Microscopic Assessment of DMWW Particle Removal Effectiveness - 2006

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The effectiveness of Des Moines Water Works treatment is assessed in several ways. Numerous chemistry tests are performed to determine proper softening and clarification. Microbiological tests are performed to assess the presence or absence of coliform indicator bacteria as well as the heterotrophic bacteria that indicate possible biofilm development. Turbidity measurements are continuously monitored during water production and particle counts are sometimes available at the Fleur plant and always available at the Maffitt plant.

However, except for the bacterial cultures, none of these tests defines what the particles are that make it into our system. To determine this, periodic microscopic analyses were performed on the Raccoon River, Des Moines River, Fleur plant finished water, and distribution finished water within each of the five TCR sample collection zones. A few samples fromat the Maffitt plant and its distribution system were also analyzed. This provided a statistical picture of the algal and cyanobacterial cells that survive treatment removal and eventually are present in our distribution system. The presence/absence of oOther inorganic and organic particles such as crystals, metazoa, and nematodes, were was also analyzedevaluated, but none werey detected. no significant detection of them occurred.

Method:

Various samples were collected for examination with an emphasis on the distribution system. 12-milliliter river samples and 200-ml distribution system samples were centrifuged at 2160 rpm (1050 rcf) for 20-minutes. The supernatant was aspirated by vacuum to ½-ml and 0.1-ml respectively. The test tubes were then vortexed to redisperse the particles. 40-microliter aliquots were placed onto microscope slides. The slides were then scanned for particles that were counted and characterized.

Results and Summary:

All viewable inorganic and organic particles of inorganic and organic natures were consideredevaluated. With the exception of calcium carbonate, which is carried over into the finished water during lime softening treatment, no crystals were detectedThere was no detection of significant crystals apart from the occasional calcium carbonate crystal as a by-product of lime softening. There was also no detection of Mmulticellular microorganisms such as metazoa, crustaceans, or nematodes also were not detected.

Green algae and cyanobacteria were observed and counted. The pumpage ratio of the rivers and infiltration gallery were recorded along with the average pH of the lime basins. The percentage of the particles penetrating the treatment process and breaking through to the finished water was aAlso considered. This will be termed “breakthrough percentage” during subsequent discussion. Because the absolute numbers of green algae and cyanobacteria vary greatly from day to day, it is important

to evaluate what percentage havepercentage has been removed in addition to the actual number in the finished water. was the percentage of particles of the overall river count. These parameters were charted and graphed to provide a visual picture of our removal effectiveness.

