Performance Analysis of Established Advanced Onsite Wastewater Treatment Systems in a Subarctic Environment: Recirculating Trickling Filters, Suspended Growth Aeration Tanks, and Intermittent Dosing Sand Filters.

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Abstract

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Household onsite septic systems with secondary wastewater treatment in Anchorage, Alaska, were sampled and analyzed for performance parameters during winter and spring months. System types included intermittent dosing sand filters, three types of recirculating trickling filters, and suspended growth aeration tanks. Total nitrogen from the trickling filter and aeration tank effluent was fairly uniform at about 30 mg/l. TSS means were mostly less than 15 mg/l. BOD_5 showed considerable variability, with mean ranging from 9.2 mg/l for ISF's up to 39.5mg/l for one type of trickling filter, even though this type showed excellent results in several test programs. The data suggests that air temperature has almost no effect on removal of BOD_5 or TSS, and only a small effect on nitrogen. Other factors not related to climate are probably of equal importance to treatment results.

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Introduction

Installing a secondary wastewater treatment unit between septic tank and leachfield in an onsite treatment system provides several advantages. Secondary or advanced onsite wastewater treatment is necessary when a property does not have suitable area or soil conditions to support a conventional sized leach field for dispersal of septic tank effluent. Existing homes that have a failed leach field might install a secondary treatment system between the septic tank and receiving soil to allow use of a mound system or modified leachfield area. Secondary wastewater treatment systems provide aeration to enhance oxidation of carbon compounds thus inhibiting soil biomat formation (Beal, et al., 2004; Larsen Consulting Group, 2007b). The aeration also facilitates nitrification, or conversion of ammonia to nitrate. When combined with recirculation back to the anaerobic conditions in the septic tank, denitrification results in removal of nitrogen compounds. Description and reactions for these processes are in Appendix A-3.The recirculation step classifies the system as advanced secondary treatment. Effluent nitrate in particular is a concern if it reaches a water table, as it is soluble and can then travel a considerable distance (Cole et al., 2006; USEPA, 2002). Nitrate in well water is one of the chief health concerns arising from unsuccessful onsite wastewater treatment (CDC, 1996).

This project involved collection and analysis of effluent from a representative sample of household secondary and advanced secondary wastewater treatment systems in Anchorage, Alaska. Wastewater treatment systems that provide treatment beyond the conventional septic tank and leachfield setup are collectively referred to as advanced treatment systems (ATS).

Table 1. Anticipated range of onsite wastewater treatment effluent parameters.(MOA, 2003; Crites and Tchobongalous, 1998; Larsen Consulting Group, 2007).

Effluent from	BOD_5 mg/l	TSS mg/l	NO_3 mg/l	TN mg/l	pH	DO mg/l
Septic tank	150 - 300	100 - 250		60 - 90		
ATS	5 – 15	5 – 15	10 – 15	15 – 25	7.2 – 8.0	2.0 – 5.5

The types of ATS's chosen were those certified for use in the Municipality of Anchorage (MOA):

1. Intermittent dosing sand filter (ISF);
2. Recirculating trickling filters (RTF):
    a. Quanics Aerocell system, which has open cell foam media;
    b. Orenco Advantex which has hanging geotextile media;
    c. Orenco Reactex, which has squares or coupons of geotextile media;
3. Biocycle suspended growth aeration tanks.

Trickling filter manufacturer addresses and system descriptions are in Appendix A-3.

Intermittent dosing sand filters

An intermittent dosing sand filter (ISF) has septic effluent distributed over the surface of a bed of sand and allowed to drain through. Pipes through which warm air from inside the house is pumped to aerate the process are buried in the sand. The systems analyzed in this study were underlain by an impermeable liner. The filtered effluent drains by gravity, or is collected and pumped to a leachfield (fig.1).

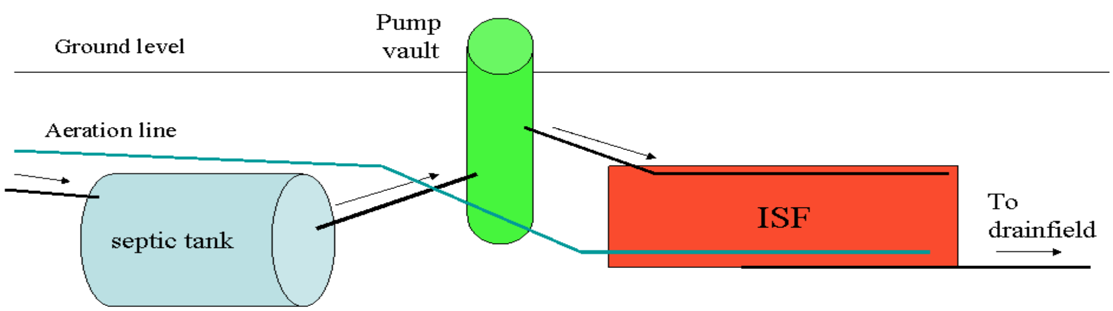

Figure 1. Intermittent dosing sand filter schematic. From Williamson, 2008.

Trickling filters

The recirculating trickling filters (RTF) have synthetic media enclosed in a plastic rectangular or cylindrical container. The media provides a substrate for the bacterial layer. Septic tank effluent is distributed over the surface of the media and trickles downward to a collection pipe where typically, 80% of filtrate is recirculated to the septic tank (fig. 2). The septic tank contents provide a source of carbon in an anaerobic environment which facilitates denitrification. 20% of filtrate collects in a vault to be periodically pumped to the leachfield. The Advantex and Aerocell TF's are aerated passively; the Reactex units were designed to have pumped in air.

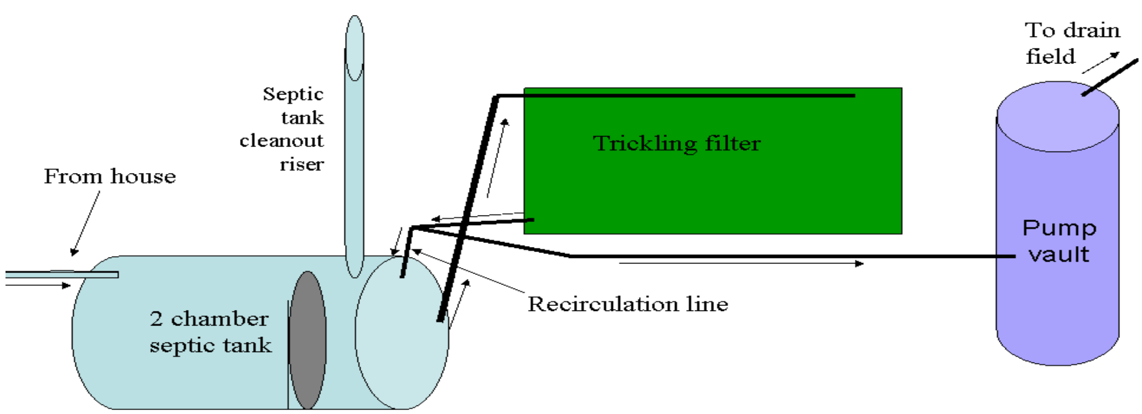

Figure 2. Trickling filter with recirculation schematic. Basic design and layout of trickle filter systems showing recirculation to second chamber of septic tank (mode 1). Arrows show flow direction. From Williamson, 2008.

Suspended growth tanks

Biocycle suspended growth aeration tanks can function without a septic tank. The first of four chambers provides the primary settling function. The second chamber has submerged tubes through which air is pumped. The third chamber provides further settling, called clarification, and the fourth chamber is a collection point to await discharge to the leachfield (fig. 3).

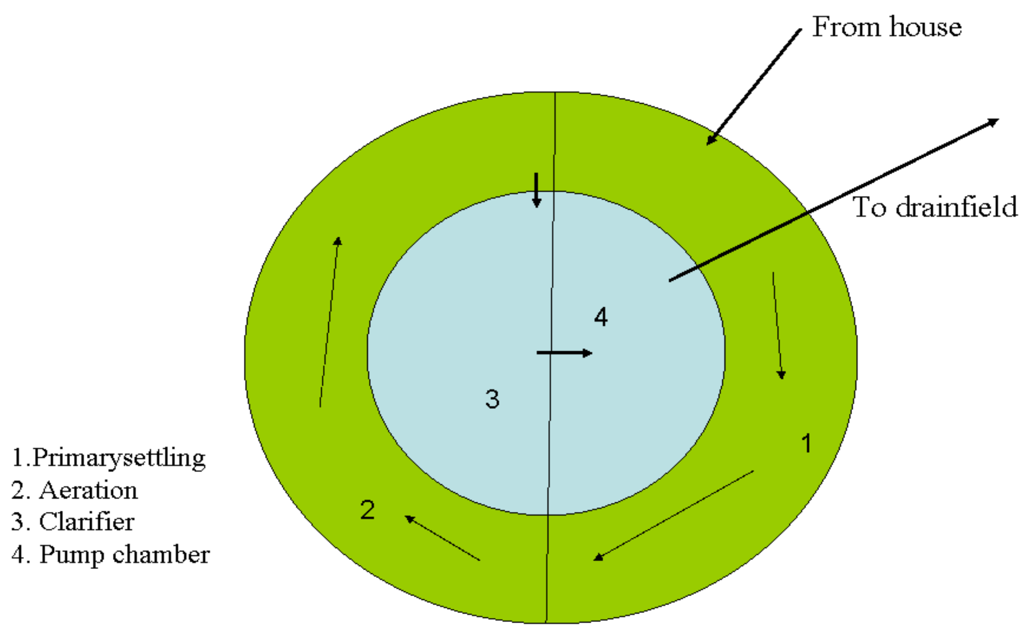

Figure 3. Biocycle 4 chamber cylindrical tank schematic. Biocycle suspended growth aeration tank, view from above. Wastewater travels through 4 chambers in sequencewith no recycling. Arrows show flow direction.
From Williamson, 2008.

