2	Log CFU/cm2	CFU/cm2	Log CFU/cm2	CFU/cm2	Log CFU/cm2	CFU/cm2	Log CFU/cm2	CFU/cm2	Log CFU/cm2
0	rep. 1	500,000,000	8.70	760,000,000	8.88	93,000,000	7.97	910,000,000	8.96	59,000,000	7.77
	rep. 2	550,000,000	8.74	990,000,000	9.00	290,000,000	8.46	530,000,000	8.72	51,000,000	7.71
	Mean		**8.72**		**8.94**		**8.22**		**8.84**		**7.74**
8	rep. 1	<1	<0.00	<1	<0.00	<1	<0.00	<1	<0.00	<1	<0.00
	rep. 2	<1	<0.00	<1	<0.00	<1	<0.00	<1	<0.00	<1	<0.00
	Mean		**<0.00**		**<0.00**		**<0.00**		**<0.00**		**<0.00**
	Reduction		**>8.72**		**>8.94**		**>8.22**		**>8.84**		**>7.74**
	% Reduction	**>99.9999998**		**>99.9999999**		**>99.9999994**		**>99.9999999**		**>99.999998**	

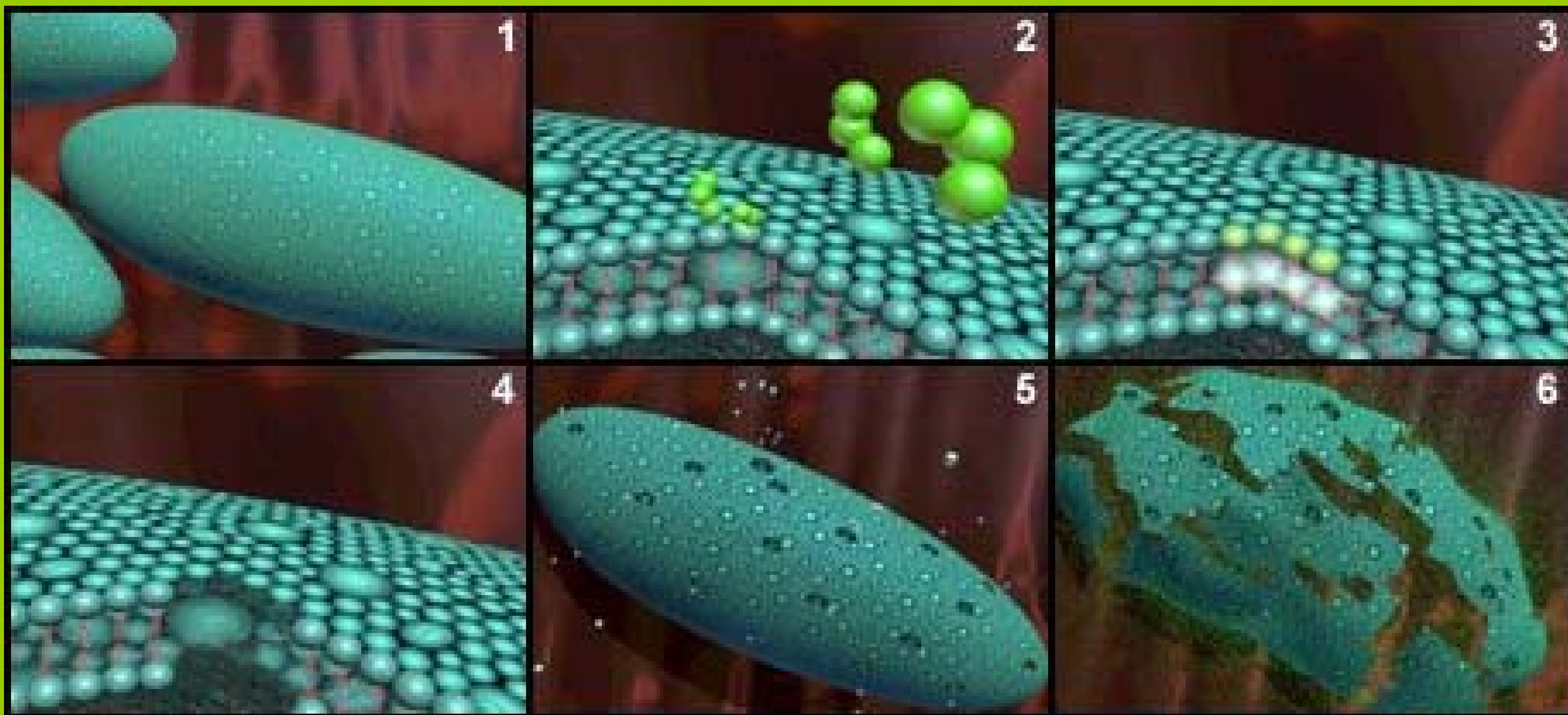
Notes: 1) Reduction = (Mean Log10 count of untreated "0" min. samples) - (Mean Log10 count of subject time variable).

