Advanced Aeration INC.

102 Midway Industrial Park, Angleton, TX 77595

Aeration Retrofit to Septic System
Phase II 30-day test
A study of the effects of aeration systems on traditional septic systems

Baylor Wastewater Research Program, Baylor University, Waco, Texas
2007 - 2009

Introduction

Vacuum Bubble® Technology (VBT™) creates micro bubbles of air that are neutrally buoyant. The bubbles are created under a partial vacuum and, as a result, the internal pressure of the bubbles is lower than that of the surrounding water. Consequently, the bubbles collapse to an average dimension of 0.25 mm in diameter. Because of their small size and neutral buoyancy, the bubbles remain in the water for many minutes. These micro bubbles increase the oxygen transfer potential in the water which, in turn, enables aerobic bacteria to consume the organic waste in the water.

Following is the report as presented by the Baylor Wastewater Research Program at Baylor University

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Baylor Wastewater Research Program
Baylor University
Waco, Texas

March 21, 2009

Introduction

Purpose

The purpose of the project was to determine the effects of adding aerators to a traditional septic system in order to assess the potential for retrofitting traditional septic tanks in an effort to improve traditional septic system performance. In addition to improving the septic tank effluent, one particular aspect of the project is to assess the impact of aeration in the septic systems to the leach field performance. The evolution of this study created two sampling phases and offered the opportunity to stress test the VBT micro bubble process under several different conditions not normally tested under NSF Standard protocols.

Location

The study was conducted at the Baylor Wastewater Research Program (BWRP) research site in Waco, Texas. The site is located at the Waco Metropolitan Regional Area Sewerage System (WMARSS) adjacent to the NSF International, Waco site.

Methods

Wastewater was pumped form the WMARSS facility to the NSF facility then to the BWRP facility where the wastewater was dosed to two 750-gallon septic tanks placed in series (figure1). The dosing followed the NSF/ANSI Standard 40 design loading format as the septic system received 500 gallons per day apportioned as 175 gallons (35%) between 6:00 am and 9:00 am in the morning, 125 gallons (25%) between 11:00 am and 2:00 pm, and 200 gallons (40%) between 5:00 pm and 8:00 pm to simulate household use. Effluent from the first tank flowed by gravity to the second tank and effluent from the second tank was pumped using peristaltic pumps to two (2) soil columns to represent the effect of a leach field. One of the soil columns was filled with a type 1b soil and the other was filled with a type 3 soil. Effluent was pumped to the soil columns scaled in volume to the column size in a flow proportional amount of (35%, 25% and 40%) and during the same dosing times as the design loading schedule. The effluent from the soil columns drained by gravity to sample bottles stored in a refrigerator and collected every 48 hours (figure 2). Effluent samples from the two septic systems were collected by peristaltic pumps in a flow proportional 24-hour composite also stored in the refrigerator.

Phase I of the study started in December, 2007 and concluded in May, 2008. Thirteen weeks of dosing without any aeration occurred from Late December, 2007 to April 1, 2008. Accumulated sewage sludge was allowed to remain in the tanks after the anaerobic start up period and before the VBT units were installed April 1st 2008. Phase I sampling was completed in May of ’08 and the sludge volumes were measured in both compartments of both tanks. The two VBT units were checked for proper operation and both reactor tanks were then operated for six months under a continuous 500 GPD load without further sampling. The Phase II sampling period was established to occur during the coldest two months, December and January, to evaluate the VBT Micro Bubble performance during lower influent temperatures and the resulting reduced rate of biological activity. Sludge volumes were again measured before and after the Phase II sampling period. Phase II began after the aerators had been running for 9 months. This phase (II) focused on the reduction of parameters from raw influent to septic effluent and then to soil column effluent (soil columns simulated potential leach fields). Samples from the raw influent and septic effluent were collected and analyzed 3-5 days a week for $CBOD_5$, TSS and Nitrogen species but only weekly for P (TP and PO_4) and bacteria (E.coli and Fecal Coliforms). The soil columns were only analyzed once a week because of the small volumes of effluent and the coordination with holding times and lab analysis. In situ parameters were measured in the septic tanks at the effluent port with a YSI 650 multiparameter probe and meter for T, Ec (electrical conductance at 25 degrees C), pH and DO.