Additional system descriptions and figures may be found in Appendix A-2 to A-7.

Cold temperature operation

It is widely accepted that temperature plays a significant role in the effectiveness of wastewater treatment. The purpose of this study was to assess the long term effectiveness of these technologies in a cold climate. The goals were to find out whether these advanced treatment systems provide the level of treatment expected based on the results of other field testing and meet Municipality of Anchorage, Alaska's certification limits during winter months.

The NOAA Regional Climate Center data for Anchorage Alaska mean October to April temperature for the years 1971 to 2000 was 24.5 degrees F (-4.2 ◦C), and the mean temp for those months in 2007-2008 was 25.6 degrees F (-3.6 ◦C). Monthly temperature data is in Appendix A-8. The amount of field testing in regions with the extended freezing period found in Alaska has been somewhat sparse.

When a permit for an onsite treatment system is granted by the Anchorage Municipality (MOA), or Alaska Department of Environmental Conservation (DEC), there has been very little if any follow up effluent testing, even if a waiver is included to allow development of a problem site by installing an alternative or advanced treatment system. (Municipality of Anchorage, 2003) This project attempted to expand this knowledge base, providing assistance to State and Municipal regulators and planners, design engineers and septic system installers. It also illuminated the wastewater treatment options for land developers and homeowners.

Literature Review

Installation and use of secondary and advanced secondary onsite wastewater treatment systems became widespread in parts of North America in the 1980's and numbers of types and usage expanded greatly in the next 20 years. There are over 300 onsite secondary treatment systems in Anchorage, Alaska (Larsen Consulting Group, 2008). The Municipality of Anchorage began testing of intermittent dosing sand filters in the early 1990's (Eagle River Environmental Services. 1994). Synthetic media trickling filters and Biocycle suspended growth aeration tanks began being used and certified in Anchorage Alaska in the late 1990's (MOA, 2000; USEPA, 2002).

Most of the literature affirms adequate performance for the types of systems in the presented test program (Larsen Consulting Group, 2007a; Orenco, 2008; USEPA, 2003). Field studies tend to have a wider range of values, with some substandard performers, likely due to variable conditions (Groves et al., 2005).

Technology test results

Biocycle suspended growth aeration tanks originated in Australia, although onsite treatment by this process has been used extensively in North America. Biocycle Alaska tanks are manufactured in Alaska. There is no recycling of sludge in the Biocycle process. This technology has had some problems withstanding surges, uneven wastewater strength, and blower malfunction, although regular monitoring and maintenance has minimized these problems (Gustafson et al., 2002; USEPA, 2002). A Biocycle Alaska maintenance person reported that sludge removal from the primary settling chamber is required only about every 4-10 years.

Intermittent dosing sand filters and the synthetic media trickling filters all have an array of pipes to distribute septic tank effluent over the surface at regular intervals. Intermittent dosing sand filters must use finer sand than recirculating sand filters to achieve adequate results (USEPA, 2002). Recirculating sand filters are not among the systems certified for installation in the Anchorage Municipality, and were not tested. ISF's in Anchorage are required to have active aeration via an array of pipes buried in the sand bed (Municipality of Anchorage, 2003). The NSF test sites near La Pine Oregon found the lined ISF to have a mean effluent BOD_5 of 2.1 mg/l and ranked 3rd out of 15 onsite treatment systems during a 2 ½ year study (Orenco Systems, 2005). The Waterloo Biofilter trickling filter, a Canadian manufactured forerunner of the Quanics Aerocell unit using the same open cell foam media was tested from 1999 to 2001 at the Massachusetts Alternative Septic System Test Center. A conventional septic tank removed 1% of total nitrogen (TN); the Waterloo Biofilter removed an additional 57% of total nitrogen. The mean total nitrogen in septic tank effluent was 34.6 mg/l; mean effluent TN from the

Waterloo Biofilters was 15.0 mg/l, nitrate being 10 mg/l. An additional interesting result was that samples collected after effluent passed through a soil absorption bed showed that septic effluent TN was reduced from 34.6 to 23.5 mg/l (24%), while the soil bed lowered Waterloo Biofilters' nitrogen effluent from 15.0 to 12.7 mg/l, only an additional 3%. The Waterloo Biofilter showed a slight effect from seasonal temperature with TN range of 11 - 16 mg /l in winter and 6- 9 mg /l in summer (Costa et al., 2002; see table 2).

A field study conducted on five Waterloo Biofilters in Rhode Island found mean effluent BOD_5 of 17 mg/l, TSS of 11 mg/l. Mean effluent total nitrogen concentration for the three systems in recirculation mode was 44.7 mg/l, with a range from 10 to 106 mg/l. Effluent temperature means ranged from 6 to 11 ◦C in winter, and 19to 24 ◦C in summer. Seasonal differences in TN or nitrate were not reported (Loomis, et al., 2001; see table 2). Additional Information on the Quanics Aerocell and Waterloo Biofilters can be found in Appendix A-3.

Orenco's Reactex trickling filter media was non-woven textile rectangles or "coupons." The Reactex is no longer manufactured, and Orenco's current onsite trickling filter is the Advantex. Ventilation for the Reactex filter was provided by an external air pump. The University of Minnesota-Duluth conducted tests on a Reactex filter in recirculation mode from 1999-2001. BOD_5 and TSS overall means were less than 6 mg/l, with 95-98% removal. Seasonal differences were very slight. The winter mean effluent total nitrogen was 52 mg/l; mean nitrate was 43 mg/l. (McCarthy, et al., 2001; see table 2). The NSF tests at La Pine, Oregon found Reactex trickling filter's mean effluent BOD_5 to be 8.0 mg/l, and ranked 5th among 13 advanced treatment systems. Mean TSS was 13 mg/l. Mean TN was 19 mg/l, ranking it 4th out of 13 ATS's. Nitrate levels ranged between 1 and 15 for one system, 8 to 38 mg/l for another (Oregon DEQ, 2005). In a California study during months with mean ambient air temp of 10 degrees C, effluent mean BOD_5 and TSS were 2.5 mg/l, NO_3 was 11 mg/l, and TN was 15 mg/l (Leverenz et al., 2001; see table 2).

Table 2. Field performance data for tested system types, 1993-2006.

System type	#sites/total # samples	Location	BOD_5 mg/l Mean/ median	TSS mg/l Mean/ median	TN mg/l Mean/ median (% reduction)
ISF	9/ 84	Alaska[1]	4 / 2	7.6/ 2.8	42/ 41.5
ISF	17/ 100's	Various[2]	5/	5/	33/
Biocycle	12/ 87	Alaska[3]	18.1/ 9	12.7/ 7	31.1/ 27.2
Reactex	/41	Alaska[4]	18.9/ 17	13.6/ 10.5	15.0/ 12.3
Reactex	1/8	Minnesota[5]	4.4/	2/	41(↓ 32%)
Reactex	2/ 14	California[6]	2.5/	2.5/	15 (↓ 25%)
Reactex	2/33	Rhode Is[7]	4/	4/	63(↓ 45%)
Advantex	3/ 93	Oregon[8]	10.8/ 5.7	7/	17.1/ 14.7
Advantex	18/ >100	Virginia[9]	10/	12/	20/
Advantex	75/ 222	N. Carolina[10]	4/	7/	24/
Waterloo TF	3/45	Rhode Is.[11]	17/	11/	44.7/
Waterloo TF	1/ 53	Mass.[12]	10/ 7.4	7/ 5	15/ 13

Sources: 1, 3 & 4. Moore & Spurkland, 2000; 2. MT DEQ, 2004; 5. McCarthey, et al, 2001; 6. Leverenz, et al., 2001; 7. Loomis et al., 2004; 8. Orenco, 2005; 9. Gross, 2005; 10. Berkowitz, 2007; 11. Loomis, et al., 2001; 12. Costa, et al, 2002. Waterloo Biofilter TF is Canadian manufactured forerunner of the Quanics Aerocell TF unit using the same foam cube media.

Orenco's Advantex geotextile trickling filter has undergone extensive testing in various states and Canadian provinces with favorable results (Orenco, 2008). The media is suspended from rods laid side-by-side and the bacterial film adheres to these sheets. Advantex AX-20 units installed for onsite treatment in Anchorage recirculate in Mode 1, which means filtrate is recycled to the second chamber of the septic tank. Field data from systems operating in this configuration have shown the following ranges of means: BOD_5, 4-10 mg/l, TSS, 4-12 mg/l, TN, 14-26 mg/l (results from 2 studies included in table 2). The La Pine, Oregon BOD_5 results ranked the AX-20 4th out of 13 advanced treatment systems tested. Total nitrogen's range was 9- 44 mg/l, mean = 17.1 mg/l, ranking it 3rd out of 13 ATS's. The Advantex's nitrate range was 8 – 18 mg/l. The Oregon systems operated in Mode 3, recirculating to the first compartment of the septic tank (Oregon DEQ, 2005).