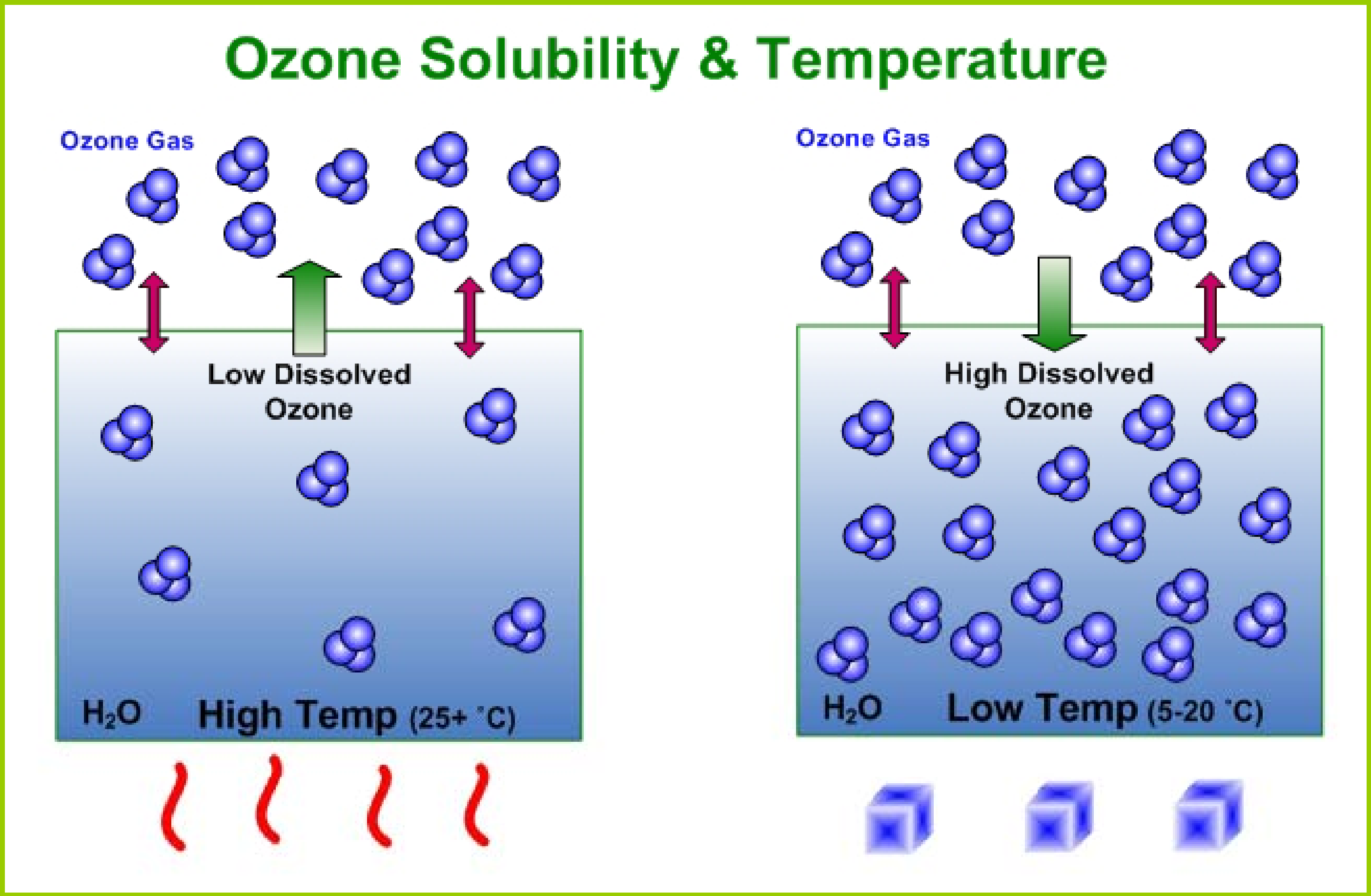
2) % Reduction based upon mean Log10 reduction.

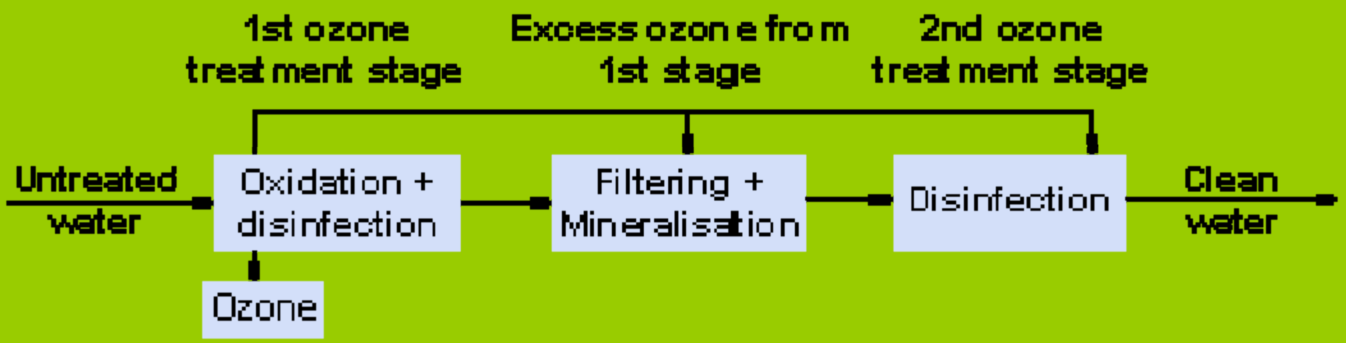
3) Ozone levels for the 8 hour treatment was ca. 158 ppm.

