FINAL REPORT

PERFORMANCE EVALUATION OF NEW ONSITE WASTEWATER TECHNOLOGIES – EXPERIENCES WITH BIOCOIR® MEDIA BIOFILTERS

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ABSTRACT

A pretreatment system using media composed of the recycled husks of coconuts (100% coir fiber) was evaluated using 20 permanently occupied single-family residences located in the State of Virginia. Sampling began in the summer of 2009 and continued through the summer of 2011. Home locations ranged from the mountainous regions of western Virginia to sandy low relief sites on the Eastern Shore of Virginia. Concentrations of five day biochemical oxygen demand, total suspended solids, nitrogen species (TKN, nitrate + nitrite) and Escherichia coli were measured in system influent and effluent four times (once in each season) for each home. Total phosphorus was measured from each home's influent and effluent once during the study. Effluent BOD was sampled a final time in August 2011 from 19 of the 20 homes. Field parameters (Dissolved Oxygen, pH, temperature) and water meter readings, if available, were also taken concurrent with sampling. This paper provides information on the performance of this attached growth treatment system under real world conditions and compares it to data collected from a test center in Massachusetts..

KEYWORDS. Attached growth, Coir, Onsite wastewater, system performance, Virginia

INTRODUCTION

In many areas of the United States, regulators use test center data to determine if wastewater treatment technologies they are unfamiliar with are appropriate for installation in their jurisdictions. An advantage of using test center data to conduct such assessments is that testing follows a consistent protocol that can be repeated for other similar treatment technologies. When products from multiple manufacturers are tested using the same protocol, an 'apples to apples' comparison is possible. This approach forms the basis for wastewater technology performance testing standards such as NSF/ANSI Standards 40 and 245 (2010).

In Virginia a different approach is used to evaluate the highest level of effluent treatment, called TL-3, for general approval. In this case, in-field performance data is sought from homes connected to the type of system being considered. This approach places greater emphasis on a system's ability to treat a variety of waste streams under uncontrolled (i.e., natural) loading regimes. With this approach, the idiosyncrasies of multiple homes' wastewater generation and usage are explicitly included in the system's evaluation.

In 2009, the Virginia Department of Health and Quanics, Inc. entered into an agreement to test the BioCOIR Advanced Treatment System under Guidance Memoranda & Policy (GMP) 147. GMP 147 spells out the scope, methods and evaluation procedures to be used to evaluate new technologies and variances to their use that may be allowed by VDH. The agreement provides clear pass/fail criteria for effluent, data clean-up steps and statistical procedures to be used.

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The BioCOIR® system is a patented natural media filter consisting of 100% coconut (coir) fiber. Details on media properties, results from test center evaluation and the design concept for the technology can be found in Sherman (2006). BioCOIR systems utilize classical biological nitrogen reduction through nominal 80% recirculation of nitrified effluent back to the first compartment of the septic/recirculation tank or to a separate recirculation tank for denitrification.

METHODS

Prior to beginning the study Quanics Inc. prepared and submitted to VDH a detailed Quality Assurance Project Plan detailing all procedures to be used to collect, measure and transport samples during the project. The QAPP was also reviewed and agreed to by all prospective state approved water quality analysis laboratories that collected samples. Contracts between Quanics Inc. and these laboratories were shared with VDH prior to beginning the project.

Under GMP 147, candidate homes were presented by Quanics Inc. to VDH for admission into the program. All homes had to be permanently occupied single family residences (i.e. no seasonal occupancy vacation homes or short term rental homes). Homes with an estimated flow greater than or equal to 1,000 gallons per day were also excluded from the study. A summary of key statistics for the homes selected for the study is provided in Table 1.

Table 1. Home statistics

Residence Code	Est. flow (gpd)	Act. wm* flow (gpd)	Module size	Start date	End date	County
BCHN	300	113	4’	4/7/2010	8/17/2011	Tazewell
BDSN	300	41	4’	7/20/2009	8/22/2011	Accomack
BLNC	300	n/a	4’	7/1/2010	8/25/2011	Accomack
BRNS	600	123	6’	7/27/2009	8/18/2011	Washington
BSWL	450	159	6’	5/17/2010	8/22/2011	Accomack
BZWL	450	n/a	8’	7/28/2009	8/18/2011	Pittsylvania
DVS	450	154	6’	2/16/2010	8/17/2011	Wise
EBRT	450	n/a	6’	9/30/2009	8/24/2011	Accomack
GLS	450	381	6’	8/23/2010	8/22/2011	Accomack
HLDN	300	n/a	4’	10/1/2009	8/25/2011	Accomack
HMN	450	176	6’	5/17/2010	8/23/2011	Accomack
HRMN	450	n/a	6’	7/21/2009	5/13/2010	Accomack
HRT	600	n/a	6’	9/30/2009	8/25/2011	Accomack
HSTN	300	144	4’	8/24/2010	8/22/2011	Accomack
LDBR	600	143	6’	8/24/2010	8/23/2011	Accomack
LFRT	450	208	6’	5/17/2010	8/22/2011	Accomack
LNRD	450	168	6’	5/19/2010	8/22/2011	Accomack
LVN	600	104	6’	10/5/2009	8/18/2011	Washington
WKNS	450	n/a	6’	7/23/2009	8/24/2011	Accomack
WLT	450	n/a	6’	2/10/2010	8/25/2011	Accomack