Temperature effects on treatment

Low water temperature slows reaction rates, bacterial growth and activity which in turn will hamper wastewater treatment. Nitrifying bacteria in particular become nearly inactive if the temperature drops below 5 degrees C (Fig. 4). The bacteria consuming carbonaceous material are essentially dormant at 2 degrees C. Low temperature also affects physical processes such as settling characteristics and slows gas transfer rate (Metcalf & Eddy, 2003). Several studies have found influent wastewater temperature's effect on BOD_5 is negligible within normal range of 10 to 22 degrees C. (Chien-Lin, 2003; Converse & Converse, 1999; Gebert & Wilderer, 2000; Loomis et al., 2001; Verma & Mancl, 2001; table 2). Chien-Lin (2003), found that the rate of clogging in a bench size sand filter decreased linearly as temp rose from 5 to 20 degrees C. The Converse & Converse (1999) field study on 47 ISF's found mean BOD_5 of 6 mg/l for winter samples with mean temp of 6 ◦C.

Low temperature tends to have a magnified affect on the nitrification process, resulting in lowered conversion of wastewater ammonia to nitrate. Temperature ideally should be above 20 ◦C; 28 ◦C is optimal for nitrification. Studies have shown nitrogen conversion processes to be inhibited by cold temperature (Chien-Lin, 2003; Costa et al., 2002; Gullicks & Cleasby, 1990; Loomis et al., 2001; Loomis et al., 2004). The La Pine, Oregon tests on Reactex and Advantex systems showed some winter sample spikes in TN and nitrate, but there was no real pattern. There were only 7 samples (out of almost 90) below 10 degrees C, none below 7.4 degrees(Oregon DEQ, 2005). McCarthy, et al., (2001) and Urynowicz et al., (2007), found just slight difference between warm and cold weather effluent nitrate and total nitrogen, although ammonia was significantly higher in the colder conditions, suggesting lowered oxidation rate(see fig. 5).

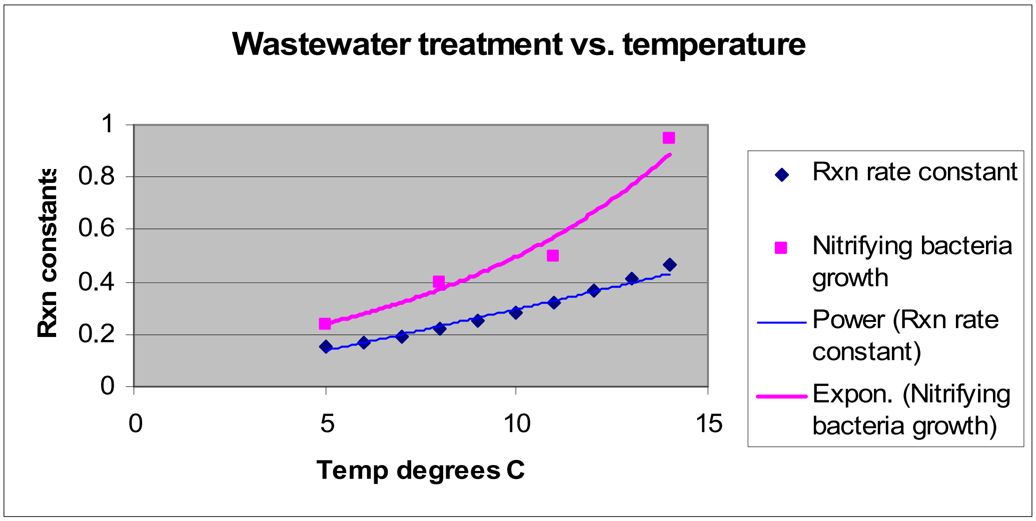

Figure 4. Ratio of biological reaction rate and bacterial population growth rate constants at a particular temperature to reaction rate constant for 20 degrees C. Rxn rate ratio line shown should curve slightly. Temperature effect on reaction or growth rate constant formula: $k_2/k_1 = \theta^{(T2-20)}$

$k_{1\,=}$ constant at 20 degrees C,

$k_{2\,=}$ constant at particular temp,

θ = temperature activity coefficient = 1.135

(p.55, Metcalf & Eddy, 2003; Geyser Pump Tech. Co., 2007).

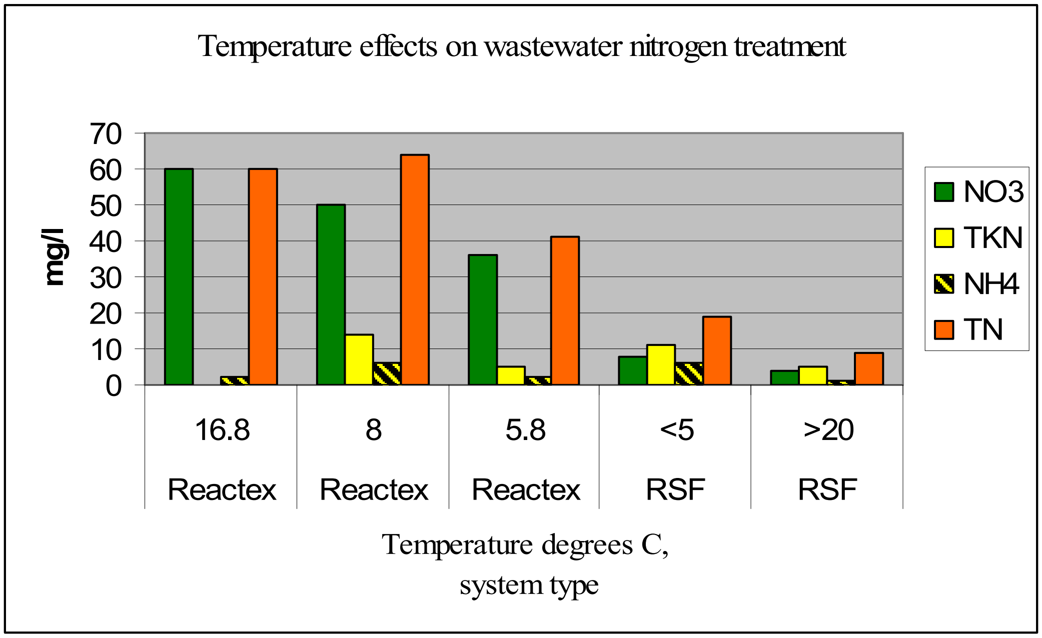

Figure 5. Temperature effects on nitrogen conversion. Reactex in Minnesota (McCarthey et al., 2001), and recirculating sand filters in Wisconsin (Urynowicz, et al., 2007).

Installation practices are intended to maintain the ambient temperature of wastewater during treatment by utilizing added insulation and soil cover (Gustafson, 2001; MOA, 2003).

Monitoring and maintenance has had to evolve along with this technology. Since 2003, Anchorage has required alarms to alert of mechanical failure and excess water level, and the homeowner to sign a contract stating that monitoring and maintenance will be performed regularly by the homeowner, or a qualified contractor (MOA, 2006).

Other influences on nitrogen removal

Additional factors which can affect nitrification include:

(1) Proportion and concentration of ammonia and nitrite;

(2) BOD_5 depresses nitrification

(3) Dissolved oxygen concentration needs to be above 1.0.

(4) pH optimum range is 7.4 - 8.2.

Some of these will combine to magnify effects, while other conditions might cancel each other out. There are also a variety of organic and inorganic agents that inhibit the growth and metabolism of nitrifying bacteria (Metcalf & Eddy, 2003).

Denitrification, the reduction of nitrate to nitrogen gas, is affected by some of the same factors, although in different ways. The BOD/ NO_3 ratio must be above two, and eight or more is best, and pH in the range of 7.0-8.5 is crucial (Metcalf & Eddy, 2003).

Methods and Materials

Site selection

All sampling was from household onsite wastewater treatment systems located in Anchorage, Alaska, except for one Aerocell system near Chugiak, AK.

Treated effluent samples were collected from 3-5 of each of the four types of advanced treatment systems certified by the Municipality of Anchorage. An attempt was made to sample from systems in use for over one year. Also, the author acted as third party for sample collection and handling of the Quanics Aerocell system for it's Municipality of Anchorage certification process (see table 3). A map of Anchorage Alaska can be found in the Appendix A-1.

Sampling procedure

All wastewater sample collection was by grab sample. The ISF, Reactex, and Aerocell systems all had sample ports from which to collect treated effluent. Biocycle systems were sampled by dipping from the fourth chamber of the tank, which receives clarified effluent prior to release. Advantex system sampling involved removing the cover from a pump basin and catching the filtered effluent as it dumped in (Converse, 2004; Wren et al., 2004.)

I adapted protocol laid out in Standard Methods, as well as MOA guidelines and 3 manufacturer's manuals, to commonly practiced methods. (American Public Health Association, 2006; Bounds, 2004; Norweco, Inc., 2005; Municipality of Anchorage, 2003; Orenco, 2004). The sampling procedure can be found in the Appendix B-1.

Some samples were measured immediately for pH, dissolved oxygen, and temperature.

Table 3. Number of sites and samples collected for each system type in test program. The number of newly installed systems is represented in column Age <2 yr

System type	Age <2yr	Age >2 yr.	Total # of sites	Total # samples
Advantex	1	4	5	30
Aerocell	3	0	3	30
Biocycle	0	5	5	22
Reactex	0	5	5	20
ISF	0	3	3	13

The intention was to collect ATS influent each time, but the ISF is the only type where septic tank effluent could be accessed. The Biocycles have no reasonable access, and the trickling filter systems contain varying proportions of recirculated fluid in the septic tank.