<u>**The test result for PIE Ozonation system for water disinfection**</u>




1
2
3
4
5
6


Ozone Solubility & Temperature
Ozone Gas
Low Dissolved
Ozone
H_2O
High Temp (25+ °C)
Ozone Gas
High Dissolved
Ozone
H_2O
Low Temp (5-20 °C)

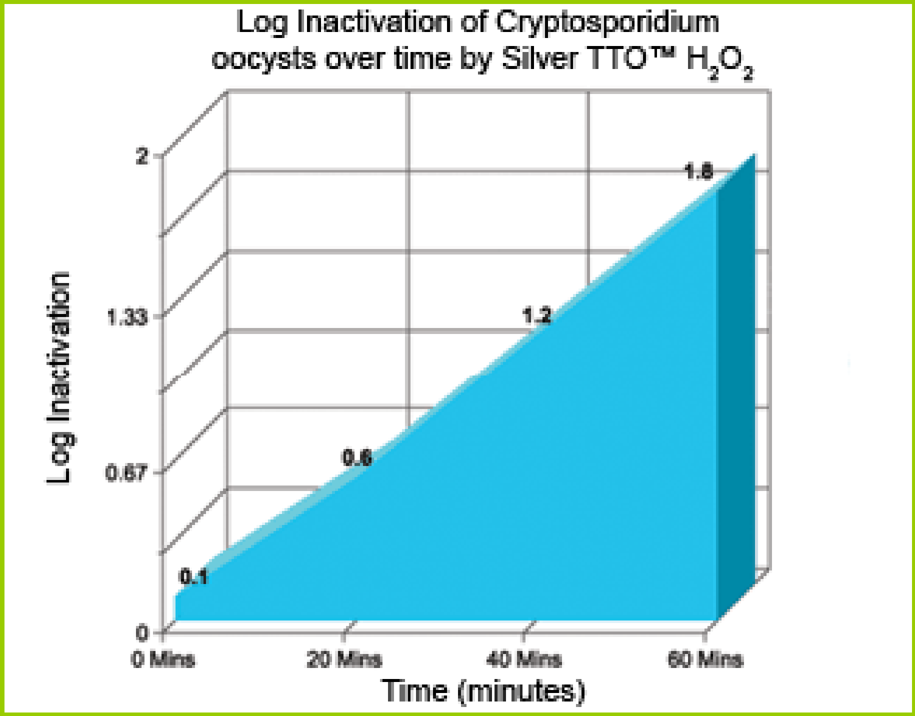


AOP (unapređeni proces dezinfekcije)
jedna meksička bolnica

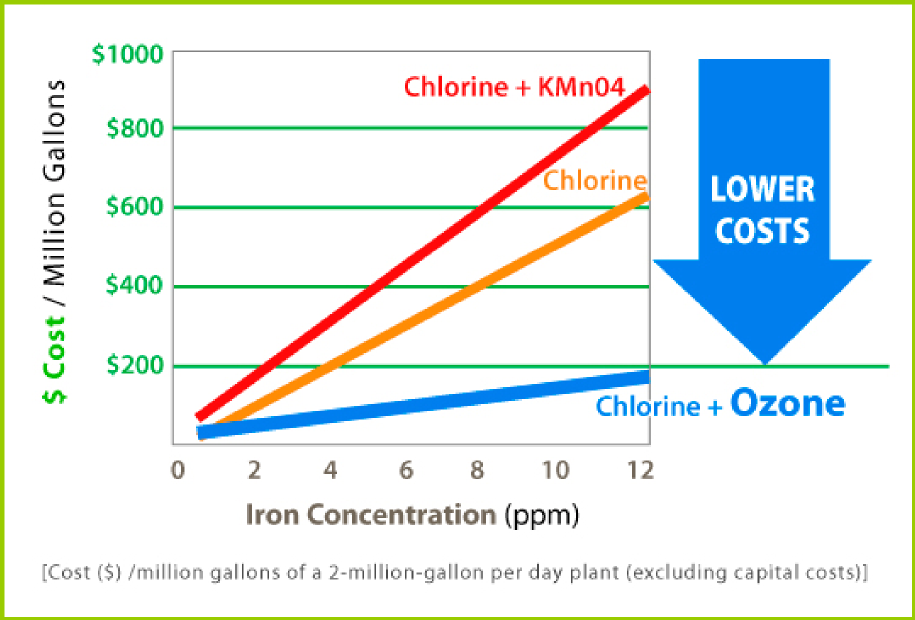
Right: control bax for electrodes. Left: control of pH and redox