Figure 1. Dosing design. The wastewater flows from the dosing bucket in the upper right to the tank oriented perpendicular to the view and then to the tank oriented parallel to the view in the forefront of the photo. The aerators are located under the black risers and due to the small ¼ mm bubble size and low velocity delivery system the air does not appear to mix or agitate the settled solids.

The two tanks contained compromised partitions that allowed fluid flow from the first to the second chamber and the aerators were placed in the first chambers of each tank. The setting of the retrofit aerators is less than optimum for efficiency but a good worst-case scenario for a test and appropriate for the situations commonly found in the field.

Figure 2. Soil columns and refrigerator.

Results and Discussion

The effluent mean values after 30-days of aeration for Septic Tank AA1, Septic Tank AA2, Type 1b soil and Type 3 soil are compared to the Raw influent during those same 30 days in Table 1. More detailed data can be found in Appendix A. The more detailed data in the Appendix show median as well as mean values for $CBOD_5$. The median values may be more applicable because of a few outliers in the data.

Table 1. Mean 30-day values for retrofitted systems after 9 months of aeration.

System	Raw	AA1	AA2	Soil1b	Soil 3	Raw to AA1	Raw to AA2
Parameter	Mean	Mean	Mean	Mean	Mean	% reduction	% reduction
$CBOD_5$ mg/l	235	43.5	29.4	NA	NA	81	87
TSS mg/l	186	22.6	7.4	NA	NA	88	96
TKN mg/l	39	36	36	5	1	NA	NA
NH_3-N mg/l	24.5	27.8	30.3	5.1	0.2	NA	NA
NO_3 mg/l	.16	.11	.11	19.5	28.4	31	31
PO_4 mg/l	4.39	4.21	3.93	0.66	0.06	4	11
TP mg/l	6.04	4.66	4.25	0.46	0.05	23	30
E. coli col/100ml	2,635,000	391,067	59,199	21	711	85	98
Fecal col/1000ml	2,322,500	166,040	41,217	10	174	93	98
Temperature C	17.6	15.8	15.7	NA	NA		
Ec *u*S	933	1289	950	NA	NA		
pH units	7.11	6.97	7.30	NA	NA		
DO mg/l	NA	.74	1.29	NA	NA		

The addition of aerators in septic tanks AA1 and AA2 produced $CBOD_5$ and TSS values that were quite low and there was significant improvement from AA1 to AA2. The addition of oxygen may have continued to drive the N cycle and appeared to increase NH_3–N in the septic tanks but the NH_3–N decreased drastically in the soil columns. However, the total nitrogen as measured by TKN appears to decrease slightly from the raw in the septic tanks then decrease drastically in the soil columns. The NO_3 values also appear to decrease in the septic tanks slightly but the differences are not statistically significant. The nitrate values increase significantly in the soil columns and much more so in the Type 3 soil column. The TP, PO_4, E. coli and Fecal coliforms all decrease throughout the treatment train. The largest decreases occur in the soil columns but the aerated septic tanks also decreased each of these parameters. Although the soils decreased the TP and PO_4 significantly in this 30-day study, the soil should eventually saturate with respect to its ability to adsorb P and then the ability to decrease P would cease. There may be some additional extraction of N and P by plants. Although there may have been some extraction from the soil during this study, there should be more during warmer weather when the plant growth is greater.

The qualitative results include no odor coming from the septic tanks, large and small bubbles forming on the surface of the septic tanks' effluent end, and no problems with soil column clogging during the study.

Early in the study (January and February, 2008) there were a few times when the soil columns overflowed. Although the columns were not disassembled, it is hypothesized that a biomat may have formed below the gravel layer where the effluent was being added. This problem was not encountered after the aerators were added but the warmer temperatures may have also contributed to better treatment in the soils.

The septic tanks were measured with a sludge judge after 6 months of operation without the aerators and the again 6 months after the retrofit with aerators and the following results were recorded both times. The sludge that had accumulated was not pumped from the tanks prior to adding the aerators. The area immediately under the aerator on the first septic tank had only 3-4 inches of sludge but the areas farther away from the aerator contained about 8 inches of sludge. There were 12 inches of sludge in the outlet area of the first septic tank. The second tank had 7 inches of sludge in the aerator area and 3-4 inches in the outlet area. Therefore, the aeration appeared to halt the development of the sludge.