Lab procedure

The lab analysis included five day biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen (TN), and nitrate. BOD_5 and TSS provide an estimate of the carbohydrate concentration in treated wastewater. Nitrate measurement reveals how well the system is nitrifying ammonia, and also is a concern when effluent reaches ground or surface water. Total nitrogen indicates the amount of this nutrient remaining, which indicates the effectiveness of the system for denitrification. Biological treatment reactions are described in the Appendix B-3. BOD_5 and TSS analysis procedure came from Standard Methods (American Public Health Association, 2005). Additional help for BOD came from Hach Technical Booklet no.7 (Hach, Klein & Gibbs, 1997). Nitrate and total nitrogen was measured with a Hach DR 2800 spectrophotometer using Hach reagents. The TN analysis procedure using TNT 828 reagents is not EPA approved, but easier, faster, and safer than methods for measuring TKN, and Hach Company has thoroughly tested its accuracy (Darula, 2006). Fecal coliform analysis was not performed as the prevailing opinion is that soil absorption removes harmful microbes within a meter of infiltration (Jennsen & Siegrist, 1990). Additional description of laboratory procedures is in the Appendix B-2.

Duplicate analysis was performed on some Aerocell samples to test lab procedure quality control by comparing results with a certification test program performed by a professional laboratory. Appendix B-3 shows the results comparison.

Data analysis

Data analysis included mean, median, geometric mean, standard deviation, maximum and minimum values, standard error, coefficient of variation, and average of independents, which is the average of site means.(Converse & Nordheim, 2004; Groves et al, 2005). Correlation coefficients were calculated between effluent temperature and sample BOD_5 and total nitrogen. Correlation coefficients were also determined between BOD_5 and total suspended solids (see Appendix C-10). Variance and standard deviation were calculated within a system type's samples and among the system type site means(see Appendix C-11).

Size of households were split into categories of those with 1 to 2 persons and those with 3 or more persons to look for similarities within those groups and a relationship between performance and household size. Analysis of Variance (ANOVA) and t tests were performed for comparison of mean effluent concentrations among system types as well as within household size categories. Appendices C-1 to C-5 contain data spreadsheets, C-6 has ANOVA statistics and C-7 contains t tests.

Results and Discussion

The intent of this study was to sample effluent from established alternative wastewater treatment systems in Anchorage, Alaska. Test results would be compared to cold weather data to test results in literature and previous Alaskan test data. The results would aid comparison of performance between the types of systems certified for use in the Anchorage municipality. There are certain caveats to these comparisons, as follows:

- The Reactex synthetic media trickling filter is out-of–date technology which Orenco replaced by the Advantex. These Reactex systems had a sample port to facilitate effluent access and some had previous sample data so they might give an idea of the longevity of synthetic media trickling filters. There is another Advantex ancestor trickling filter using hanging media that was lumped in with the Reactex data. Some of the Reactex systems sampled were poorly maintained. Indeed, several were unsuitable due to damage or other difficulties. Despite the misgivings about inclusion of Reactex data, there were some interesting aspects to the results. BOD_5, TSS, and TN overall means were very similar to the newer Advantex systems (fig. 6 & 7). This was consistent with data from Alaska and other states (table 2). Total nitrogen levels came out similar to the newer trickling filters’ effluent data in table 7. Reactex sample results show the technology compares well, and withstands neglect.
- The Quanics Aerocell systems were checked out prior to commencement of the sampling series, and results were an expansion of data used to certify this technology by the Municipality of Anchorage Onsite Services. Much larger

sample sizes were analyzed than for the other system types but from only three sites. Nearly all samples were collected during January, 2008. The Aerocell systems showed relatively tight ranges for effluent constituents. This possibly enabled the discovery of correlations between pH, temperature, and total nitrogen.

- Biocycle systems had to be unlocked by the maintenance worker for each sample collection.
- Some Advantex systems, all Reactex systems and all ISF's were sampled without prior arrangements with the maintenance workers or vendor.
- All the Advantex, Aerocell, and Biocycle systems are on modems and alarm systems which alert both homeowner and vendor/ maintenance worker of any problems. ISF's had audible alarms without modems.

BOD_5 and TSS were measured from all effluent samples. Figure 6 shows BOD_5 means for the Advantex and Reactex systems to be considerably higher than results from other systems. Mean concentrations for Biocycle aerated tanks also came out slightly above previous test data. Aerocell and intermittent dosing sand filter numbers are quite good.

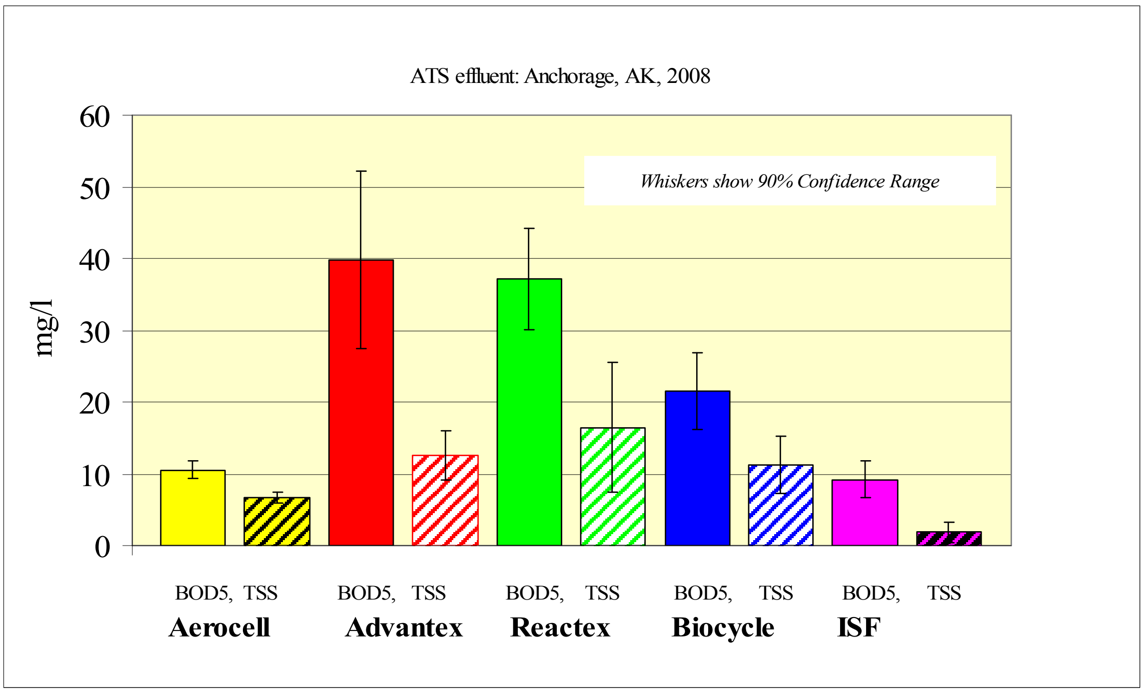

Figure 6. Advanced treatment system types' effluent BOD_5 & TSS.

In table 4, the BOD_5 median for the Advantex is substantially lower than the mean, reflecting the few outliers included in the analysis. 90% confidence intervals remain wide for Advantex and Reactex.

Table 4, effluent BOD_5 analysis for each system type.
N= total number of samples, All other values mg/l.
Avg mean: average of site means, rather than entire sample group (average of independents.) Stand dev: range of site mean standard deviations.
Confidence interval spread above and below the mean.

System type	**N=**	**Minimum-maximum**	**Mean**	**Avg mean**	**Median**	**Stand. Dev.**	**90% Conf. Interval spread**
Advantex	30	6.3 - 165	39.8	40.3	25.0	4.5 - 46	27.4 - 52.2
Aerocell	30	5.4 – 22.5	10.4	10.4	9.1	3.5 - 4.8	9.1 - 11.7
Biocycle	22	8 - 58	21.5	23.5	17.4	3.6 - 14.6	16.2 - 26.8
Reactex	20	14 - 86	37.1	37.1	39.5	5.7 - 16.7	30.1 - 44.1
ISF	13	3.6 – 21.2	9.2	12.8	9.6	4.0 - 10.9	6.7 - 11.7

Effluent TSS values came out much more in line with other test results (fig. 6). Notice in table 5 that medians are considerably lower than the means in Reactex and Biocycle systems.

Table 5, effluent TSS analysis for each system type. All values mg/l.
Avg mean: average of site means, rather than entire sample group (average of independents.) Confidence interval spread above and below the mean.

System type	Minimum-Maximum	Mean	Avg mean	Median	Standard Dev.	90%Conf. Interval spread
Advantex	0.8 – 52.3	12.5	12.1	10.9	10.6	9.1 - 15.9
Aerocell	2.3 - 14	6.3	6.2	6	3.2	5.6 - 7.0
Biocycle	4 - 42	11.5	13.4	6.6	10.8	7.4 - 15.6
Reactex	2 - 96	16.4	18.4	8.9	24.6	7.3 - 25.5
ISF	0.2 – 11.8	2	2	1	3.1	0.6 - 3.6

Total nitrogen (TN) as the sum of nitrate and total Kjeldahl nitrogen, is shown in figure 7. The trickling filter and Biocycle systems tested were quite even as far as TN. The Aerocell systems seemed to nitrify ammonia well, resulting in high proportion of nitrate. Intermittent dosing sand filter results came out as would be expected from other field testing. These ISF's don't recirculate effluent, so are not expected to reduce nitrate or remove nitrogen as well as the trickling filters. The nearly equal TN mean for the Biocycle came as a surprise, as this system is not classified as a nitrogen reducing technology.