* Act. wm = Actual water meter

GMP 147 called for quarterly sampling of influent and effluent from 20 homes for the following parameters: Biochemical Oxygen Demand over a five day period (BOD_5), Total Suspended Solids (TSS), and one of two approved assessments of bacterial concentration, either fecal coliform or Escherichia coli. In-field measurement of dissolved oxygen, pH and temperature in influent and effluent samples were also required during each sampling visit (results in Appendix A). The policy allowed for BOD_5 and TSS samples to be collected either by grab or composite methods. Bacterial measures must be collected via grab sample per Standard Methods for the examination of water and wastewater (2005).

Homes not served by private wells had water meters. The water meter was read some time during each sampling trip to directly assess water use at the home and is provided as column 3 of Table 1 and in detail in Appendix B. Estimated flow is a function of the number of bedrooms in the home at 150 gallons per bedroom.

Because the BioCOIR® system is capable of nutrient reduction, parameters were analyzed for in addition to those required by GMP 147. Nitrogen species (total Kjeldahl nitrogen and Nitrate + Nitrite) samples were also collected from influent and effluent every time the full suite of GMP 147 parameters were sampled. Total phosphorus was sampled from each home's influent and effluent once during the study.

Data handling and transformation protocols are specified in GMP 147. BOD_5, TSS and bacterial data sets had to be log-transformed prior to statistical analysis. Logarithmic transformation of bacterial data is commonplace, but log transformation of BOD_5 and TSS data is relatively rare. The procedure was used successfully by Groves, Bowers, Corriveau, Higgins, Heltshe & Hoover (2005). Data reported at less than the detection limit for the parameter of interest would be input as follows: for BOD_5 and TSS, any result less than 2 mg/L would be reported as 1 mg/L (the logarithm of 0 is undefined). For TSS any result < 1 mg/L and E. coli any result <1 MPN/100mL would be reported as 0.9 mg/L or 0.9 MPN/100 mL respectively. Instructions for data cleanup for greater than/TNTC results are given in GMP 147 as well, but did not occur in the Quanics Inc. data set.

Homes were entered into GMP 147 starting in June 2009 and ending in August of 2010 when the 20 home threshold was achieved. Consequently, influent and effluent samples were collected over eight quarters (Figure 1). Once sampling began at a home, it was continued for three more continuous quarters. The pink colored bars in Figure 1 indicate a final sample from a home in Western Virginia and baby blue colored bars indicate a final sample from a home located on Virginia's Eastern Shore. Not shown in Figure 1, an additional round of effluent BOD_5 samples were collected in the fall of 2010 at 19 of the 20 homes in the project (all but HRMN).

Composite samplers (two ISCO GLS and two Sigma samplers) were used for effluent samples for BOD_5, TSS, Nitrogen species and Phosphorus samples in all but one home (BZWL). Influent grab samples used either a mid-point jar sampler or one of the composite samplers reset to collect a desired volume via grab. To minimize systematic error from cross contamination, sampling at a home proceeded from the expected cleanest (i.e., effluent) to the expected dirtiest (i.e., influent) sample. Gear was rinsed with tap water and cleaned with disposable wipes in the field after each sample. Gloves were worn for all sample collections.

The QAPP specified that 5% of the samples collected would be randomly selected QA/QC samples. The types of QA/QC samples were 1) duplicate (both effluent and influent), 2) trip blank (double distilled water sample taken out into the field and transported with collected samples back to the laboratory) and 3) equipment blank (double distilled water run over field cleaned sampling equipment). During the course of the study 4 rounds of QA/QC samples were collected (Appendix C - 2 duplicates HRMN and LDBR, one trip blank DVS, and one equipment blank HSTN).

The majority (75%) of homes used in this study were located on the eastern shore of Virginia (Accomack County on Table 1). The area is relatively flat with sandy soils and shallow groundwater tables. Fourteen of 15 homes used pressure recirculation to send nitrified effluent back to the septic tank for denitrification. Pressure recirculation involves a patented process. The pump's discharge is run vertically from the pump chamber through a Tee fitting with a ball valve on either side of the Tee. Two stand pipes are temporarily placed: one in the drainfield distribution box and the other in the first compartment of the septic tank. When a pump is activated, the effluent flows to both areas simultaneously. The orifices in the two pipes are sized so that when the operating heads are equal, 80% of the pump's flow discharges back to the septic tank. The valves on both lines are set to adjust the flow so operating heads in both locations are equal. The standpipes are removed and replaced with threaded caps. Should the recirculation ever need to be reset (for instance if a defective pump is replaced) the process can be repeated.