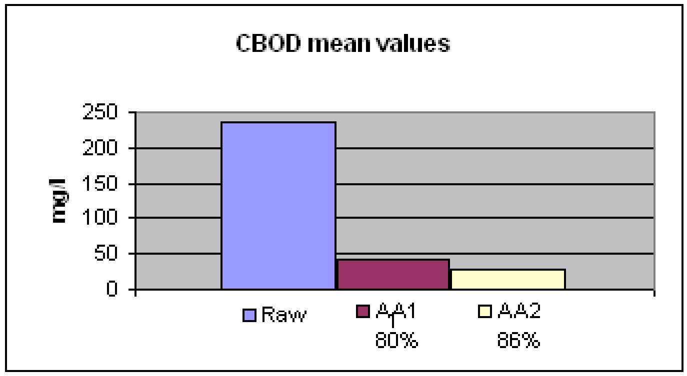
This 30-day test for a retrofitted aeration unit was conducted during December, 2008 and January, 2009. The temperatures were not optimum for bacterial development and decomposition of organic matter (high 20.2C, mean 17.6C and low 12.7C) but they did not drop low enough for any extended period of time to halt bacterial growth completely. Therefore, the test is somewhat of a worse case scenario in this regard. On the other hand, the lower temperatures can be helpful for dissolved oxygen levels. However, because the oxygen source in this case included actual bubbles in the water column for extended periods of time, bacteria had oxygen available that was not dissolved. It is possible, and perhaps probable, that there would be similar amounts of oxygen available to bacteria even with warmer temperatures and therefore there would be increased bacterial growth and better treatment with warmer temperatures.

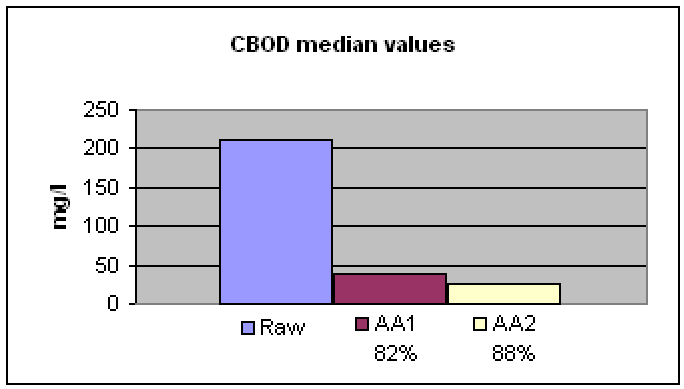
Conclusions

The addition of the aeration units appears to produce a relatively high quality effluent from the two septic tanks in series with regard to all the parameters that were measured except the nitrogen. Total Nitrogen increased 4% after both reactors indicating the settled solids may have contributed to the total N load and therefore the total organic load. Because this increase in total N appears to be in the NH_3-N phase, there may have been some additional ammonification from the aeration or the maturation of the influent. Reported effluent values for Nitrogen, CBOD, TSS and other constituents probably include partial digestion of settled solids. The two reactor tanks were undersized and did not provide adequate retention time for the 500 GPD flow, but did provide a demonstration of anticipated performance when retrofitting smaller septic tanks resulting in short retention times.