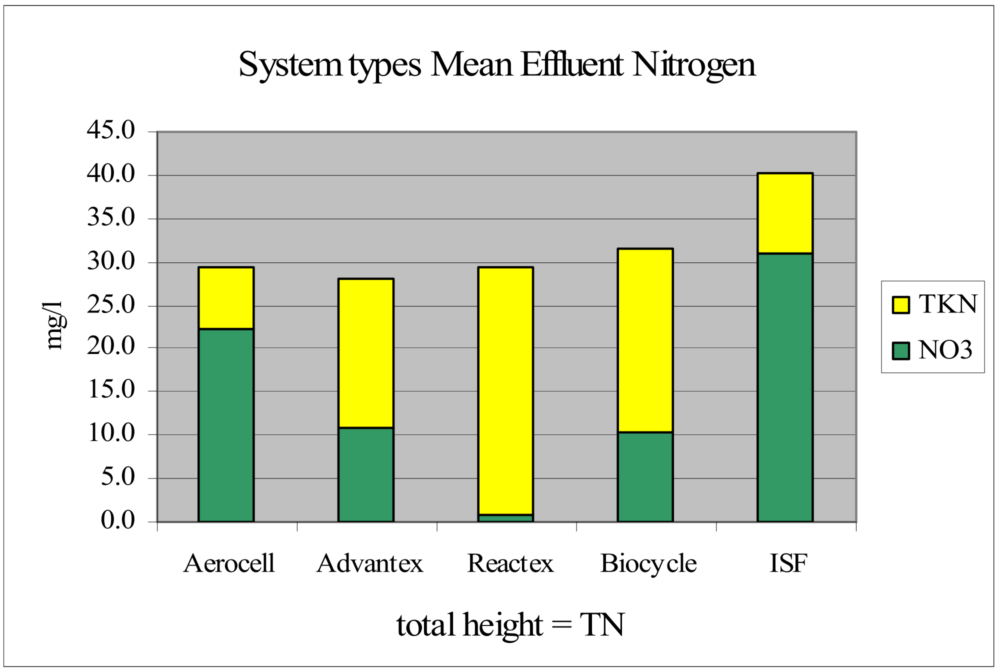

Figure 7. Advanced treatment system types' effluent nitrogen: TN= TKN+NO_3.

Nitrate levels for the Reactex systems tended to be very low, making up a very small proportion of total nitrogen. A clue as to the reason is mean dissolved oxygen in Reactex effluent was 1.9 mg/l, while Advantex and Biocycle effluents' DO averaged 5 mg/l. The ISF's had a mean DO of 8.1 mg/l and nitrified influent ammonia quite well, resulting in high proportions of nitrate (Table 6).

Table 6. Effluent nitrate analysis for each system type. All values mg/l.
Avg mean: average of site means, rather than entire sample group (average of independents.) Confidence interval spread above and below the mean.

System type	Minimum-Maximum	Mean	Avg mean	Median	Standard Deviation	90% Conf. Interval spread
Advantex	0.3 – 33.4	10.8	10.6	9.6	8.2	8.3 – 13.3
Aerocell	10.1 – 39.8	23.3	22.5	19.1	9.2	20.1 – 24.5
Biocycle	0.1 – 34.3	9.9	9.6	10.3	7.5	7.3 – 12.5
Reactex	0.1 - 66	0.8	0.7	0.5	14.6	
ISF	15.2 - 58	31.0	30.1	32.9	10.5	26.2 – 35.8

Table 7 shows the medians for total nitrogen came out very similar to the means for all system types (symmetric data sets), except Reactex systems which had a wider confidence interval than the other system types.

Table 7. Effluent total nitrogen analysis for each system type. All values mg/l. Avg mean: average of site means, rather than entire sample group (average of independents.) Confidence interval spread above and below the mean.

System type	Minimum-Maximum	Mean	Avg mean	Median	Standard Deviation	90% Conf. Interval spread
Advantex	10 - 82	26.0	26.0	25.2	17.4	20.8 – 31.2
Aerocell	13- 56	29.4	28.4	29.4	11.6	26.7 – 32.1
Biocycle	13 - 64	31.4	30.3	29.8	14.5	26.3 – 36.5
Reactex	12 - 75	29.3	29.2	23.9	21.0	21.2 – 37.4
ISF	26 - 51	40.3	39.8	39.2	8.0	36.3 – 44.3

Comparison to other studies

Some results mirrored those of earlier tests and certification data collected in Alaska and elsewhere. Intermittent dosing sand filters' effluents had mean BOD_5 of 9.2 mg/l, and mean TSS of 2 mg/l. BOD_5 and TSS of Quanics Aerocell sample means at 10.4 and 6.3 mg/l respectively, compared well. Biocycle aeration tanks also performed at the level of previous Alaskan testing, with BOD_5 of 21.5 mg/l and TSS at 11.5 mg/l (fig.6; tables 2, 4 & 5). One Biocycle system (B-6) with a septic tank ahead of it provided excellent treatment for a large household: mean BOD_5 of 14.2 mg/l, TSS of 4.8 mg/l, and TN of 20.3 mg/l.

Among the recirculating trickling filters and Biocycle aeration tanks tested, effluent TN ranges and means were very similar, although about 40% higher than some other test studies on the Advantex, Reactex, and Aerocell systems in table 2 (see p. 10). The Biocycle tanks' total nitrogen mean was well within the range of test results published by the EPA from much warmer locations (USEPA, 2002).

Temperature effects

Temperature was expected to have a negative correlation on wastewater treatment (lower temperature associated with higher remaining constituent concentration). Table 8 shows that if there is any correlation between BOD_5 and temperature, it seems to be positive, and just slight negative correlation of temperature to effluent nitrogen levels. It should be noted that all Reactex, ISF, and Aerocell data was collected before April 1, and the temperature range is lower than for the Advantex and Biocycle samples. The Aerocell systems had only 5 temperature readings with corresponding TN and nitrate measurements, so although table 8 lists the expected correlation, the sample size causes concern for the accuracy of this calculation.

Table 8. Correlation of temperature with treatment effectiveness.
A negative correlation coefficient indicates lower temperature is associated with lowered performance.

System type	Temp Range, °C	Temp mean °C	Mean NO_3, mg/l	NO_3 Cor. coeff	Mean TN, mg/l	TN Cor. Coeff.	BOD_5 Cor. Coeff.	TSS Cor. Coeff
Advantex	5 - 14	10.2	10.8	-0.08	26.0	-0.16	0.37	0.01
Aerocell	6 - 11	8.6	22.3	-0.64	29.4	-0.61	-0.03	-0.52
Biocycle	5.5 - 16	12.8	9.9	0.20	31.4	0.28	0.40	0.33
Reactex	4 - 10	7.1	0.8	0.44	29.3	0.5	0.65	0.01
ISF	1 - 4	3	31.0		40.3			
Advtx OR demo sites	7.4 - 22	14	12.1	-0.76	17.1	-0.43	-0.06	

ISF effluent has been exposed to soil temperature several minutes before sample collected. Other systems' effluents have no exposure prior to collection.
Avtx OR: Advantex Oregon test data from Orenco, 2005.

Figure 8 shows the data point trend lines showing negative temperature correlation for Aerocell data and the Advantex data from the 3 Oregon test sites.

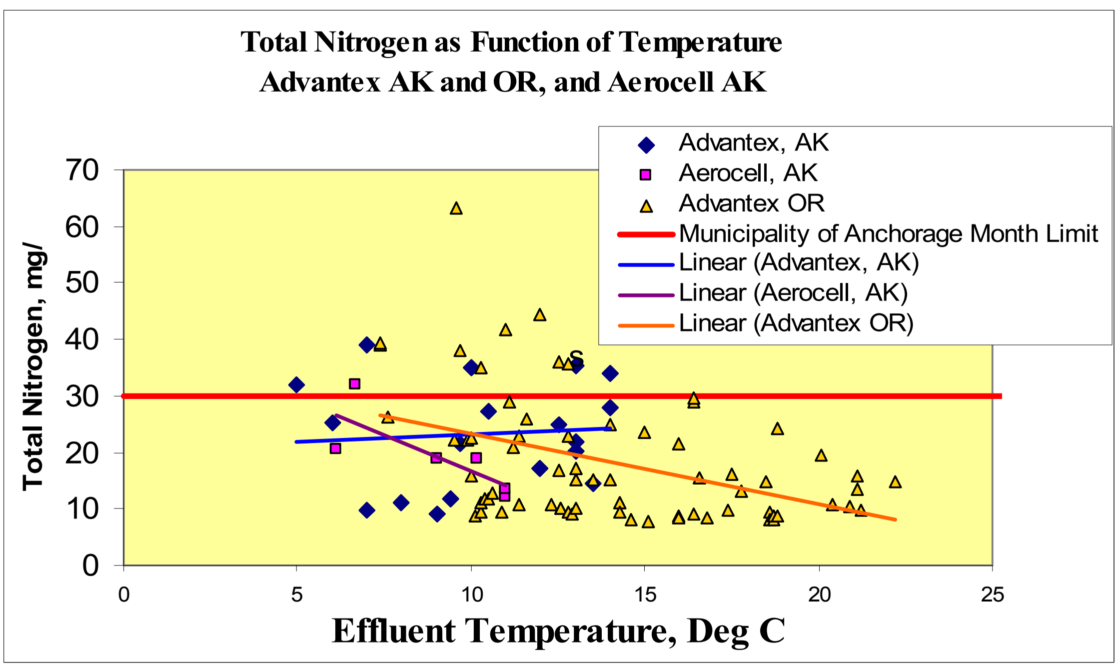

Figure 8. Total nitrogen vs. temperature data points in Aerocell and Advantex systems.