Chart of Data

	Microscopic Analysis of DMWW Treatment Effectiveness - 2006									
Date	Raccoon River MGPD	Des Moines River MGPD	Infiltration Gallery MGPD	Total MGPD	Average Softening Basin pH	Site	Green Algae per ml	Algae Overall % of Raw	Cyanobacteria per ml	Cyano Overall % of Raw
06/07/2006	7.8	**46.7**	17.2	71.6	10.05	**RR**	**11,450**		**40**	
	14.30%	85.70%				**DMR**	**1,374**		**7360**	
	Algae average= 2815/ml					FA	25	0.888	**460**	**13.264**
	Cyano average= 3468/ml					FE	3	0.107	**40**	**1.153**
						F Lab	5	0.178	**30**	0.865
						F Earlham Maffitt	0	0.000	0	0.000
						F Urbandale	5	0.178	0	0.000
						F 222, Zone 2	1	0.036	2.5	0.072
						F 308, Zone 2	1.25	0.044	12.5	0.360
						F 319, Zone 2	2.5	0.089	2.5	0.072
						F 515, Zone 2	0	0.000	0	0.000
06/19/2006	17	**46.6**	9.1	72.7	10.04	**RR**	**49,464**		**690**	
	26.70%	73.30%			low=8.92	**DMR**	**3206**		**2530**	
	Algae average= 15,557					FA-E	36.8	0.237	**222.5**	**10.918**
	Cyano average= 2038/ml					FA-W	43.5	0.280	**220**	**10.795**
						FE	27.3	0.175	**92.5**	**4.539**
						F Lab, 10-sec.flush	16.3	0.105	5	0.245
						F Lab, 3-min.flush	12.5	0.080	10	0.491
						F Lab, water cooler 2-wks old	0.5		0	
						F 339, Zone 4	3.5	0.022	5	0.245
						F 340, Zone 4	1.5	0.010	2.5	0.123
						F 448, Zone 4	4.5	0.029	1	0.049
						F 343, Zone 4	3.75	0.024	0	0.000
06/22/2006	**26**	**23.1**	17.2	66.3	10.14	F 253, Zone 4	1	0.0036	0	0.000
	53%	47%				F 254, Zone 4	1.25	0.0045	0	0.000
	Algae average= 27,723/ml					F 255, Zone 4	2	0.0072	2.5	0.161
	Cyano average= 1553/ml					F 509, Zone 4	**25.25**	0.0911	**15**	0.966
06/26/2006	**22**	0	17	39	10.50	**RR**	**27,488**		**230**	
	100%	0%				**DMR**	**3,664**		**3220**	
06/28/2006	**33.2**	0.1	17.8	10.32	10.32	F Lab	4	0.015	0	0.000
	100%	0%				F 376, Zone 1	11.5	0.042	0	0.000
						F 377, Zone 1	4	0.015	0	0.000
						F 477, Zone 1	10.25	0.037	0	0.000
07/10/2006	**40.3**	3.3	16.8	60.5	10.61	**RR**	**32,060**		**460**	
	92.40%	7.60%				**DMR**	**916**		**9660**	
07/11/2006	**15.2**	0	14.6	29.8	10.79	F 322, Zone 3	9.5	0.030	20	0.435
	100%	0%				F 446, Zone 3	18	0.056	7.5	**1.630**
						F 480, Zone 3	11	0.034	0	0.000
						F 502, Zone 3	9.75	0.030	0	0.000
07/18/2006	**45.6**	0.3	17	62.9	10.56	**RR**	**36,640**		**2300**	
	100%	0%				**DMR**	**1374**	**Fleur** **Maffitt**	**13,570**	**Fleur** **Maffitt**
						F 200, Zone 1 - Maffitt	3.25	0.009 0.142	**285**	12.391 1.007
						F 205, Zone 1 - Maffitt	2	0.005 0.087	**75**	3.261 0.265
						F 442, Zone 1 - Maffitt	3.25	0.009 0.142	**32.5**	1.413 0.115
						F 479, Zone 1 - Maffitt	0.75	0.002 0.033	1.25	0.054 0.004
	Crystal Lake/5 = Raw water value.					**Crystal Lake**	**2290**		**28,290**	
	Algae= 458, Cyano = 5658					F Lab, Maffitt	8.75	0.024 0.382	**377.5**	16.413 1.334
						F, Maffitt plant hot	0.5		30	
07/24/2006	**33.3**	0.2	16.6	50.1	10.61	**RR**	**13,740**		**1380**	
	100%	0%				**DMR**	**5496**		**19,550**	
						F 253, Zone 4	4.25	0.031	2.5	0.181
						F 255, Zone 4	4.75	0.035	0	0.000
						F 262, Zone 4	3	0.022	2.5	0.181
						F 509, Zone 4	4.25	0.031	2.5	0.181
08/16/2006	0	**24.2**	14	38.2	10.49	**RR**	**3772**		**0**	
	0%	100%				**DMR**	**828**		**690**	
						FA-W	5.75	0.694	0	0.000
						FA-E	6.75	0.815	0	0.000
						FE	6.25	0.755	0	0.000
						F Lab	2.25	0.272	0	0.000
10/31/2006	0	8	17	25	10.64	**RR**	**1832**		**1380**	
	0%	100%				**DMR**	**2290**		**4140**	
						F 285, Zone 5	0.25	0.011	0	0.000
						F 511, Zone 5	0	0.000	2.5	0.060
						F 390, Zone 5	0	0.000	1.25	0.030
						F 387, Zone 5	0.25	0.011	0	0.000

Chart of Plant Treatment

Date	Raccoon River MGPD	Des Moines River MGPD	Infiltration Gallery MGPD	Total MGPD	Average Softening Basin pH	Site	Green Algae per ml	Algae Overall % of Raw	Cyanobacteria per ml	Cyano Overall % of Raw
06/07/2006	7.8	**46.7**	17.2	71.6	10.05					
	14.30%	85.70%				**Average Raw Count**	**2,815**		**3468**	
	Algae average= 2815/ml					FA	25	0.888	**460**	**13.264**
	Cyano average= 3468/ml					FE	3	0.107	**40**	**1.153**
						F Lab	5	0.178	**30**	0.865
06/19/2006	17	**46.6**	9.1	72.7	10.04					
	26.70%	73.30%			low=8.92	**Average Raw Count**	**15557**		**2038**	
	Algae average= 15,557					FA-E	36.8	0.237	**222.5**	**10.918**
	Cyano average= 2038/ml					FA-W	43.5	0.280	**220**	**10.795**
						FE	27.3	0.175	**92.5**	**4.539**
						F Lab	12.5	0.080	10	0.491
						F Lab, Maffitt	8.75	9.910	377.5	6.672
						Average Raw Count	**828**		**690**	
08/16/2006	0	**24.2**	14	38.2	10.49	FA-W	5.75	0.694	0	0.000
	0%	100%				FA-E	6.75	0.815	0	0.000
						FE	6.25	0.755	0	0.000
						F Lab	2.25	0.272	0	0.000
						F Lab	2.25	0.272	0	0.000

(Microbe Breakthrough)
The data and graphs of the distribution system supplied primarily by Fleur plant water revealed a range of algal cells from 0 to 25 per milliliter. When the breakthrough percentage waspercentages of cells in the system were compared to the algal cell count of the rivers, no distinct relationship was discernable. Furthermore, proximity of the sample collection zones to the treatment facility had no bearing on algal numbers.