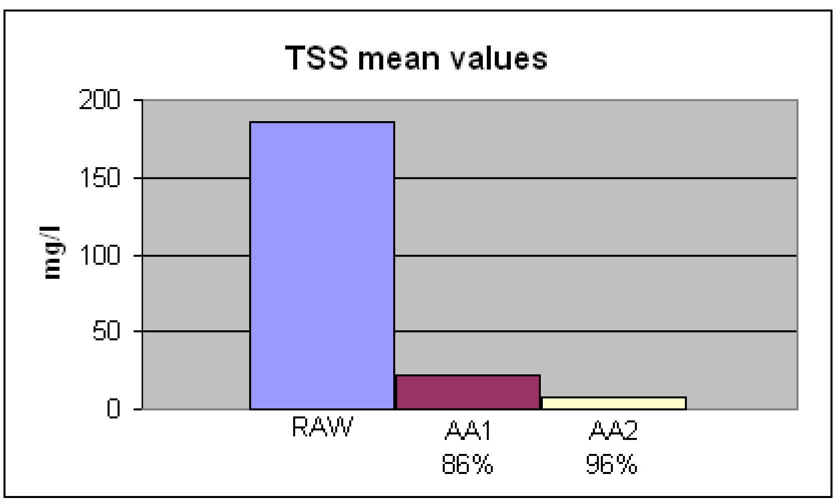
Appendix A

CBOD	RAW	AA1	AA2
10-Dec	182	64	25.2
11-Dec	188	40.7	22.3
12-Dec	279	31.2	22.8
17-Dec	195	39.1	20.9
18-Dec	535	37.9	21.7
19-Dec	215	35.4	20.8
22-Dec	226	36.9	21.7
23-Dec	258	39.5	24.2
24-Dec	285	46.6	21.7
25-Dec	215	86.1	55.7
26-Dec	208	96.9	70.9
29-Dec	195	46.4	35
30-Dec	192	35.4	26.9
31-Dec	211	26.5	26.1
1-Jan	172	22.7	37.1
2-Jan	161	22.3	23.3
5-Jan	292	49.4	29
6-Jan	205	53.2	34.2
7-Jan	168	37.3	27.1
8-Jan	280	38.3	27.4
9-Jan	274	28.4	22.8
Mean	**235**	**43.5**	**29.4**
Median	**211**	**38**	**25**
	mg/l	mg/l	mg/l

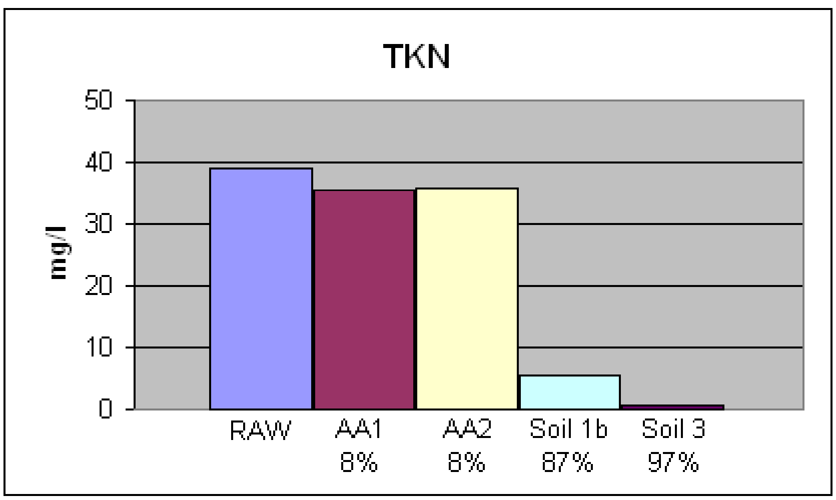




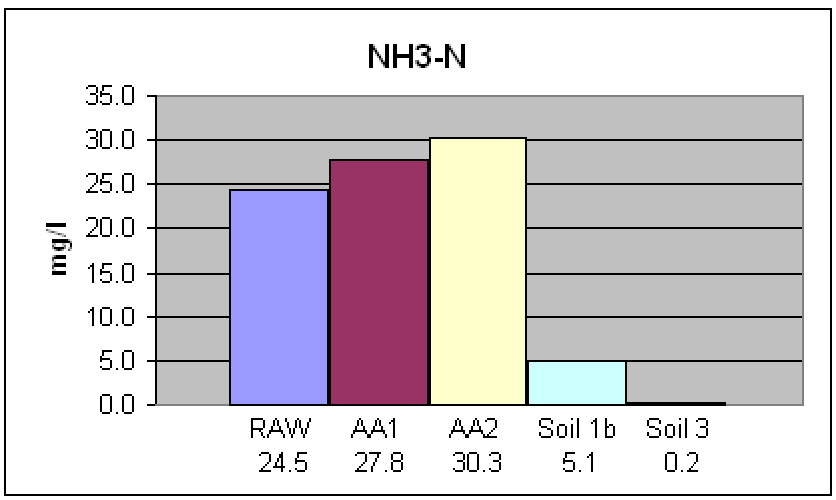
TSS	RAW	AA1	AA2
10-Dec	120	29	5.5
11-Dec	88	32.5	7
12-Dec	234	15	7.6
17-Dec	84	7.2	3
18-Dec	426	14.2	4
19-Dec	96	11.2	5
22-Dec	152	22.5	8.5
23-Dec	234	25	4.5
24-Dec	290	28.7	5.5
25-Dec	176	44	22.5
26-Dec	248	50	23
29-Dec	126	17	9
30-Dec	102	15.2	5
31-Dec	176	14.3	4
1-Jan	102	26.7	2.6
2-Jan	134	5	2.83
5-Jan	278	32.5	10.3
6-Jan	280	31.8	10.7
7-Jan	80	20.5	5.33
8-Jan	244	19.3	6
9-Jan	234	12	3.82
Mean	186	22.6	7.4
Median	176	21	6
	mg/l	mg/l	mg/l