Dissolved oxygen effects

The relationship between dissolved oxygen and BOD_5 was tested by calculating correlation coefficients. Results showed negative correlation coefficient between BOD_5 and DO: -0.55 for Advantex, -0.58 for Biocycle. Mean DO for Advantex was 5.0 mg/l, and for Biocycle it was 5.2 mg/l, so there seems to be adequate dissolved oxygen for carbonaceous oxidation in these systems. Reactex systems had a mean DO of 1.9 mg/l, but the BOD_5 results are nearly the same as the Advantex numbers in table 4 (p.22). When individual sites were scrutinized in table 9, it was discovered that Ax-5, the worst performing Advantex (mean BOD_5 = 96 mg/l), had a mean DO of 1.5 mg/l, although the poor performing system that was dropped, Ax-6 with a mean BOD_5 of 96 mg/l, had a mean DO of 3.7 mg/l.

Table 9. Trickling filters showing substandard performance. Ax-6 was an Advantex that was dropped from inclusion after discovery of a clogged air intake. Values are means. Ax: Advantex systems; Rx: Reactex systems.

sites	**BOD_5** mg/l	**TSS** mg/l	**NO_3** mg/l	**TN** mg/l	**pH range**	**temp ◦C**	**DO** mg/l
Ax-1	54.5	24.3	12.2	40.1	6.7-7.2	8.6	5.7
Ax-5	96.5	21.3	0.6	32.2	5.5-6.8	12.1	1.5
Ax-6	96	28	0.5	60	6.9-7.4	5.7	3.7
Rx-3	63.0	13.0	0.2	64.0	5.5-7.1	8.8	1.4
Rx-6	32.5	5.3	1.3	25.0	6.4-7.1	6.1	2.4
Rx-5	36.3	63.0	0.2	22.0	6.7-7.5	6.3	1.9

Effluent total nitrogen tended to be lower when pH readings were 7- 7.5, and higher if pH was less than 6, but not always. Nitrogen removal is enhanced when DO is above 2.0 mg/l, and pH is 7.2-8.4 (Metcalf & Eddy, 2003). Biocycles had the highest average pH, at 7.3, which coupled with adequate oxygen are probably responsible for their fine nitrogen removal ability.

Household size effects

To analyze another independent variable which could influence performance, two categories of household sizes were compared: those with two persons or less and those with three or more living in the house. There appears to be a positive correlation in most cases (fig. 9 & 10). Appendix C-7 contains the results of t tests which indicated that what these two graphs suggest to be differences between size categories are indeed significant. For the data in figure 9, the p value for the two household categories with Advantex systems was 0.19; for Biocycle systems $p = 0.09$; and for Reactex systems $p = 0.01$. For figure 10, effluent TN in respective household categories, for Advantex systems, $p = 0.004$; for Biocycle systems, $p = 0.02$; and for Reactex systems $p = 0.32$.

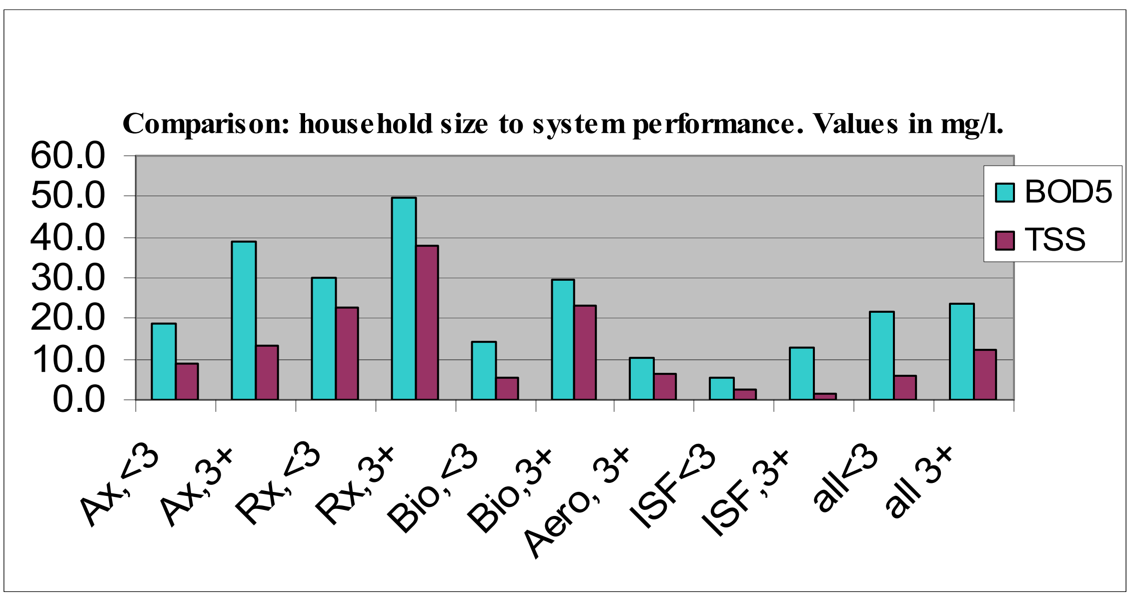

Figure 9. Comparison of 2 categories of household size to effluent BOD_5 and TSS from system types (Ax =Advantex; Rx = Reactex; Bio = Biocycle; Aero =Aerocell; ISF; all <3 w/o ISF & Ax5; all 3+ w/o ISF, see table 11).

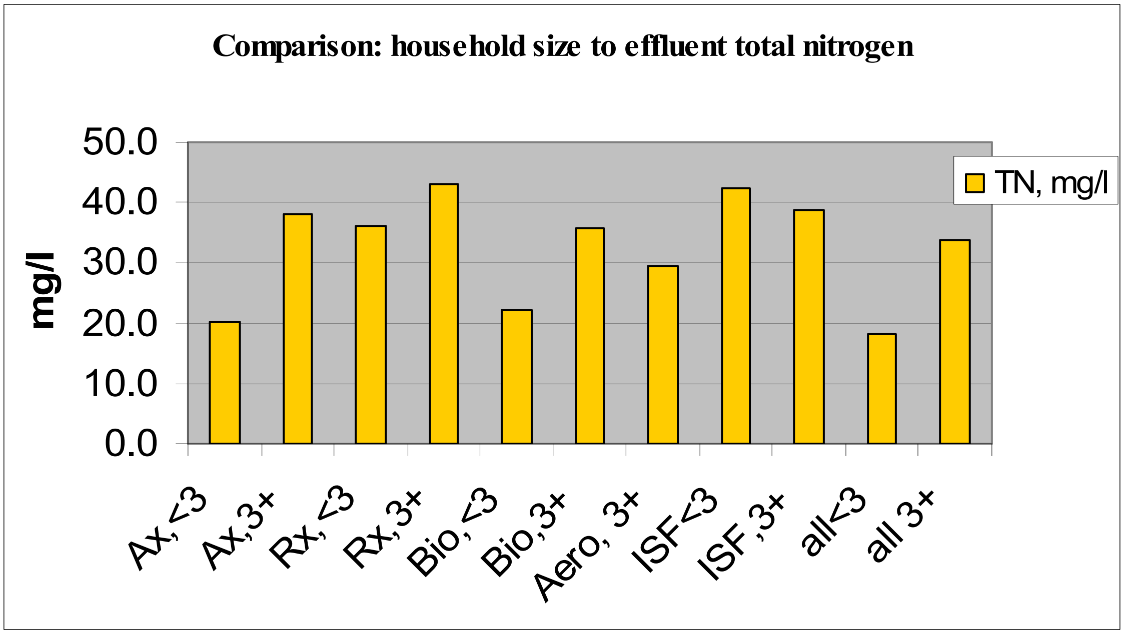

Figure 10. Comparison of 2 categories of household size to effluent total nitrogen from system types (Ax =Advantex; Rx = Reactex; Bio = Biocycle; Aero =Aerocell; and average of each size category.)

Table 10 shows even more obvious differences between household categories if the average mean or average of independents was used, rather than sample means. Figure 9 uses the BOD_5 and TSS means leaving out the ISF's and the overall poorest performing Advantex among the smaller household category.

Table 10. Relationship of household size to system performance.
Avg mean: average of site means, not all samples (average of independents).
*xSF indicates Sand filter data removed from averages; xA5 indicates the poor performing Advantex system's data removed in addition to ISF. All values in mg/l.

# persons	**mean BOD_5**	**Avg. mean BOD_5**	**Mean TSS**	**Avg. mean TSS**	**Mean TN**	**Avg. mean TN**
all<3	29.9	28.6	7.5	7	23	22.9
all<3xSF*	33.9	31.9	18.3	7.6	20.4	20.1
all<3xA5,SF	21.8	21.1	5.8	5.3	18.1	18.1
A5 only	96.5		21.3		32.2	
all 3+	23.4	27.5	12.3	16.5	33.8	34.5
3+,xSF*	24.7	30.4	13.5	19.6	33.3	33.6

The household size data might indicate a bias if a system type was over represented in one or the other household size category. The Biocycle systems were represented by only one site in the household <3 category, and three sites in the 3+ category, so there is a possible source of bias among that system type data. Advantex and Reactex system types were both represented by three sites with <3 persons; two sites with 3+ persons.

Further comparisons

The mean effluent BOD_5 of nearly 40 mg/l coupled with standard deviation of 38.5 for the Orenco Advantex AX-20 systems is somewhat troublesome (fig.6, table 4),although a Colorado study found similar excursions (Wren et al., 2004). There was a sixth Advantex system serving a large household from which four rounds of samples were collected, but when the system's poor results were blamed on an air intake buried by snow, that data was dropped from analysis. The means for Ax-6 are included in Table 9. The DO measurements don't reflect a problem with air flow. Effluent from the Alaskan systems has much higher BOD_5 than test data from most other sites, but the ratio of variance within sites to variance between sites was similar to that found by Groves et al.(2005) in their analysis of Lapine, Oregon Advantex demo sites' BOD_5 data(ratios of 0.33 for Alaska, 0.29 for Oregon). This bears some semblance of correlation in that regard (table 11).