Even though the zZone-1 distribution water is largely supplied from the considered to be from the Maffitt treatment plant. Raw water green algae are less abundant in Maffitt water than what is found in Fleur water. Nonetheless, samples from Zone 1 showed higher breakthrough percentages for the Maffitt Plant.had moderately low algal cell numbers, the percentages of algal cells in the finished water, when compared to the original raw water counts, were higher than that found in the Fleur plant water.

The number of cyanobacterial cells entering the distribution system from the Maffitt plant was significantly higher than the number entering the system from the Fleur plant. Crystal Lake represented on average only 20% of the Maffitt well water which had no cyanobacterial cells. Again, this supports the conclusion that the breakthrough percentage at Maffitt is greater than Fleur Drive.

Algal and cyanobacterial breakthrough during three different days of treatment at Fleur processes was variable. The lime basin pH was 10.05 and 10.04 for the first two trials when algal and cyanobacterial breakthrough was highest. The second of these two trials had the most breakthroughs, which may have been due to a problem with one of the softening basins where the pH dipped to 8.92. The pH was at 10.49 for the third trial, where algal breakthrough was low, and cyanobacterial breakthrough was undetectable. The raw counts were only about one-third that of the first two studies, which general explains the lower algal breakthrough numbers for the first two trials.

However, theThe cyanobacterial breakthrough numbers in the third trial were exceptionally low relative to the raw counts, which may relate to softening pH.

When a Maffitt tap finished water sample was studied, it revealed relatively moderate-to-high algal breakthroughs and high cyanobacterial breakthrough percentages., with the algal percentage of raw being relatively high and the cyanobacterial percentage of raw being relatively moderately high. The softening pH was at 10.3.

(Microbe Viability)

When microbial particles are detected in finished water, their viability often-times is in doubt questioned. We know from routine heterotrophic bacterial plate counts (HPC's), that our Fleur finished water bacterial average ranges between 0 and 1 cells per milliliter. HPC's taken from our distribution system average 23 cells per milliliter. (Some or most of these may be bacteria recovered from the faucet nozzles, as opposed toversus them being a part of the actualtrue distribution system bacterial flora.)

Viability Ddetermination of algael and cyanobacterial viability cells is is more difficult. To determine this, two methods of culture were used. The first method simply employedused bottles of treatment plant and distribution finished water that were placed in indirect sunlight for six weeks. Eventually, green growth of algae was observed in the four bottles used. Microscopic analysis revealed two species of unicellular algae.

No cyanobacteria sum werewasas observed, but this did not rule out their viability, considering that their growth requirements differ from algae.

Water dDistribution systems are not exposed to light under most circumstancesdo not contain light in most of their components, so algae would not be expected to flourish., Bbut where the water is exposed toreaches light, such as in showers, clear hoses, etc., the algae would could potentially grow.

The second test for viability used an agar medium that I developed several years ago called natural matrix medium (NMM). The sample is affixed in sterile agar with no additional nutrients added, to avoid inhibition of protein sensitive environmental organisms. The NMM allows development of cells into distinct colonies.

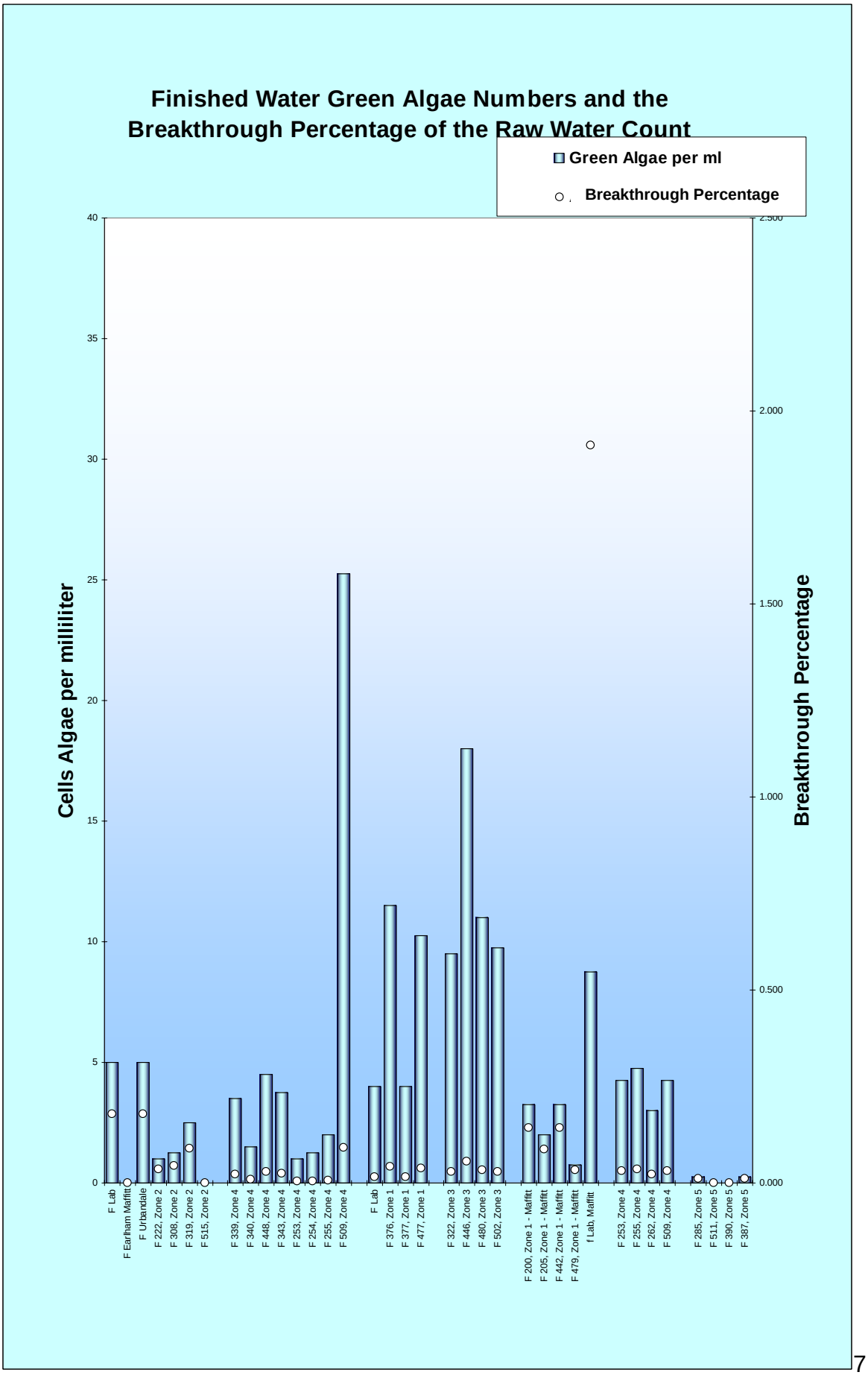
The finished water NMM plates were placed into indirect sunlight and incubated for several days. In this test there grewO only the expected bacterial colonies grew. No algal or cyanobacterial colonies formed.