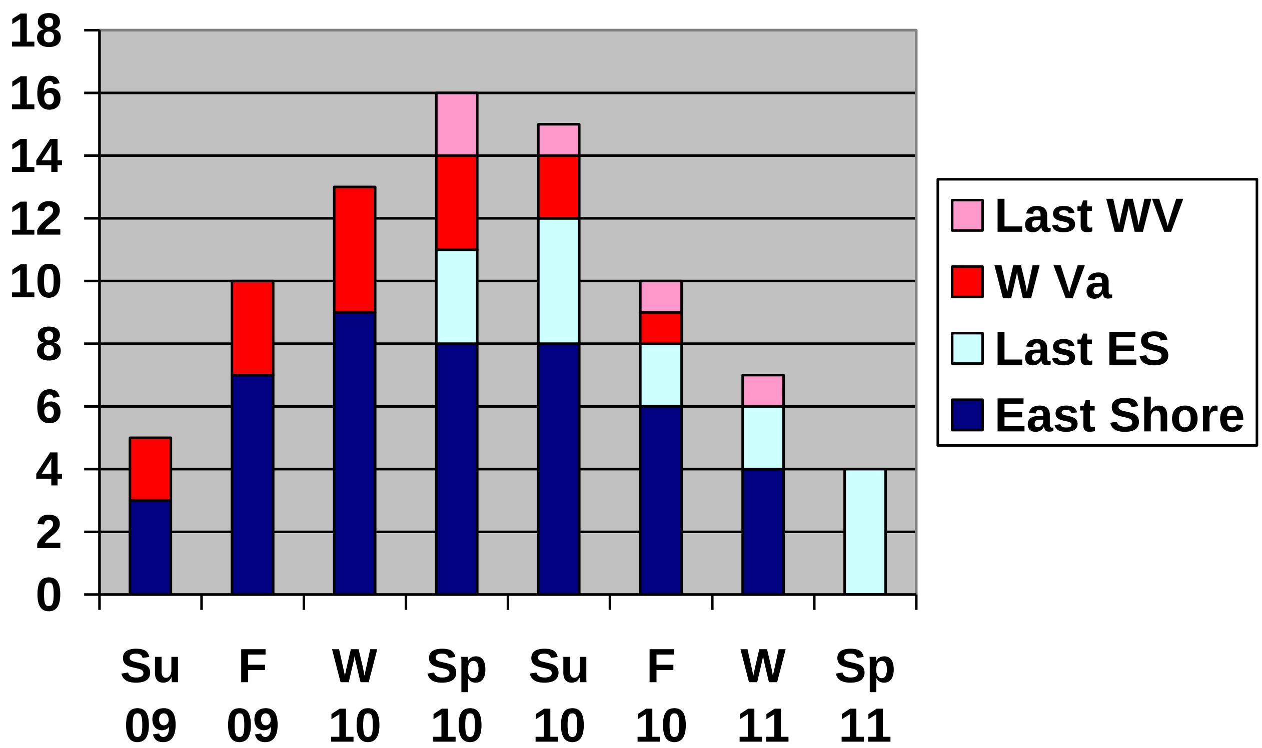

Figure 1: Homes sampled per quarter of study.

The western Virginia sites had sloping lots and finer textured soils with deeper water tables. In these sites, BioCOIR® modules were placed at the highest elevation needed to ensure gravity flow. Flow ran from the modules ran back to a gravity recirculation splitter. In 4 of 5 cases (all but DVS) recirculation ran into the second tank in the series.

RESULTS

The QAPP specified the following dates in each quarter. Summer consisted of the months June, July and August. Fall consisted of the months September, October and November. The months of December January and February were considered Winter. Finally, March, April and May made up the Spring quarter. Influent and effluent data for the study is summarized in Table 2 and provided in detail in Appendix D.

Table 2. Summary statistics of influent and effluent for parameters of interest using log transformed values for BOD_5, TSS and e. coli and non detects recorded as per GMP 147

	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
median	146.7	48.3	24.4	9.6	212,483	7.2	3.8	7.7	3.9	2,192
mean	145.9	51.5	48.4	9.9	220,412	6.8	3.9	11.5	4.3	1,441
S. Dev.	3.2	2.9	63.9	4.6	4.5	3.9	3.0	13.1	3.1	58
n	82	82	82	21	82	103	83	82	21	84

Sample results for influent parameters had very wide ranges. Homes from western Virginia usually had higher influent values than Eastern Shore homes. The September 21, 2010 sample of BCHN had the highest influent BOD_5 (4,380 mg/L), TSS (13,820 mg/L) and TN (377.05 mg/L) and the April 7, 2010 sample from this same residence had the highest TP (21.4 mg/L). These results can be explained by the different recirculation methods described earlier. When treated effluent is routed to the second tank in series, the first tank operates as a conventional septic tank. On the Eastern Shore, recirculation routinely sent 80% of the treated effluent back to the first compartment of the first tank for denitrification. Influent samples from the Eastern Shore were essentially a sample of raw wastewater blended with varying amounts of treated effluent. The lowest influent BOD_5 value (17.4 mg/L) was taken from the HMN residence on June 28, 2010. Another Eastern Shore residence (WLT) provided the lowest influent TSS value (7.2 mg/L) on February 10, 2010. Recirculation is also responsible for low Nitrogen concentrations in the effluent due to denitrification. The BLNC residence recorded a TN concentration of 0.42 mg/L on September 23, 2010. The lowest concentration of TP was found at the WKNS residence May, 10, 2010 (1.4 mg/L). Eastern Shore homes provided the highest and lowest e. coli concentrations measured during the study. The BSWL residence recorded an e. coli concentration of 3,972,600 org/100mL on September, 27, 2010 while two quarters earlier, on May 10,2010 a concentration of 3,420 org/100mL was obtained from the WKNS residence.