Table 11, Orenco Advantex AX-20 system between and within site variance compared to an analysis done on AX-20 test systems in Oregon by Groves, et al (2005). Between site variance is average variance among sites.

location	variance	BOD_5	TSS	NO_3	TN
Ax AK sites	between	1266.83	98.76	74.10	140.02
	within	417.0	45.3	11.3	105.5
Ax OR sites	between	100.9	49.1		
	within	29.1	7.2		

If Advantex sites 1 and 5 whose BOD_5 means seemed abnormally high (56 and 96 mg/l respectively), are removed from analysis, the BOD_5 and TSS means from the other 3 sites become very close to that of published studies mentioned in figure 11.

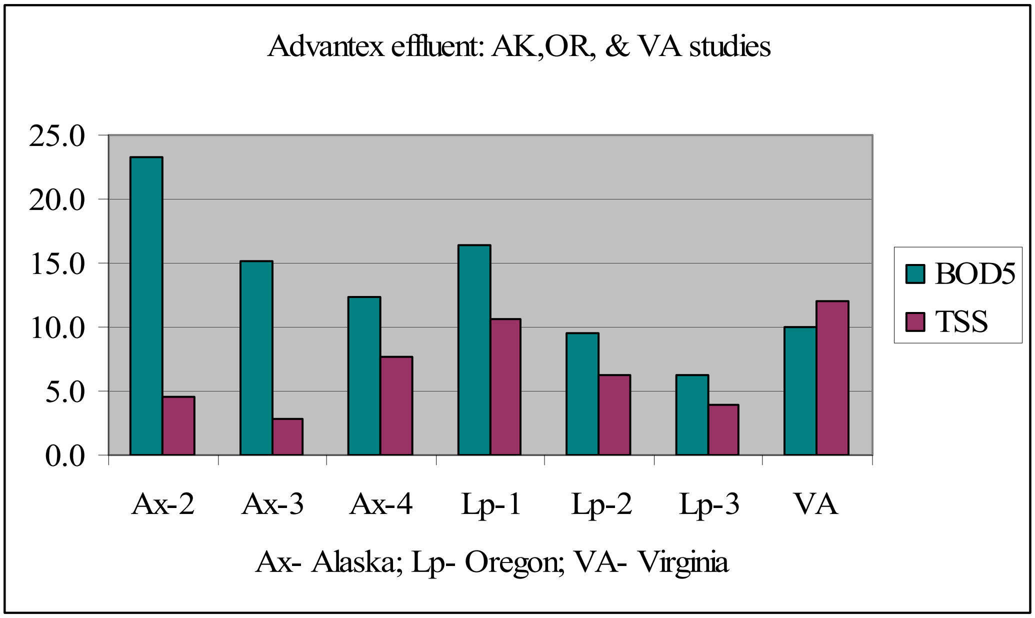

Figure11. Individual site mean effluent BOD and TSS from Advantex systems in Alaska, Oregon, and Virginia. Ax-2, Ax3, and Ax-4 from present Alaska study; Lp-1 to Lp-3 are sites used in Oregon demonstration tests, and VA is means of sites used in Virginia tests. Oregon data are from Orenco, 2005; Virginia data are from Gross, 2005.

As shown in figure 7 on page 24, the total nitrogen in the various system effluents is quite similar. Means range from 26.0 to 31.4 mg/l, with the exception of TN mean of 40.3 for the ISF's which is as expected. Table 7 on page 26 lists the mean TN from Advantex effluent as slightly lower than all other systems tested, although it has the largest spread with both highest and lowest TN measured. Notice the fine comparison by Reactex in the mix as well, with the lowest median effluent TN at 23.9 mg/l. An analysis of variance for the four system types excluding ISF gives a low F value (0.52) and high p value (0.66) indicating relatively small statistical difference for effluent total nitrogen among effluent data from these four systems (see ANOVA in Appendix C-6).

Percent removal

Sampling of septic tank effluent upstream of the secondary treatment to get an idea of system reduction of constituents proved to be problematic, as mentioned in the Methods section. By averaging the few influent samples collected and rounding slightly toward expected values from the Municipality of Anchorage information and other published figures (Municipality of Anchorage, 2003; USEPA, 2002), percent reduction was calculated and presented in figure 12.

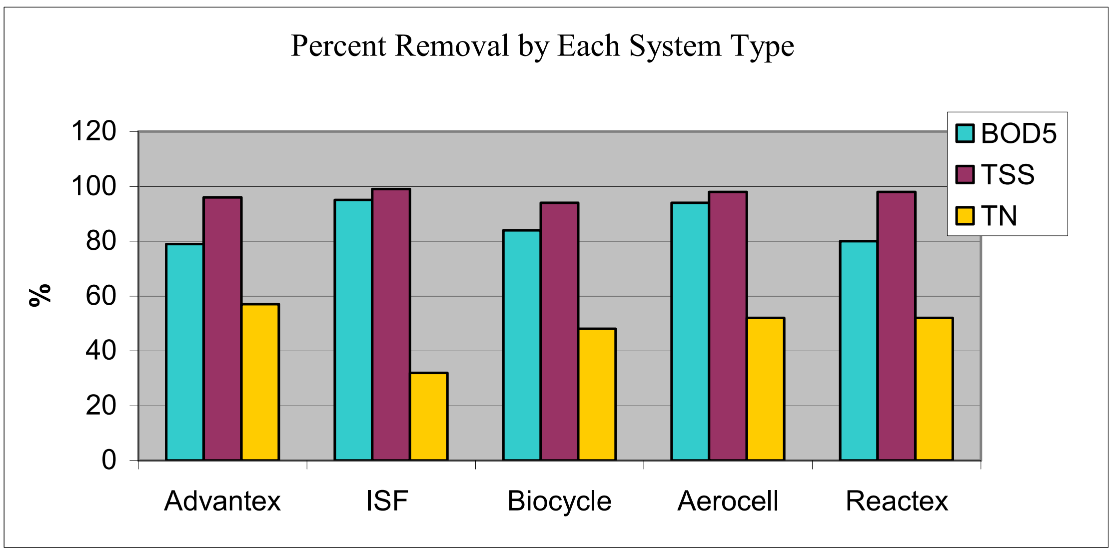

Figure 12. Percent removal of wastewater constituents by onsite systems tested using typical septic tank effluent values: BOD_5 = 200 mg/l, TSS = 300 mg/l, TN = 62 mg/l.

Designated performance limits

Each of the types of system tested has been certified by the Municipality of Anchorage's Onsite Wastewater Treatment Regulatory Board to meet certain effluent limits. Intermittent dosing sand filters and Biocycle aeration tanks have Category II ratings, specifying a monthly mean BOD_5 and TSS not exceeding 40 mg/l, and yearlong mean not exceeding 30 mg/l. Orenco's Advantex AX-2 system has Category III with nitrogen reduction rating, and Quanic's Aerocell has been approved for Category III/ TN reduction rating as well (Municipality of Anchorage, 2003). A Category 3 rating is analogous to the NSF/ ANSI Class 1 certification. Appendix D-2 gives additional information from the Wastewater Disposal Code used by the Municipality of Anchorage. Table 12 lists the percent of samples from each system type meeting specified limits, and also the percent of Advantex, Aerocell, and Biocycle site means meeting those limits.

Table 12, Percentage of total means from each system type tested meeting specified Municipality of Anchorage onsite wastewater treatment limits. All category limits in mg/l. "% site means" is the percent among sites whose mean met the indicated limit. If the overall system type mean meets MOA limits, it is indicated.

System	Cat 2	Cat 3/ N reduction	duration	BOD5	TSS	TN
Biocycle	< 40		month	90%	95%	
Biocycle	<30		year	74%	95%	
Biocycle		<20	month	58%	80%	
Biocycle		<10	year	32%	70%	
Biocy % site means		<20/ TN <30	month	60%	60%	60%
Biocycle mean	<30		year	yes	yes	
ISF	<30		year	100%	100%	
ISF		<20	month	92%	100%	
Reactex		<20/ TN <30	month		90%	66%
Advantex		<20/ TN <30	month	46%	77%	60%
Advantex		<10/ TN <20	year	15%	65%	40%
Ax % site means		<20/ TN <30	month	40%	60%	60%
Advantex mean		<20/ TN <30	month	no	yes	yes
Aerocell		<20/ TN <30	month	100%	100%	51%
Aerocell		<10/ TN <20	year	54%	77%	32%
Aero, % site means		<20/ TN <30	month	100%	100%	60%
Aerocell mean		<20/ TN <30	month	yes	yes	yes

Conclusions

The uneven results of advanced treatment systems tested were difficult to attribute to any single factor. Groves et al. (2005) expressed it well: “There are simply too many variables inherent with how each field system is operated and maintained, and how each system is independently and differently loaded.” Outside temperature seemed to play only a small role in onsite treatment effectiveness. Number of persons in the household was a significant influence on average, although Ax-5, the Advantex system that performed the worst had only two persons using a system sized for three or four bedrooms. There are several possible factors not investigated which could confound the study results: disposal of garbage, hair, chemicals, drugs, etc. into the system. Use of chlorine bleach did not seem to definitely affect system treatment, based on knowledge of which households used it. Since these are likely to be added sporadically, determining impact would require more frequent system sampling accompanied with interviews and water usage measurements. Maintenance is always stressed as vital to wastewater system treatment, but the Reactex systems functioned amazingly well despite age, neglect, and abuse (e.g., addition of chlorine bleach). Certainly the excellent performance data for the Aerocells, some Advantex, and some Biocycle systems might be attributed to regular maintenance and monitoring. Figure 11, showing percent reduction, illustrates that overall the advanced treatment systems certified for use by Anchorage, Alaska households are extending absorption soil area life, reducing necessary drainfield footprint, and maintaining aquifer quality. Effluent means for total nitrogen were acceptable, considering the winter-spring sampling period. However, none of these systems was actually submitted to a yearlong certification test period.