Even though I was unable to prove that the cyanobacteria observed remained viable in the distribution system, their overall appearance gave them a look of vitality. There was no deterioration of their cell walls and little or no bleaching of their chlorophyll.

The algal cells that were viewed and proved viable in our distribution system were similar or larger in size than *Cryptosporidium* and *Giardia* oocysts and cysts. This

suggests that protozoa could breakthrough into our system if they arewere present in the raw water in high numbers similar to that seen for green algaewould be potentially possible, if the raw water numbers reach that of the algae. Thus far, tests have shown the presence of very few *Giardia*, but notand very rare *Cryptosporidium*, in the raw water. Sufficient CT values are maintained in the clearwell to kill *Giardia*.

The algal and cyanobacterial cells in the distribution water would not equal a detectable amount of disinfection by-product producing organic material.


Finished Water Green Algae Numbers and the Breakthrough Percentage of the Raw Water Count
Green Algae per ml
Breakthrough Percentage
Cells Algae per milliliter
Breakthrough Percentage
0
5
10
15
20
25
30
35
40
0.000
0.500
1.000
1.500
2.000
2.500
F Lab
F Earlham Maffitt
F Urbandale
F 222, Zone 2
F 308, Zone 2
F 319, Zone 2
F 515, Zone 2
F 339, Zone 4
F 340, Zone 4
F 448, Zone 4
F 343, Zone 4
F 253, Zone 4
F 254, Zone 4
F 255, Zone 4
F 509, Zone 4
F Lab
F 376, Zone 1
F 377, Zone 1
F 477, Zone 1
F 322, Zone 3
F 446, Zone 3
F 480, Zone 3
F 502, Zone 3
F 200, Zone 1 - Maffitt
F 205, Zone 1 - Maffitt
F 442, Zone 1 - Maffitt
F 479, Zone 1 - Maffitt
f Lab, Maffitt
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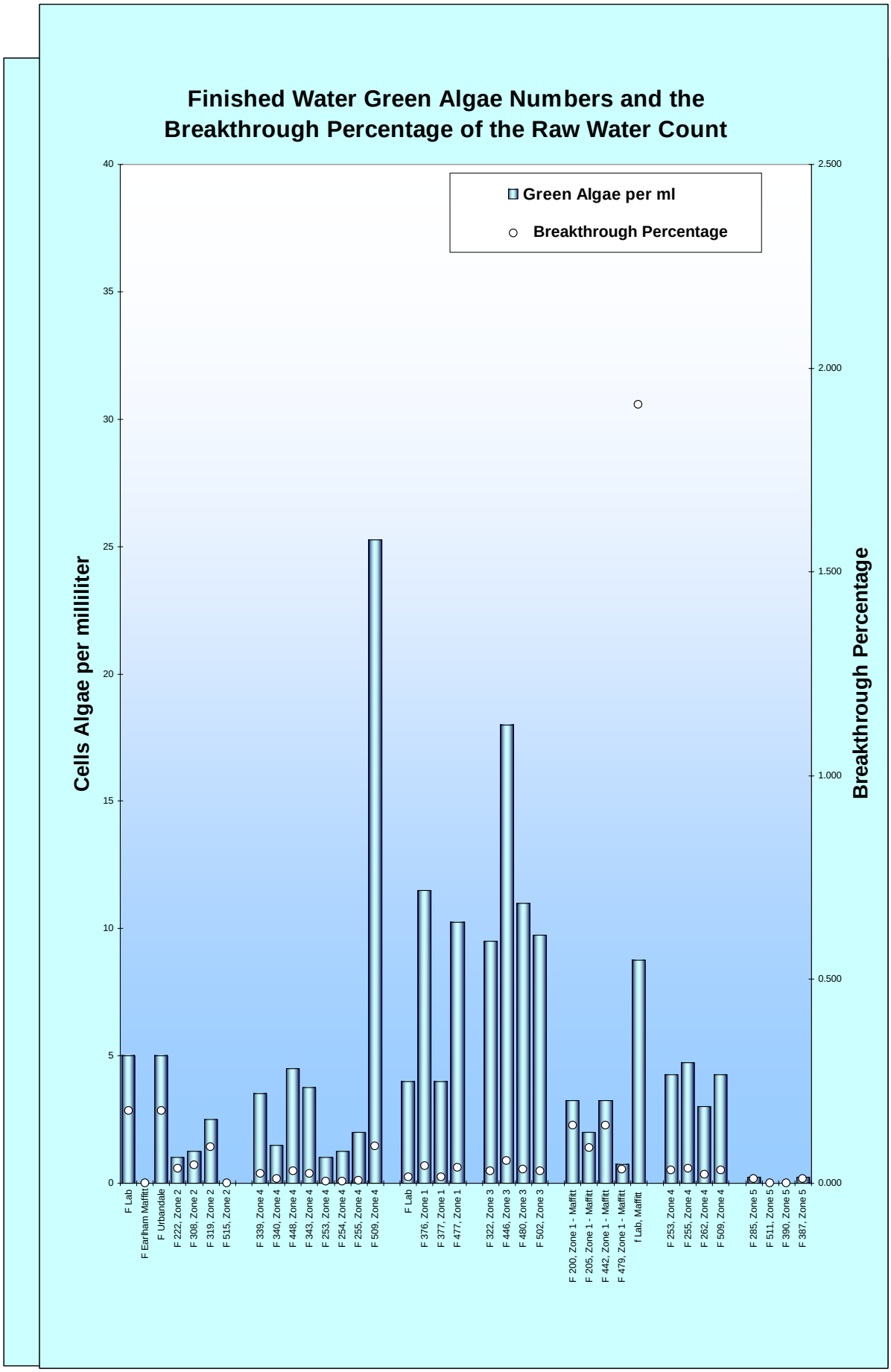
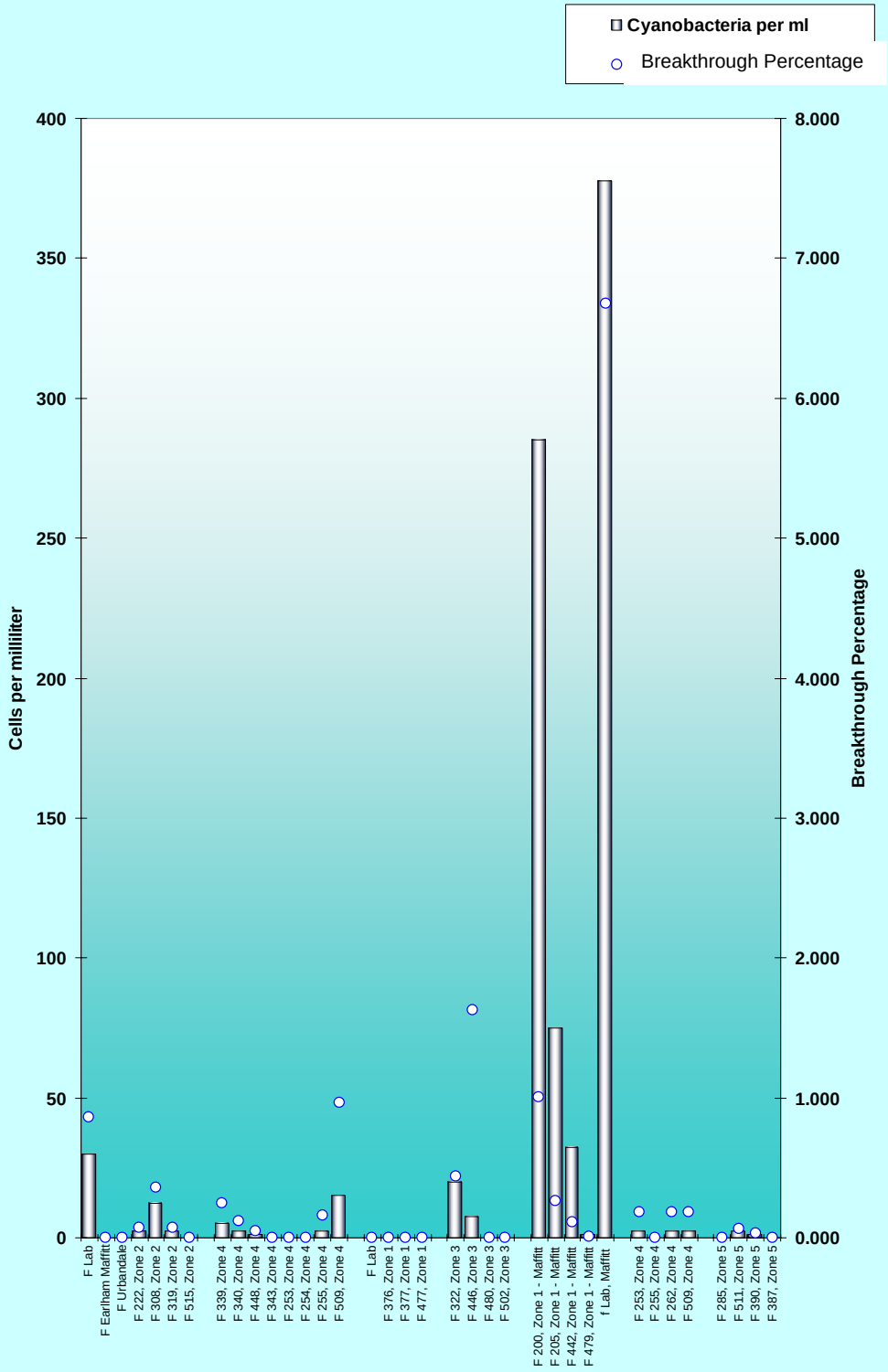
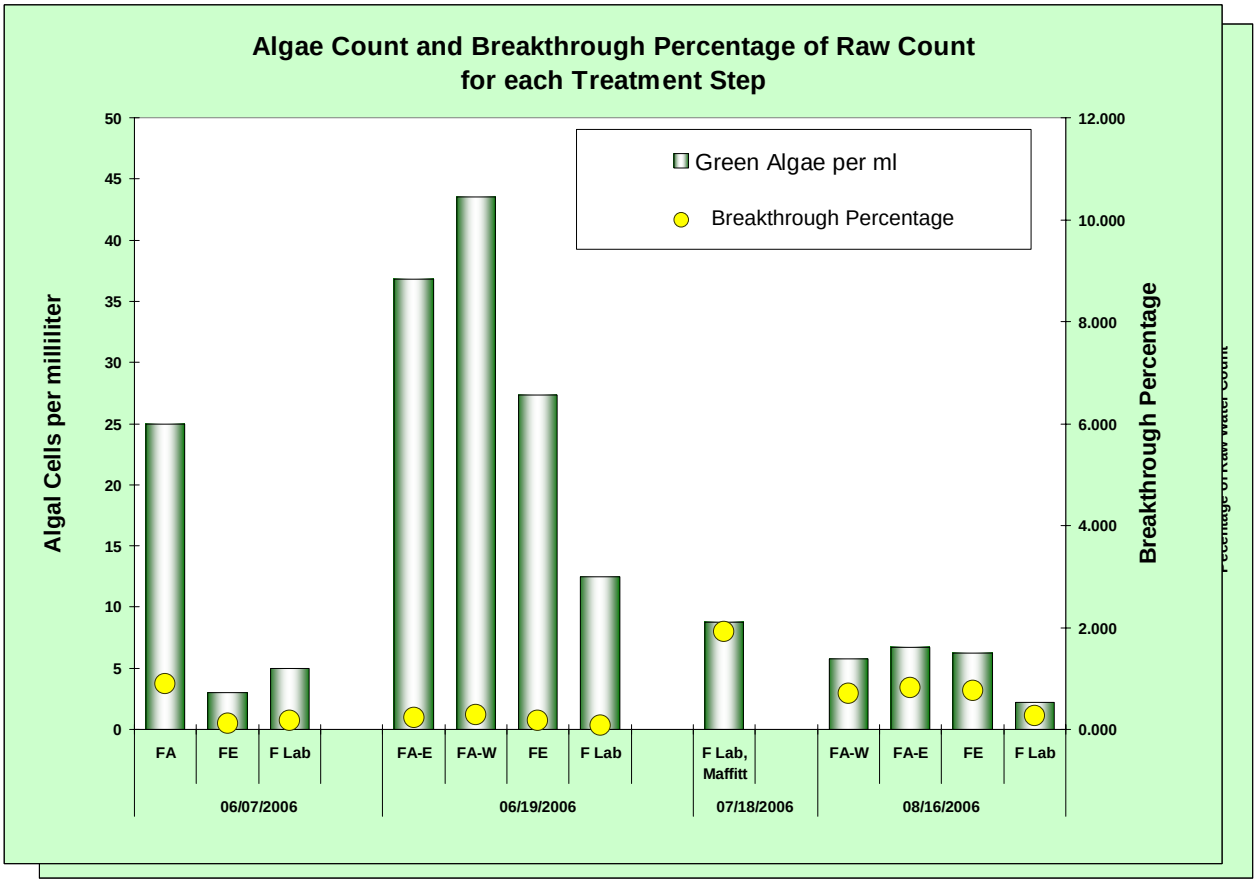
F 511, Zone 5
F 390, Zone 5
F 387, Zone 5