The most remarkable feature of the effluent data, on the other hand, was its consistency. Effluent BOD_5 ranged from 19 below detection limit readings to a high of 109 mg/L at the LNRD residence taken on May 19, 2010. Effluent TSS concentrations ranged from 0.4 mg/L at the BRNS residence on October 5, 2009 to a high value of 40.5 mg/L at the DVS residence on June 16, 2010. The highest recorded effluent TN (79.86 mg/L) was collected from the BZWL residence on October 6, 2009. The corresponding effluent was 199 mg/L on that day. Overall nitrogen reduction for the project is given as approximately 76%. The lowest effluent TN was found at the WLT residence on February 10, 2010. Effluent TP was highest at the HSTN residence on April, 5, 2011 (11.7 mg/L) and lowest at the WKNS residence on May 10, 2010 (0.47 mg/L). Although a gross reduction of TP in the study was given at 56%, the author cautions against giving too much credence to such a small sample size.

The data contained in Appendix D for BOD_5, TSS and e.coli were then statistically analyzed to obtain upper limits of 99% confidence intervals. The limits were then compared to the target values provided by GMP 147. The results are shown in Table 3. .

Table 3. Statistical comparisons of effluent BOD_5, TSS and e. coli to GMP 147 limits

		TSS	BOD	Ecoli
STATISTICS (ln)	Count =	83	103	84
Natural logarithm used	Mean =	1.36	1.92	7.30
	Std Dev =	1.11	1.37	4.04
	Std Err =	0.12	0.14	0.44
	Upper 99% T =	2.64	2.62	2.64
	Upper 99% T Conf Interval =	1.69	2.28	8.46
	Upper 99% T Conf Int (Orig Units) =	5.4	9.75	4,708
	GMP 147 Limits (Max.) =	10.0	10.00	2,000

From this analysis the BioCOIR® system passes criteria for BOD_5 and TSS, but not for e.coli. This last issue became a moot point when revised sewage regulations promulgated by VDH required disinfection units (e.g., UV, chlorine) be incorporated in designs for the level of treatment (TL-3) Quanics Inc. was seeking under GMP 147.

DISCUSSION

The above narrative may sound like a 'cut and dry' account of the in's and out's of getting advanced systems approved in Virginia, but there is more to the story. In 1984, Stuart Hurlbert published a seminal paper on the design of ecological field experiments. The paper 'named names of individuals who had misapplied statistical analysis in published papers. And my Master's Thesis (Sherman and Coull, 1980) was cited.

Hurlbert was correct in his assessment of my work. After reading and understanding his criticism, I stopped my planned dissertation project that I had worked a solid year on and started from scratch (it had been set up the same way as my thesis!). So please forgive me for reacting so strongly when the identical difficult and time-consuming issue crops up in the onsite wastewater field. The issue to be rectified is pseudoreplication. It means statistically analyzing related data as if they were independent measures.

An analogy may be the best way to explain what pseudoreplication is to non-statisticians. Imagine that you want to investigate insect damage on oak trees in your county. You decide to sample leaves from oak trees and note presence of insects and or past damage to a leaf. Now, you must decide how many leaves to examine. Daniel (1999) can help decide how large a sample is required. Let's say you do the required calculations and decide you need to examine a thousand leaves. Problem solved, right?

Wrong! The next crucial step in designing the experiment is deciding how many experimental units should be used. A survey tells you how many oak trees there are in your county. They must be selected randomly from a pool of all the oaks in your county. You can't just walk out to your back yard, unless the goal of your research is limited to your back yard. You could potentially select one tree at random and take one thousand leaves off it. If you did that you would know alot about that one particular tree on that one particular day. You could take one leaf off of one thousand oak trees selected at random. Neither of these options are ideal. In most cases you would choose to take several leaves from multiple experimental units (oak trees). Each leaf from the same tree are pseudoreplicates. A researcher takes enough pseudoreplicates to get a representative central value (mean, median) within their experimental units.

In the case of the GMP protocol the experimental unit is the home. Four repeated measures were taken from 20 homes over time (seasonally). So statistics evaluating this study should be based on n=20, not, 83 or 103 because sampling data from a single home in one season is related to sampling data taken from that same home in another season. Statistically speaking, they are dependent.

Three technologies have previously gone through field evaluation with VDH, Anua (formerly Bord na Mona), Orenco, and Premier Tech using pseudoreplication in their analysis of data. A synopsis of the origins of the program is given by Alexander & Jantrania (2001).

CONCLUSIONS

It is not my intent to ask manufacturers who have gone through a far more arduous technology evaluation process than Quanics Inc. did to retest or to modify any of their existing approvals. Rather, I would like to see their data reevaluated to find out what exactly VDH has already approved minus pseudoreplication. This would give an exemplary evaluation program a valid statistical foundation. Hurlberg would be proud!