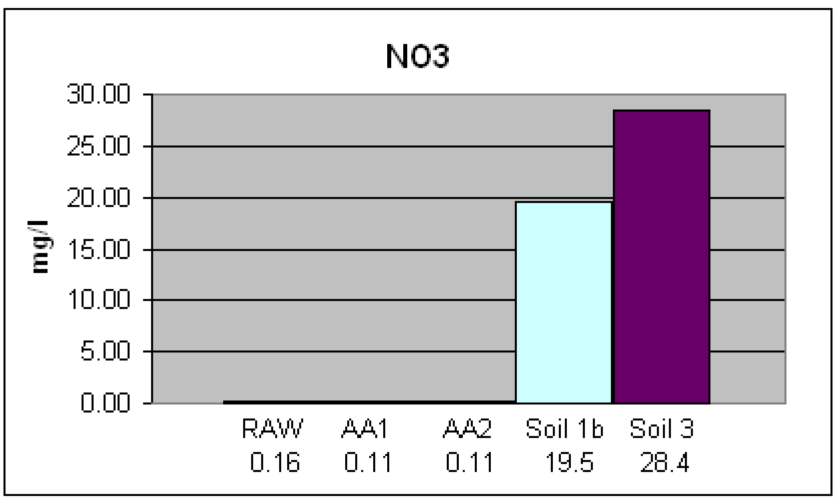
TKN	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	44	37.7	35.7	4.09	1.27
11-Dec	35.1		36.4		
12-Dec			35.1	4.06	0.5
16-Dec	38.1	37.5	44.8		
17-Dec	47.3		38.5		0.96
18-Dec	32.3	46.3			
19-Dec	33	36.2		5.95	
22-Dec		39.2	38.1		0.5
23-Dec	47.2	35.7	37		
24-Dec	37.7	41.4	35.7	5.47	0.5
26-Dec		31.4	31.3	8.02	0.5
29-Dec	34.4	33.4	36.5	5.29	0.5
30-Dec	52.1	34.7	35.5		
31-Dec		34.2	35.1	7.18	
1-Jan	30.8	33	35.2		
5-Jan	34.1	32.8	35.6	2.98	0.5
6-Jan		32.2	29.4		
8-Jan	35.2	27.4	36.5		
9-Jan	43.7	37.1	32.9		0.5
Mean	**39**	**36**	**36**	**5**	**1**
	mg/l	mg/l	mg/l	mg/l	mg/l



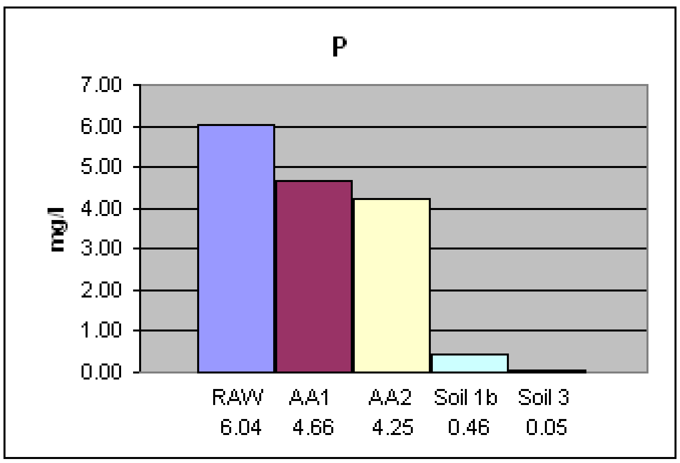
NH_3-N	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	28.9		29.4	3.87	0.79
11-Dec	31.2		29.4		
12-Dec			34.7	3.93	0.05
16-Dec	26	34.9	38.1		
17-Dec	26.6		37.6		0.05
18-Dec	26.5	34.9		5.78	
19-Dec	24.3	28.1			
22-Dec		33.4	36		0.05
23-Dec	25.4	28.2	34		
24-Dec	23.7	26.9	34.9	5.96	0.5
26-Dec		24.2	23.5	6.93	0.05
29-Dec	22.9	23.9	25.8	5.18	0.05
30-Dec	16.4		25	5.55	
31-Dec		34.5	27.7		
1-Jan	18.9	14.9	25.5		
5-Jan	21.2	24.5	27.7	3.22	0.05
6-Jan	22.4	27.9	22.6		
8-Jan	28.4	24.9	31.3		
9-Jan		27.6	31.9		0.05
Mean	**24.5**	**27.8**	**30.3**	**5.1**	**0.2**
	mg/l	mg/l	mg/l	mg/l	mg/l