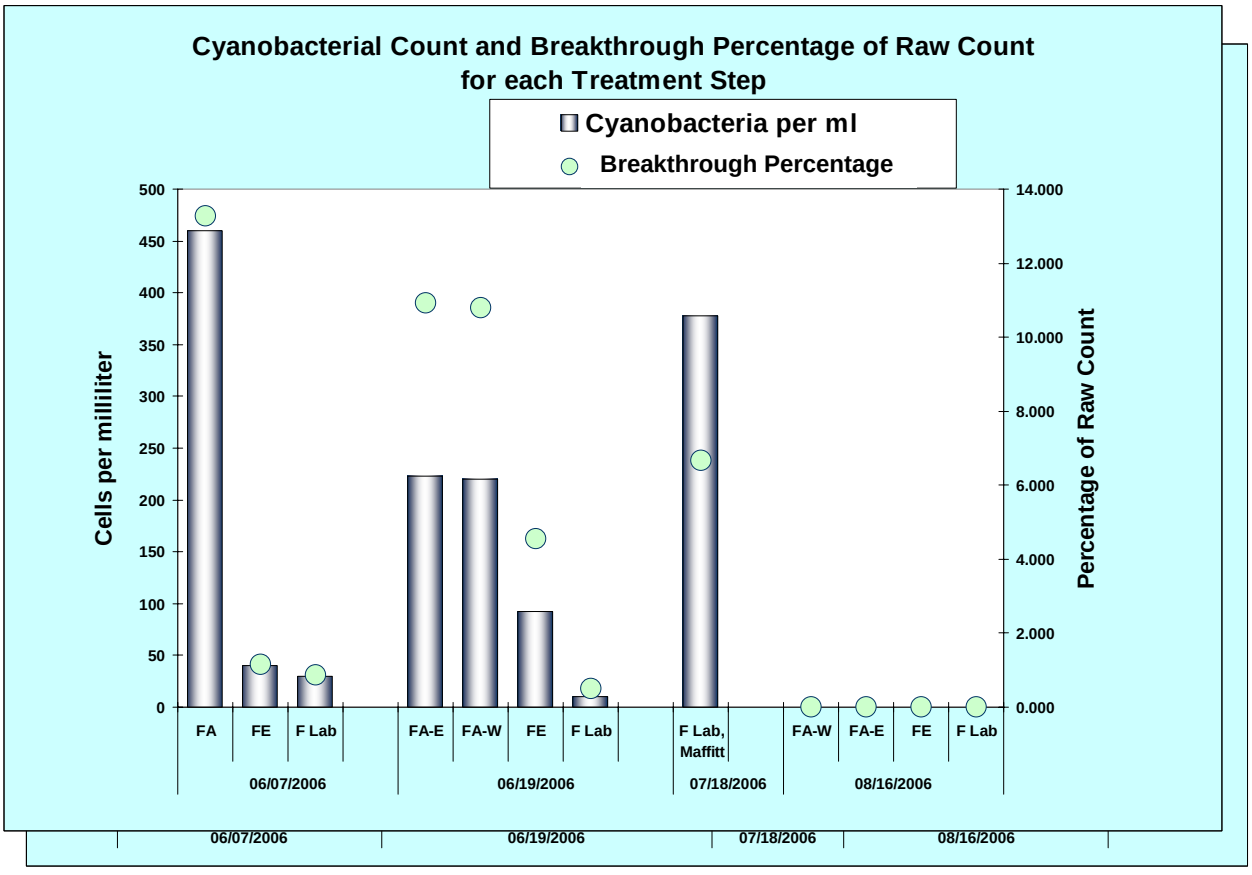

Finished Water Green Algae Numbers and the Breakthrough Percentage of the Raw Water Count
Green Algae per ml
Breakthrough Percentage
Cells Algae per milliliter
Breakthrough Percentage
0
5
10
15
20
25
30
35
40
0.000
0.500
1.000
1.500
2.000
2.500
F Lab
F Earlham Maffitt
F Urbandale
F 222, Zone 2
F 308, Zone 2
F 319, Zone 2
F 515, Zone 2
F 339, Zone 4
F 340, Zone 4
F 448, Zone 4
F 343, Zone 4
F 253, Zone 4
F 254, Zone 4
F 255, Zone 4
F 509, Zone 4
F Lab
F 376, Zone 1
F 377, Zone 1
F 477, Zone 1
F 322, Zone 3
F 446, Zone 3
F 480, Zone 3
F 502, Zone 3
F 200, Zone 1 - Maffitt
F 205, Zone 1 - Maffitt
F 442, Zone 1 - Maffitt
F 479, Zone 1 - Maffitt
f Lab, Maffitt
F 253, Zone 4
F 255, Zone 4
F 262, Zone 4
F 509, Zone 4
F 285, Zone 5
F 511, Zone 5
F 390, Zone 5
F 387, Zone 5