I would also like to caution that the use of test center data to evaluate the performance of novel wastewater technologies has not been invalidated by the results of this study. To the contrary, data collected during this field evaluation closely track those collected in 2006 from a single BioCOIR® system installed at the Massachusetts Test center (Table 4)

Table 4. NSF ANSI Std 40 plus nitrogen results for BioCOIR®

	Infl	Infl	Infl	Effl	Effl	Effl
	BOD_5	TSS	TN	BOD_5	TSS	TN
mean	160	190	38	9	12	17
median	160	180	39	9	10	15
St. dev	59	50	5.2	5	10	7.4
Sample events	118	118	25	118	118	25

In the end, a test center evaluation is like taking every leaf off one tree. Every sample event is a pseudoreplicate. The inference that can be made after conducting a test center evaluation of a technology must inherently be narrower than that of a field evaluation from multiple homes. After all, by the end of a test center evaluation we learn what one unit can do at one location at one point in time under tightly controlled conditions. Enter NSF ANSI standard 360 “Field Performance Verification”

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Appendix A: Field data from 20 homes in Virginia. dissolved oxygen (mg/l), temperature (^{o}C), and pH influent and effluent..

BDSN resid	Influent			Effluent			Notes
	D.O.	Temp	pH	D.O.	Temp	pH	
7/20/2009	2.3	23	6.1	11.8	23.5	6.9	
9/28/2009	1.8	21.6	6.2	8.6	9.6	7.1	
2/9/2010	7	7.1	5.5	14	1.8	6	
5/19/2010	2	18.5	6.8	10	4.6	5.9	
HRMN resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
7/21/2009	0.5	23.1	6.3	11.8	23.5	6.9	
9/29/2009	1.4	22	6.5	6.1	16.3	5.3	
2/4/2010	0.9	8.8	5.8	16	1	4	
5/13/2010	2	17	7.1	11	13.5	6.8	
WKNS resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
7/23/2009	0.5	23.2	6.9	10	6.7	5.8	
10/1/2009	2.5	15.6	6.1	7.1	9.7	5.1	
2/9/2010	11	7.6	5.9	10	8.5	5.2	
5/10/2010	3.9	16.8	6.5	11.1	3.7	4.6	
BRNS resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
7/27/2009	0.5	25.7	6.3	1.8	24.1	7.8	
10/5/2009	0.3	22	6.6	2.2	21	7.2	
2/15/2010	0.8	13.1	6.4	8.1	9.5	7.1	
4/5/2010	1.1	13.9	5.9	3.8	13.5	6.2	
BZWL resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
7/28/2009	0.6	24.2	6.3	3.2	28.2	6.5	
10/6/2009	0.8	21.7	6.9	3.6	24.2	6.3	
2/17/2010	0.7	10	6.5	6.5	9.4	6.1	
4/5/2010	0.6	15.6	6.6	3.8	17.7	6	
LFRT resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
9/28/2009	1.3	23.6	6.1	7.7	13.6	6.3	
2/10/2010	4	8.3	5	11	3.3	4.2	
5/17/2010	1.8	14.8	6.5	10	3.4	6.9	
6/29/2010	1.2	25.6	6.9	8	11	7.5	
HRT resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
9/30/2009	1.2	19.6	5.3	7	12.2	5.3	
2/10/2010	11	5.6	4.6	10	8.8	3.6	
5/11/2010	7.2	18.2	5.7	15	6	5.8	
6/30/2010	2	26.7	6.5	6.3	11.9	6.6	
EBRT resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
9/30/2009	2.1	19.1	6	8.8	11.5	5.3	
2/9/2010	3	8.1	5	5	9.1	4	
5/12/2010	2.5	15	6	9.5	12.4	6	
6/30/2010	2.8	27.2	7.1	6.7	6.9	7.6	

HLDN resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
10/1/2009	2.2	16.6	6	8.6	4.6	4.8
2/4/2010	0.9	8.8	5.6	10	2.8	4.1
5/13/2010	2	17	7	12	17	7.4
7/1/2010	2.7	23.4	7.1	7.3	4	7.2

LVN resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
10/5/2009	0.5	19.7	8.2	3.2	18.9	6.8
2/15/2010	1	12	6.9	8.5	6.5	6.2
6/16/2010	0.8	16.1	6.3	4.7	17.2	5.3
4/5/2010	2.3	13.9	6.5	4.1	13.3	7

HMN resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
2/9/2010	0.9	7	5	15	1.4	2.7
5/17/2010	3	17.1	5.6	10	3.8	5.1
6/28/2010	7.6	24	7	10	9.3	6.7
9/27/2010	2.8	23.6	6.3	4.7	8.4	5.5

WLT resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
2/10/2010	14	5.5	4.9	12	4.7	2
5/11/2010	7	18.7	5.7	11	5.3	5.1
6/30/2010	2.4	25.9	6.8	5.9	15.3	6.9
9/23/2010	3.2	23.5	6.4	5.6	5.5	6.3

DVS resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
2/16/2010	1.5	6	6.8	10.2	5.5	6.8
4/6/2010	0.8	13	6.4	6.3	10.6	6.6
6/16/2010	1.5	18.5	6.3	3.1	20.2	6.5
9/20/2010	0.4	20.7	6.5	3.8	20.6	6.8