3 copper/silver electrodes

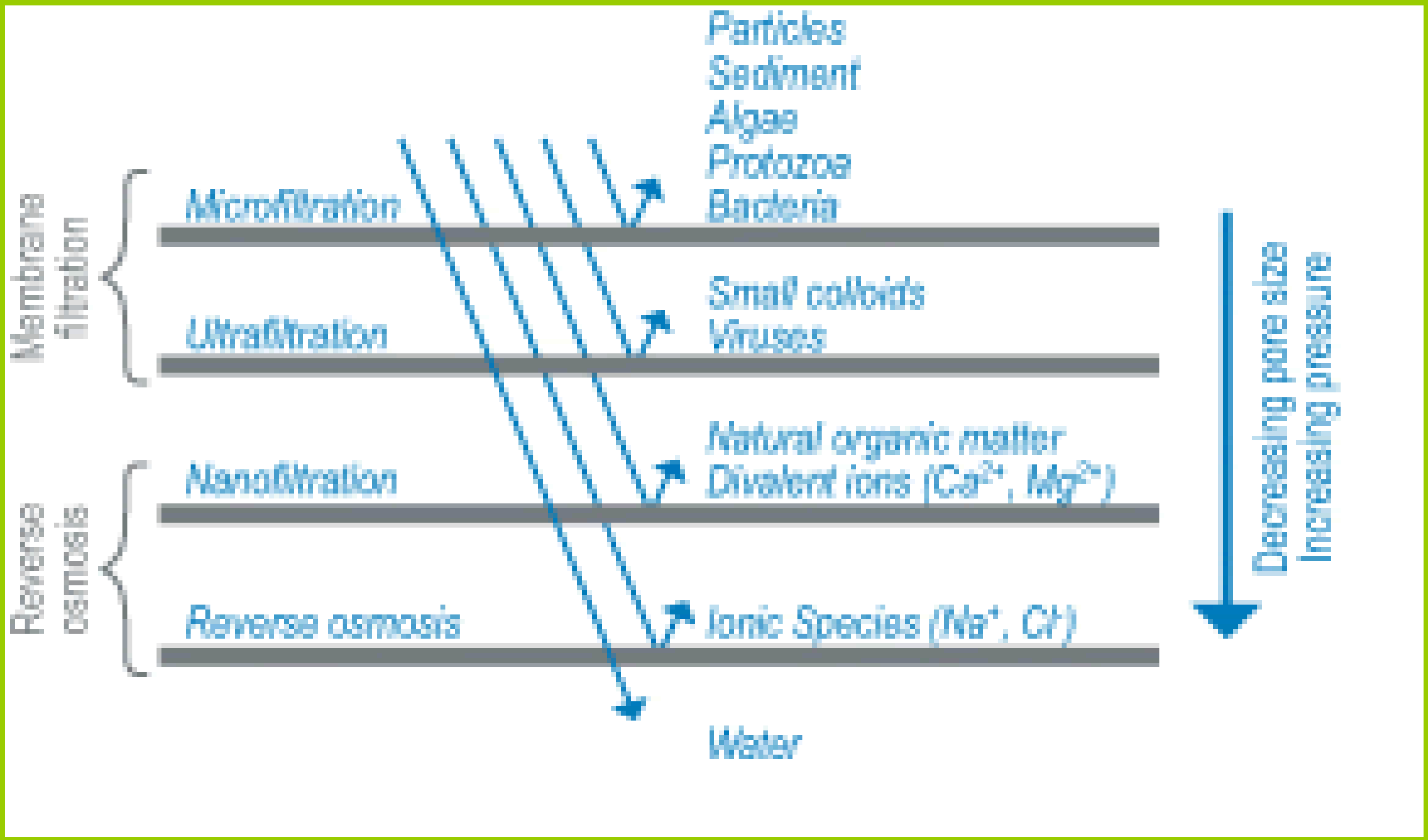
Ionization (desinfection) with 2 copper/silver electrodes.



Log Inactivation of Cryptosporidium oocysts over time by Silver TTO™ H2O2
Log Inactivation
2
1.33
0.67
0
1.8
1.2
0.6
0.1
0 Mins
20 Mins
40 Mins
60 Mins
Time (minutes)