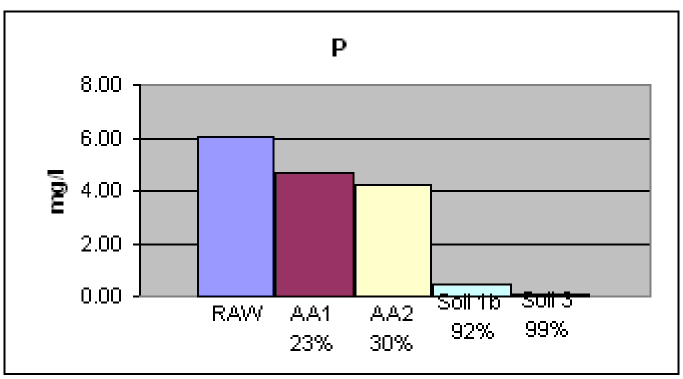


NO_3	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	0.13	0.13	0.1	15.9	6.68
11-Dec	0.43	0.1			
12-Dec				23.2	9.72
16-Dec	0.1	0.1	0.1		
17-Dec	0.1		0.1		13.9
18-Dec	0.1	0.1			
19-Dec	0.1	0.1	0.1	21.2	
22-Dec		0.1	0.1		31.7
23-Dec	0.39	0.1	0.1		
24-Dec	0.1	0.1	0.1	28.4	37.5
26-Dec		0.1	0.1	26	38
29-Dec	0.1	0.1	0.1	12.2	44.6
30-Dec	0.2	0.16	0.1		
31-Dec		0.1	0.1	12.4	
1-Jan	0.1	0.1	0.1		
5-Jan	0.1	0.1	0.1	16.4	39
6-Jan		0.1	0.1		
8-Jan	0.13	0.1	0.1		
9-Jan	0.1	0.1	0.2		34.2
mean	**0.16**	**0.11**	**0.11**	**19.5**	**28.4**
	mg/l	mg/l	mg/l	mg/l	mg/l

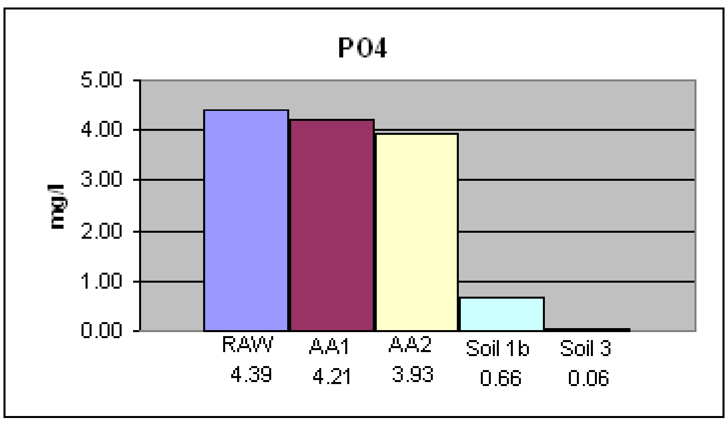


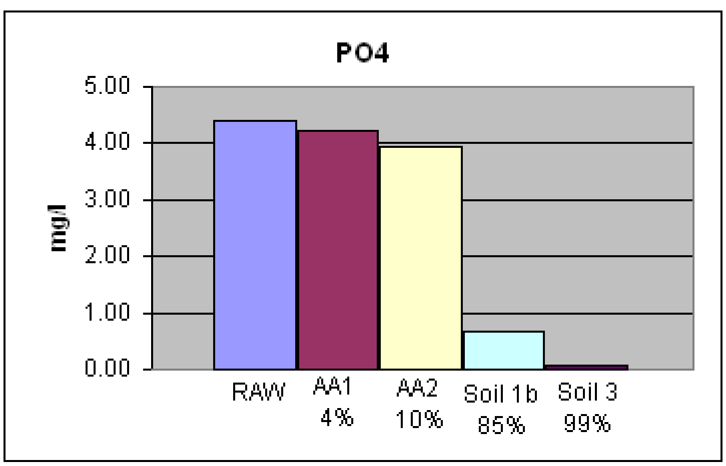
P	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	6.18	4.33	3.92	0.05	0.05
11-Dec					
12-Dec					
16-Dec					
17-Dec	5.23		4.03		0.05
18-Dec					
19-Dec					
22-Dec					
23-Dec					
24-Dec	6.7	4.92	4.72	0.6	0.05
26-Dec					
29-Dec					
30-Dec					
31-Dec		4.72	4.33	0.73	
1-Jan					
5-Jan					
6-Jan					
8-Jan					
9-Jan					
mean	**6.04**	**4.66**	**4.25**	**0.46**	**0.05**
	mg/l	mg/l	mg/l	mg/l	mg/l