BCHN resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
4/7/2010	0.4	18.8	7.1	5.9	14.6	4.8
6/17/2010	0.3	25	6.1	3.6	24.6	6
9/21/2010	0.7	24.3	6.5	4.4	22	6
12/9/2010	1.3	13.9	6.7	5.8	8.7	7.5

	Influent			Effluent		
BSWL resid	D.O.	Temp	pH	D.O.	Temp	pH
5/18/2010	3.5	16.4	6.4	9.7	2.8	6.5
6/29/2010	3	25.5	6.4	5	18	5.8
9/28/2010	2.5	24.2	6.5	3.9	14.6	5.1
12/6/2010	1.2	13	5.3	2.9	2.1	5.4

LNRD resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
5/19/2010	2.5	17.4	7.1	11.5	2.8	7.7
6/28/2010	3.7	24.8	6.9	11	10.8	7
9/28/2010	2.6	23.6	6.4	4.7	16.3	6.1
12/6/2010	1.2	9.9	5	2.4	2.6	5.7

BLNC resid	Influent			Effluent		
	D.O.	Temp	pH	D.O.	Temp	pH
7/1/2010	2.5	22.5	7.6	6.4	5.7	7.7
9/23/2010	3.6	22.9	7.5	4.5	7.3	6.3
12/22/2010	0.1	10.4	7.4	0.2	9.8	6.2
4/4/2011	0.45	15.9	6.9	11.07	4.3	5.8

HSTN resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
8/24/2010	3.3	19.7	5.7	6.3	12.6	7.3	
9/28/2010	1.9	22.9	6.3	3.2	7.6	6.1	
12/22/2010	5.3	7.1	6.8	6.4	9.8	7.8	
4/5/2011	1.2	14	5.3	5.4	11.7	5	

LDBR resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
8/24/2010	2.5	20.4	7.1	5.4	13.3	8.2	
9/27/2010	2.5	23.5	7.6	3.4	10	6.1	
12/7/2010	0.5	18.6	6.3	0.5	17.2	6.2	
4/6/2011	2.7	10.7	4	4.7	2.6	3.8	pH meter failure

GLS resid	Influent			Effluent			
	D.O.	Temp	pH	D.O.	Temp	pH	
8/24/2010	3.8	19.4	6.2	6.7	12.3	7.3	
9/27/2010	2.7	26.6	6.7	4	15.9	6	
12/6/2010	1.5	16.4	6.3	3.4	3.1	6.9	
4/5/2011	1.5	17	0	11.6	6	0	pH meter failure

Appendix B. Water meter readings from 12 residences during GMP 147

Home	date	reading	usage	#days	av gpd
BDSN	7/20/2009	26500			
	9/27/2009	29315	2815	69	40.80
	2/8/2010	33870	4555	134	33.99
	5/16/2010	37726	3856	97	39.75
BSWL	5/17/2010	45563			
	6/28/2010	7973		42	
	9/27/2010	141633		91	
	12/5/2010	148335	6702	69	97.13
BRNS	7/27/2009	43104.8			
	10/4/2009	51853.5	8748.7	68	128.66
	2/14/2010	69115.6	17262.1	134	128.82
	4/4/2010	74890.3	5774.7	49	117.85
LFT	5/17/2010	3465433			
	6/28/2010	3478700	13267	42	315.88
LNRD	5/19/2010	49341			
	6/28/2010	61030	11689	40	292.23
	9/27/2010	82150	21120	91	232.09
	12/5/2010	109118	26968	69	390.84
LVN	10/5/2009	7386.1			
	2/14/2010	21522.1	14136	133	106.29
	4/4/2010	25380.3	3858.2	49	78.74
	6/15/2010	33721.7	8341.4	71	117.48
DVS	4/6/2010	66464.2			
	4/7/2010	66560.1	95.9	1	95.9
	5/8/2010	70805.7	4245.6	31	136.95
	6/15/2010	76686.5	10126.4	38	266.48
	9/19/2010	93230.7	16544.2	96	172.34
	12/8/2010	103149	9918.3	80	123.98
BCHN	4/7/2010	433164			
	6/16/2010	439486.8	6322.8	69	91.63
	9/20/2010	458530.6	19043.8	96	198.37
	12/8/2010	474411.4	15880.8	79	201.02
HMN	5/17/2010	1270149			
	6/28/2010	1276495	6346	42	151.10
	9/26/2010	1310172	33677	90	374.19
GLS	8/23/2010	97945			
	9/26/2010	109596	11651	34	342.68
	12/5/2010	134305	24709	70	352.99
	4/4/2011	177260	42955	120	357.96
LDBR	8/24/2010	1552700			
	9/26/2010	1559854	7154	33	216.79
	12/6/2010	1571204	11350	71	159.86
	4/5/2011	1580685	9481	120	79.01
HSTN	8/24/2010	506630			
	9/27/2010	515077	8447	34	248.44
	12/6/2010	522988	7911	70	113.01
	4/4/2011	535726	12738	119	107.04

Appendix C – Details of QA/QC samples collected in the course of GMP 147

Duplicate samples HRMN residence performed by EG&G lab

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
	125	19.4	0.8		62,940	1	8.4	4.38		0.9
	119	23.4	0.85		54,930	1	9.9	4.12		0.9