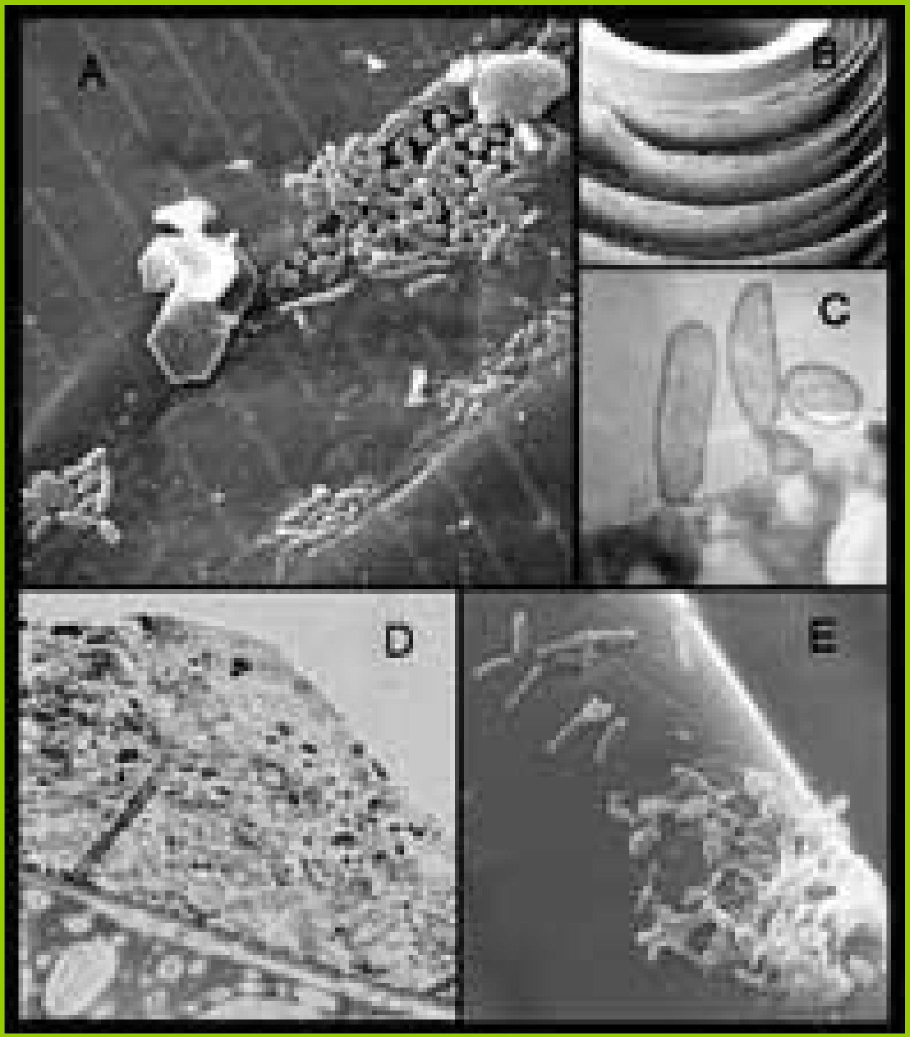


$ Cost / Million Gallons
$1000
$800
$600
$400
$200
Chlorine + KMn04
Chlorine
Chlorine + Ozone
LOWER COSTS
0
2
4
6
8
10
12
Iron Concentration (ppm)
[Cost ($) /million gallons of a 2-million-gallon per day plant (excluding capital costs)]