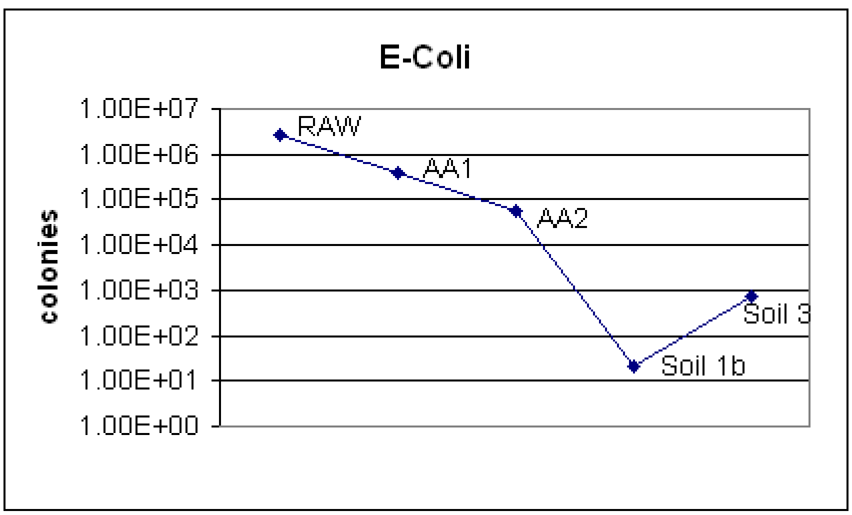


PO_4	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	5.63	4.14	4.11	0.23	0.06
11-Dec					
12-Dec					
16-Dec					
17-Dec	3.55		4.19		0.05
18-Dec					
19-Dec					
22-Dec					
23-Dec					
24-Dec	3.98	3.97	3.82	0.86	0.06
26-Dec					
29-Dec					
30-Dec					
31-Dec		4.53	3.6	0.9	
1-Jan					
5-Jan					
6-Jan					
8-Jan					
9-Jan					
mean	**4.39**	**4.21**	**3.93**	**0.66**	**0.06**
	mg/l	mg/l	mg/l	mg/l	mg/l





E-Coli	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	1870000	604000	77600	1	26.9
11-Dec					
12-Dec			5180		
16-Dec					
17-Dec	3450000		2010		88.2
18-Dec				1	
19-Dec	2820000	48400			
22-Dec		437000	24500		2420
23-Dec					
24-Dec	2400000	261000	29100	3.1	308
26-Dec		980000	155000	101	
29-Dec					
30-Dec					
31-Dec		16000	121000	1	
1-Jan					
5-Jan					
6-Jan					
8-Jan					
9-Jan					
mean	**2635000**	**391067**	**59199**	**21**	**711**
	colonies	**colonies**	**colonies**	**colonies**	**colonies**
	2.64E+06	**4.E+05**	**6.E+04**	**2.E+01**	**7.E+02**



Fecal	Raw	AA1	AA2	Soil1b	Soil3
10-Dec	2500000	670000	84000	10	10
11-Dec					
12-Dec			70500	10	
16-Dec					
17-Dec	2400000		2000		80
18-Dec					
19-Dec	2800000	4200		10	
22-Dec		57000	12800		560
23-Dec					
24-Dec	1590000	63000	17000	10	210
26-Dec					
29-Dec					10
30-Dec					
31-Dec		36000	61000	10	
1-Jan					
5-Jan					
6-Jan					
8-Jan					
9-Jan					
mean	**2322500**	**166040**	**41217**	**10**	**174**
	colonies	**colonies**	**colonies**	**colonies**	**colonies**
	2.3E+06	1.7E+05	4.1E+04	1.0E+01	1.7E+02