Duplicate samples LDBR residence performed by EG&G lab

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
4/6/11	207	51.2	69.09	8.1	22.800	42	19.7	0.979	3.84	7,800
4/6/11 dup	222	53	62.15	8.2	32,700	47	20.7	0.949	3.88	7,760

Trip Blank samples DVS residence performed by EMS lab

Date samp	BOD_5	TSS	TN	TP	e. coli
2/16/2010	<2 (n.d)	<1 (n.d.)	<0.11 (n.d)	Not sampled	<1 (n.d)

n.d. = not detectable

Equipment blank HSTN residence performed by EG&G lab

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
	<5	<1	<1.05	n. s.	54	<5	<1	<1.05	n. s.	47

n.s. = not sampled

Appendix D: Data from 20 homes in Virginia. BOD_5, TSS & e. coli Avg log transformed back to original units.

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
BCHN										
	598.5	118	151.04	**21.4**	344,800	6.3	2.9	6.52	4.48	0.9 (<1)
										1,986.3
	714	121.3	232.02		201,400	1 (<2)	5.7	8.45		2,419.2
	4,380	**13,820**	**377.05**		52,100	1	3	12.92		789
	792	136.4	144.009		313,000	1	0.9 (<1)	0.54		0.9
						1				
	1,103.7	405.3	226.03		183,443	1.44	2.58	7.11		35.3
BDSN										
	30	10.2	2.88		19,350	4.5	1.5	0.98		116
	31	18.4	7.62		91,390	3	1.7	3.44		1,553
	42	15.6	30.47		82,000	9.3	7.5	35.4		14,010
	40	24.5	10.249	11.6	39,900	2	2.2	7.19	5.21	0.9
						1				
	40	16.4	12.8		49,045	3.02	2.55	11.75		218.3
BLNC										
	322	63.3	24.41		1,960,800	101	17.3	19.55		132,000
	316	53.5	0.42		1,732,800	21	1.5	0.91		**547,500**
	200	79.3	32.89		13,400	77	0.9	1.07		2,790
	282	66	117.579	11.7	1,732,900	17	4.6	15.11	1.57	**547,500**
						11.5				
	275.2	64.9	43.8		529,987	31.7	3.22	9.16		102,503
BRNS										
	402.9	178	81.64		435,200	1.4	2.1	7.73		0.9
	401.9	90	156.7		31,300	1.5	**0.4**	11.36		36.8
	182.3	44	47.56		435,200	14.3	3.7	23.91		2,419.6
	460.5	85	128.05	17.6	387,300	15.1	2.4	18.43	2.2	0.9
						1				
	341.5	88	103.5		218,898	3.4	1.65	15.36		16.4
BSWL										
	204	16.5	3.96	7.42	166,400	67	0.9	4.53	3.35	1,986
	170	22.3	14.889		258,900	15.6	1.4	9.12		2,880
	81	51.5	18.37		**3,972,600**	28	9.6	6.96		173,290
	63	26.3	23.54		1,226,200	2.9	1.3	1.31		98,040
						5.7				
	115.3	26.6	15.2		676,831	13.7	1.99	5.48		17,656

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
BZWL										
	541.5	76	139.15		755,600	1.7	0.6	14.46		115.3
	278	75	199.25		344,800	2.8	2.5	**79.86**		325.5
	258.6	58	102.16		2,419,600	2.6	2	53.16		1,732.9
	223.2	60	113.11	9.97	2,419,600	4	4.8	30.96	9.85	640.5
						10.3				
						8.6				
	305.3	66.7	138.42		1,111,313	4.0	1.95	44.61		452
DVS										
	101.7	40	64.47		1,413,600	41	28	41.75		1,732.9
	284.7	240	56.45	8.64	178,900	1	23.2	3.83	0.51	91.2
	150.6	77	72.88		67,000	22.4	**40.5**	23.65		6.131
	56.7	30	25.08		1,119,900	5	10.6	3.64		19,863
						1				
	125.4	68.6	54.72		371,149	5.4	23	18.22		2,095
EBRT										
	26	32.7	1.49		101,120	3	2.2	3.76		68,670
	31	15.8	19.53		689,300	5.1	2.5	28.28		241,960
	104	21	33.85	9.6	547,500	18.6	9.5	17.2	6.14	290,900
	143	42.5	55.149		651,000	25	7.1	20.41		248,100
						4.1				
	58.8	26	27.5		397,011	9.18	10.55	17.41		186,089
GLS										
	600	53	22.049		517,200	36	9	6.26		310
	200	72.7	20.02		116,900	97	29.5	4.93		54,760
	140	40.4	23.3		648,800	31	7.7	3.29		120,330
	153	45.5	28.87	3.69	2,187,000	6	3.8	3.149	0.59	32,550
						7.1				
	225	51.6	23.56		541,200	21.52	9.39	4.4		16,057
HLDN										
	165	97	0.53		198,630	13.1	4.4	2.73		410
	284	438	1.44		24,800	72	34	14.93		980
	310	131	51.99	15.8	412,800	29	21.8	26.91	7.74	22,820
	270	88	83.68		1,034,400	6.8	3.8	12.32		1,046
						2.6				
	250.3	148.8	34.41		214,156	13.7	10.55	14.22		1,760