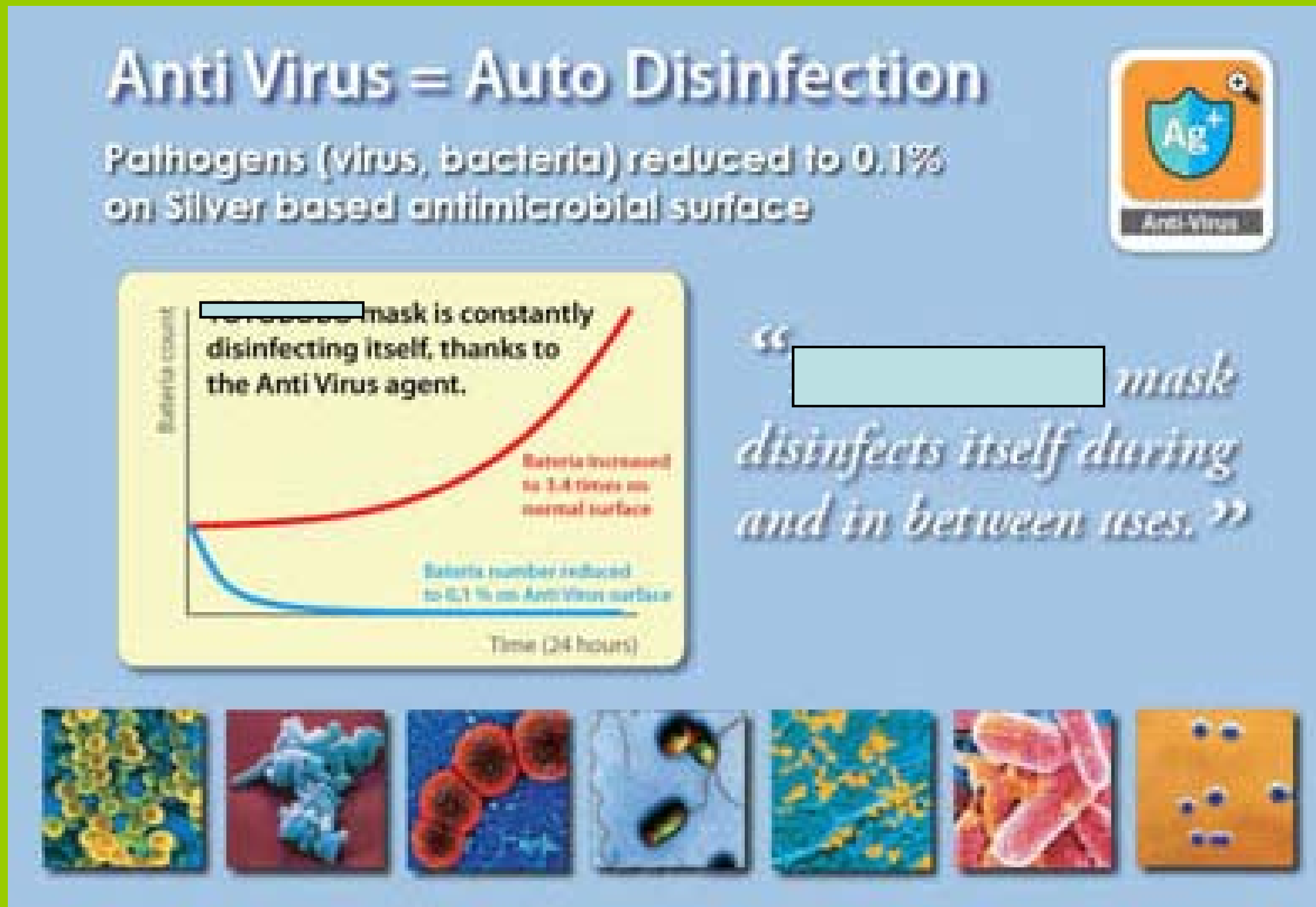
Particles
Sediment
Algae
Protozoa
Bacteria
Membrane filtration
Microfiltration
Small colloids
Viruses
Ultrafiltration
Natural organic matter
Divalent ions (Ca^{2+}, Mg^{2+})
Reverse osmosis
Nanofiltration
Reverse osmosis
Ionic Species (Na^{+}, Cl^{-})
Water
Decreasing pore size
Increasing pressure

Biological fouling of RO membranes



A = scanning electron microscope (SEM) image of bacterial micro-colonies formed on the surface of a cellulose acetate RO membrane after approximately 3 days of operation on pretreated municipal wastewater;
B = a biologically fouled spiral-wound RO membrane element;
C = transmission electron micrograph (TEM) of rod-shaped bacteria attac-hed to an RO membrane surface;
D = TEM of a mature membrane biofilm;
E = nascent biofilm on permeate surface of a CA membrane

primena nanomaterijala u dezinfekciji


Anti Virus = Auto Disinfection
Pathogens (virus, bacteria) reduced to 0.1%
on Silver based antimicrobial surface
Anti-Virus
[redacted] mask is constantly disinfecting itself, thanks to the Anti Virus agent.
Time (24 hours)
“[redacted] mask disinfects itself during and in between uses.”