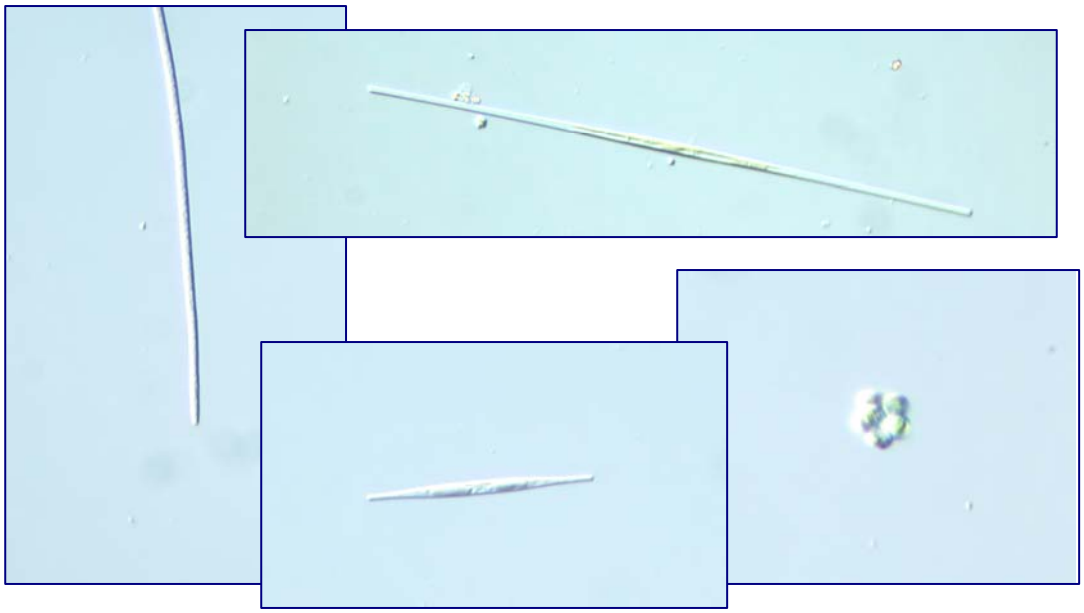
Finished Water Cyanobacterial Numbers and the Breakthrough Percentage of the Raw Water Count

Cells per milliliter



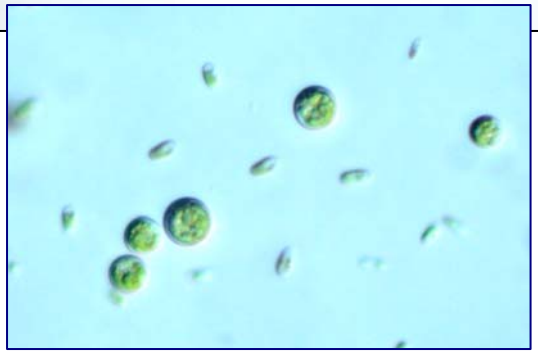

Algae Count and Breakthrough Percentage of Raw Count for each Treatment Step
Green Algae per ml
Breakthrough Percentage
Algal Cells per milliliter
Breakthrough Percentage
50
45
40
35
30
25
20
15
10
5
0
12.000
10.000
8.000
6.000
4.000
2.000
0.000
FA
FE
F Lab
FA-E
FA-W
FE
F Lab
F Lab, Maffitt
FA-W
FA-E
FE
F Lab
06/07/2006
06/19/2006
07/18/2006
08/16/2006

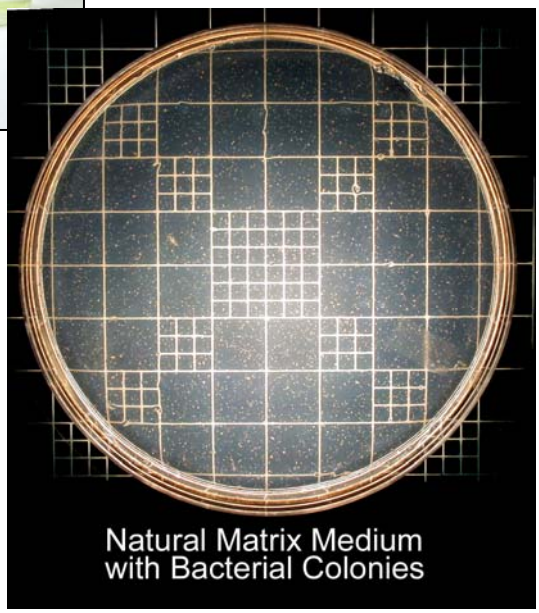

Cyanobacterial Count and Breakthrough Percentage of Raw Count for each Treatment Step
Cyanobacteria per ml
Breakthrough Percentage
Cells per milliliter
Percentage of Raw Count
500
450
400
350
300
250
200
150
100
50
0
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
FA
FE
F Lab
FA-E
FA-W
FE
F Lab
F Lab, Maffitt
FA-W
FA-E
FE
F Lab
06/07/2006
06/19/2006
07/18/2006
08/16/2006



Photomicrographs of algae and cyanobacteria that entered into our distribution system

Finished water algal growth after 6-weeks in light





Natural Matrix Medium
with Bacterial Colonies

Des Moines Water Works Total Coliform Rule Sampling Zones