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
HMN										
	241	114	0.58		83,600	1	0.9	1.11		0.9
	35	30.5	29.79	4.82	37,300	9.3	6.2	12.08	1.98	961
	17.4	27.5	16.14		178,500	8.1	2.9	7.26		26,130
	36	36	8.7		151,500	6.4	3	3.96		6,090
						1				
	47.9	43.1	13.83		97,087	3.44	2.64	6.1		609.1
HRMN										
	108	29.8	0.44		198,630	7.4	6.4	4.08		30
	125	19.4	0.8		62,940	1	8.4	4.38		0.9
	119	23.4	0.85		54,930	1	9.9	4.12		0.9
	114	47.6	0.76		52,260	25	9.3	13.32		1
	246	44.8	1.17	10.9	215,200	29	7.1	10.7	6.53	180
	135.1	31	0.804		94,964	5.57	8.11	7.32		5.35
HRT										
	87	90	41.71		96,060	10.4	7.7	10.12		17,850
	55	28.8	43.98		18,700	1	1	29.97		548
	77	40.7	12.3	10.8	2,239,800	29	10.8	11.59	8.15	141,360
	30	30	6.01		1,553,100	30	1.8	4.16		64,880
						2.5				
	57.7	42.2	26		281,157	7.43	3.5	13.96		8,508
HSTN										
	185	80	31.47		120,100	2.6	0.9	14.08		300
	284	90	36.52		139,600	18	8.4	3.92		86,640
	282	134.3	1.41		62,400	83	7.5	1.04		38,730
	137	43.7	47.32	11.7	80,800	25	3.9	9.26	11.7	7,490
						3.5				
LDBR										
8/24/10	330	49	39.28		325,500	23	9	9.04		38,730
9/27/10	173	52	0.52		115,300	8.4	4.9	2.97		29,090
12/7/10*	140	70.7	13.54		517,200	54	1.8	2.79		129,970
4/6/11	207	51.2	69.09	8.1	22.800	42	19.7	0.979	3.84	7,800
4/6/11 dup	222	53	62.15	8.2	32,700	47	20.7	0.949	3.88	7,760
8/24/11						8.2				
Avg	205.6	54.7	36.9	8.15	107,672	23.5	7.98	3.35	3.86	24,520

Res code	Inf	Inf	Inf	Inf	Inf	Eff	Eff	Eff	Eff	Eff
Date samp	BOD_5	TSS	TN	TP	e. coli	BOD_5	TSS	TN	TP	e. coli
LFRT										
9/28/09	57	24.2	1.23		141,360	2.9	0.9	1.03		1,011
2/10/10	61	41	4.68		290,900	2.1	0.9	11.68		104,620
5/17/10	132	124	35.44	8.74	689,600	35	12.7	12.6	4.5	4,410
6/29/10	81	19.5	31.37		496,200	3.9	0.9	1.49		48,840
8/22/11						8				
Avg	78.1	39.4	18.18		344,414	5.82	1.74	6.7		12,286
LNRD										
5/19/10	198	55	25.96	6.4	488,400	**109**	32	12.21	4.14	198,630
6/28/10	121	46.8	69.959		866,400	29	15.5	26.77		64,500
9/27/10	108	26.5	14.47		13,050	8.4	3.6	0.6		0.9
12/6/10	225	108	3.07		816,400	1	6.4	0.91		98,800
8/23/11						10.4				
Avg	155.3	52.1	28.4		259,121	12.25	10.34	10.12		5,810
LVN										
10/5/09	134	61.7	151.93		920,800	15.5	5.8	18.36		4.1
2/15/10	428.3	73.8	113.17		387,300	2.1	1.3	36.9		1,732.9
4/5/10	496.5	100	112.05	13.1	51,200	1	0.9	5.12	1.2	0.9
6/16/10	1,986	1,472	226.1		146,700	1	4.7	25.22		113
8/18/11						1				
Avg	487.7	160.9	150.8		227,498	2.01	2.38	21.4		29
WKNS										
7/23/09	51	16	14.08		3,420	3.9	1.9	1.35		2
7/23/09grb						8.1	3.8	4.39		33
10/1/09	22	9.2	9.38		173,290	3	0.9	3.67		520
2/9/10	33	19.8	6.14		209,800	3.2	8.2	8.74		1,733
5/10/10	54	18	6.35	**1.4**	93,200	28	2	7.98	0.47	0.9
8/24/11						9.3				
Avg	37.6	15.1	8.99		58,345	6.55	2.54	5.23		35.13
WLT										
	41	7.2	4.88		13,100	1	0.9	0.539		1,120
	55	30.3	21.37	5.85	248,900	21	8	11.32	2.74	141,360
	60	19.3	6.18		285,100	7.2	1.1	0.919		4,570
	54	18.2	4.74		461,100	1	0.9	1.79		15,850
						2.8				
	52	16.6	9.29		143,887	3.35	1.63	3.64		10,348

* Effluent BOD_5 and e. coli resampled by lab on 12/22/10

** Effluent e. coli resampled by lab 5/2/11

*** Author asked sampler to take another grab sample

Bold - largest and smallest values for parameter in set