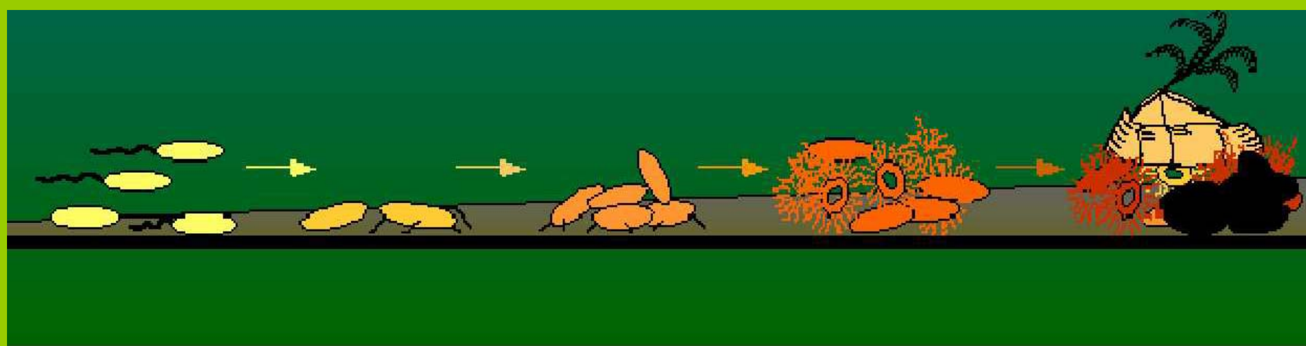


Figure 1 Conceptualization of biofilm development and dynamic behaviors

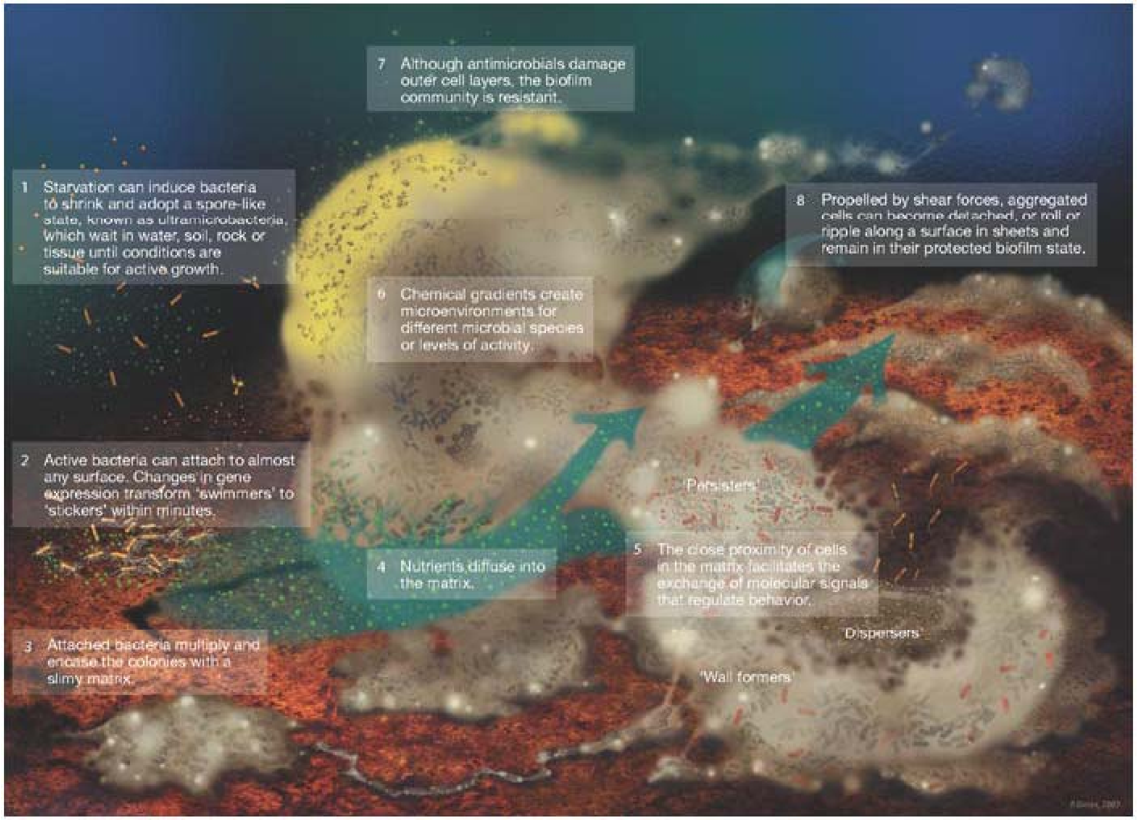
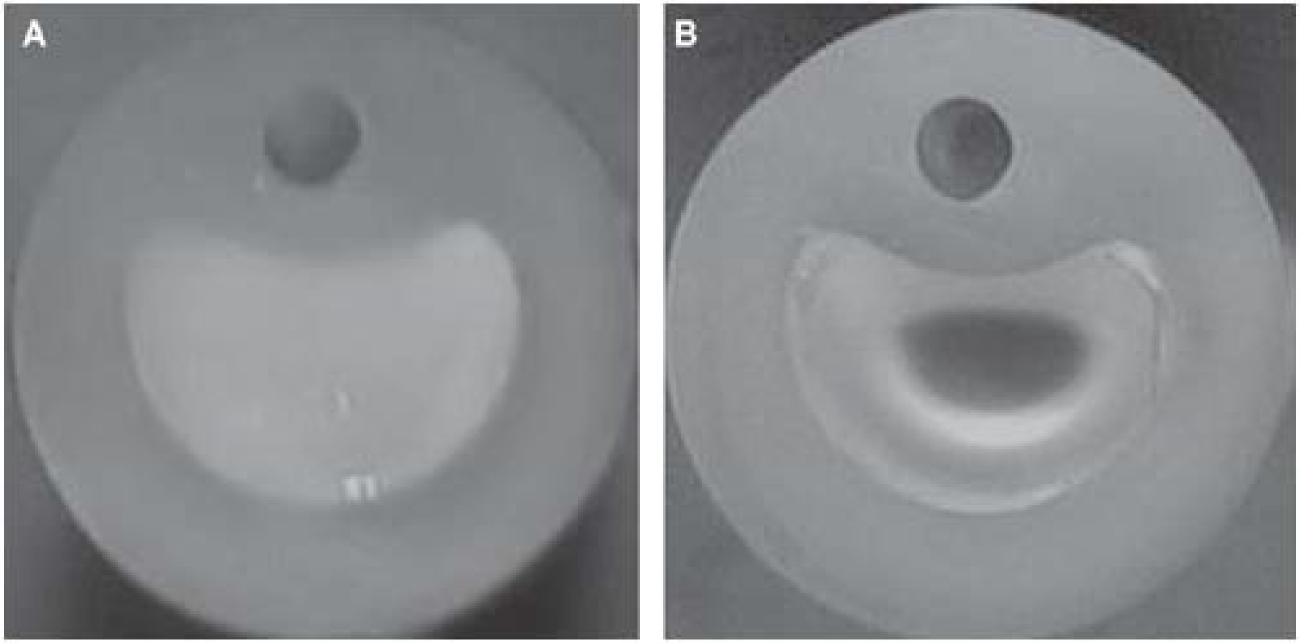


Image courtesy of P Dirckx, Center for Biofilm Engineering, USA. Permission obtained from Nature Publishing Group © Hall-Stoodley L *et al*. (2004) *Nat Rev Microbiol* **2**: 95–108

Stickler DJ (2008) Bacterial biofilms in patients with indwelling urinary catheters
Nat Clin Pract Urol doi:10.1038/ncpuro1231

nature CLINICAL PRACTICE UROLOGY

Figure 9 Examples of mucoid, noncrystalline biofilms formed on all-silicone catheters after 4 days of incubation in a laboratory model of the bladder

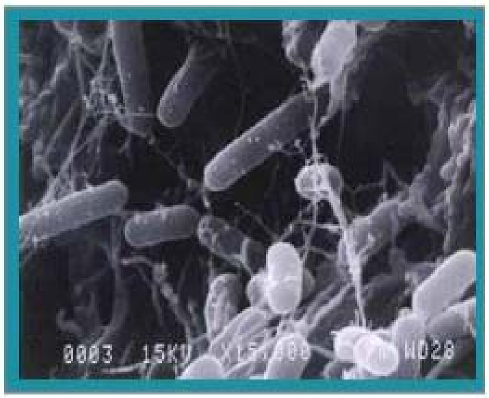


Stickler DJ (2008) Bacterial biofilms in patients with indwelling urinary catheters
Nat Clin Pract Urol doi:10.1038/ncpuro1231

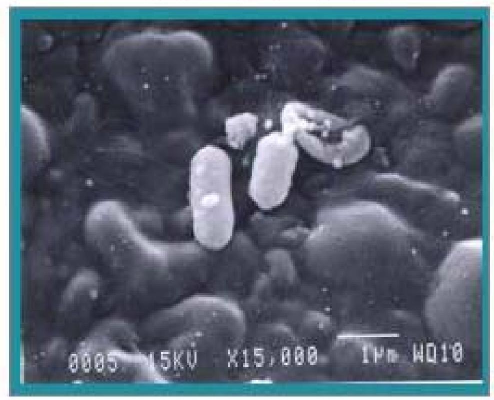
nature CLINICAL PRACTICE UROLOGY

Ozone Biocidal Behavior

Before ozone treatment

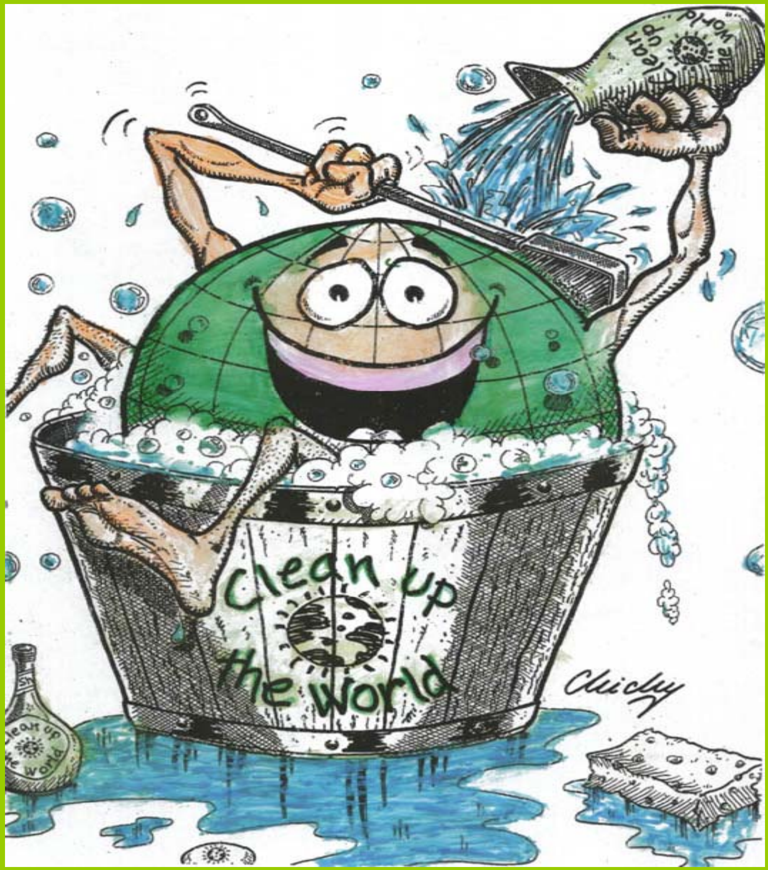


After ozone treatment



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



ZAHVALJUJEM NA PAŽNJI !