There is some question whether the system types tested could meet the certification limits if subjected to the twelve monthly samples required by the yearlong test cycle. Tables 9 and 10 on pages 30 and 31 show that while these systems are sized for a household of up to six or eight, if we use data from only those households having three or more people, the mean effluent concentrations for Advantex and Reactex systems rise well above the Municipal limits.

Recommendations

The results of this study imply that adequate performance of advanced onsite treatment systems should not be taken for granted. Scrutiny of all phases of design, installation, operation and maintenance must continue in order to sustain the reputation and performance expectations of these technologies. In most cases a chronic poor performing system can be suspected by odor and clarity of samples collected during routine inspection and maintenance. Onsite analysis of pH and dissolved oxygen can give further evidence as to whether the system is functioning properly or requires attention. Further analysis will help identify problems and steps then taken by involved parties to resume expected treatment level.

The Anchorage Hillside District Plan currently being revised contains many revisions to municipal onsite code which will certainly improve onsite wastewater treatment in general. A Groundwater Protection plan encourages increased analysis of well water samples which will aid in locating sources of contaminants, such as malfunctioning or inadequate wastewater treatment systems.

The percent of systems and samples which didn't meet municipal certification limits in table 12 should be a reason for the Anchorage Onsite Technical Board to discuss whether a yearlong recertification for all ATS's is warranted to ensure groundwater protection. Table 12 data also suggests that a revisit of the Category III numbers is called for to determine whether the limits are attainable under Alaska's conditions. A review of the data in table 2, page 10, lists test results from other states that wouldn't have met Anchorage's Category III limits.

The ATS effluent means associated with larger households shown in figures 9 and 10, should raise questions about whether they are capable of servicing households of 5 or more people.

The University of Alaska needs to offer graduate and undergraduate students more exposure to onsite wastewater treatment methods, options, and analysis.

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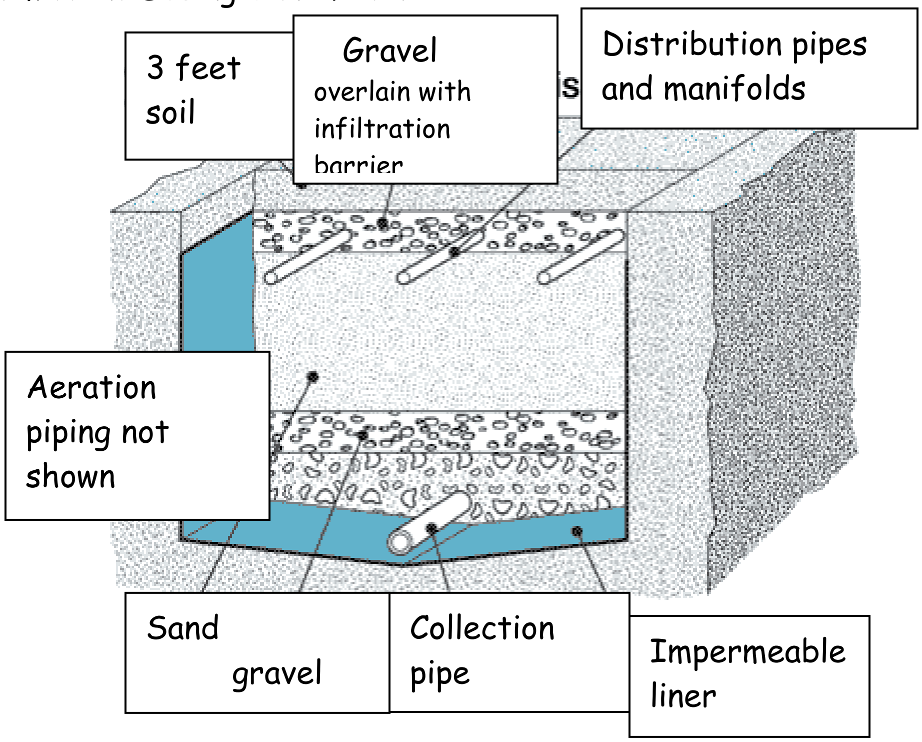
Appendices 44

Map of Anchorage Alaska, showing study area and position on the earth.

Intermittent Dosing Sand Filter



ISF diagram, adapted from Converse and Converse, 1999.

Description of intermittent dosing sand filter wastewater treatment systems

The Intermittent Dosing Sand filter or ISF, has been in use for over a century. Installation of ISF's depends on availability of suitable sand with appropriate particle size and purity. The dosing rate is usually about 12 gallons/ hr and 2 gallons/ sq. ft/day and is controlled by a timer at the STEP tank pump chamber, and preferably with high water level alarm and low water level shutoff. In Alaska the ISF is underlain with aeration tubes through which air from the house's crawlspace air is pumped to maintain aerobic conditions. The pit might be lined with an impermeable liner, usually concrete or PVC sheeting. Some ISF systems are constructed to rest on the receiving soil, known as "bottomless", so the effluent is allowed to drain into the underlying soil strata.

Description of trickling filter wastewater treatment systems

The package units for onsite domestic wastewater treatment include recirculating trickling filters or RTF's, also known as a packed bed filter. Those currently being installed in Anchorage are the Advantex by Orenco Systems, and Aerocel, manufactured by Quanics Incorporated. Those RTF systems having a modem and alarm are well liked by Anchorage regulators because accurate and reliable monitoring of system operation is possible and maintenance can be timely and straightforward. These units undergo considerable testing, by the manufacturer and third party laboratory particularly NSF International, (formerly the National Sanitation Foundation,) to obtain NSF/ ANSI certification. The goal for most is to meet Class 1 criteria, which is advanced secondary treatment.

In a RTF, the septic tank effluent is sprayed over the top of and trickles through the media which provides a substrate for bacteria to adhere. This media is generally synthetic, such as the closed-cell foam in the Aerocel and Waterloo units, or geotextile fabric, as in the Advantex. Fine gravel, coarse sand, ground glass, or slag can also be used as media, in which case the system might be labeled a recirculating sand(gravel) filter(RSF, RGF). Tests on RTF's have shown excellent reduction of nitrate and total nitrogen. The reduction of TN can be enhanced if the system is set up to recirculate back to the front of the septic tank, which provides a carbon source for denitification. The Advantex and Reactex systems tested in this study operate in mode 1, meaning the filter effluent is recirculated to the second chamber of the septic tank.

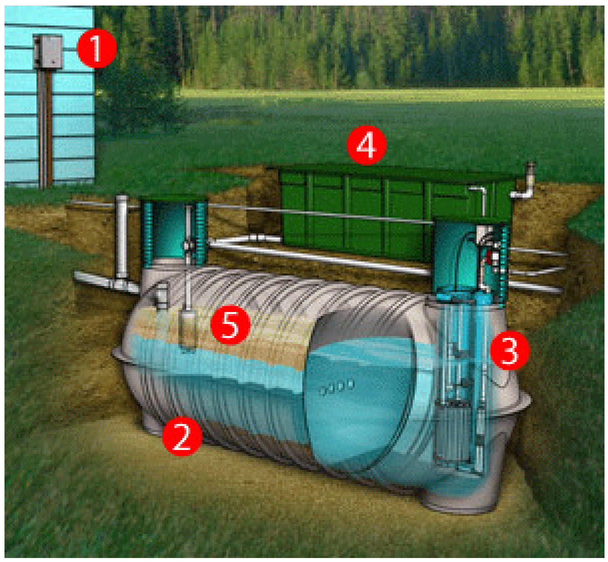
Manufacturer addresses:

Advantex and Reactex: Orenco Systems, Inc., 814 Airway Ave, Sutherlin, Oregon, 97479

Aerocell: Quanics Inc., P.O. Box 1520, 6244 Old LaGrange Road, Crestwood Kentucky, 40014.

Waterloo Biofilter Systems Inc., P.O. Box 400, 143 Dennis Street, Rockwood ON, N0B 2K0

Orenco Advantex diagram. Other trickle filters are similar.



1. electrical controls, alarm, and modem
2. septic tank
3. dosing pump vault
4. trickle filter
5. recirculating valve (mode 3)

From Orenco brochure: www.orenco.com

Orenco Advantex AX-20 trickle filter with lid lifted.
Riser to left is septic tank pump-out port.
Upright at lower right is air intake.
Manhole to right of filter is recirculation vault.
Manhole beyond is collection vault prior to release.

Quanics Aerocell open cell foam media, showing that discoloration on top layer does not extend downward.

Reactex trickle filter distribution manifolds and media.

NOAA Regional Climate Center data for Anchorage Alaska:
Monthly Totals/Averages

Avg. Maximum Temperature (degrees F)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2007-2008	40.8	35.0	23.6	18.3	23.7	37.1	42.1	55.4	58.9
1971-2000 avg	40.0	27.7	23.6	22.2	25.8	33.6	43.9	54.9	62.3

Avg. Minimum Temperature (degrees F)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2007-2008	30.2	26.2	14.4	8.0	9.7	24.0	25.8	38.0	45.5
1971-2000 avg	28.5	16.1	11.6	9.3	11.7	18.2	28.7	38.9	47.0

Average monthly Temperature (degrees F)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2007-2008	35.5	30.6	19.0	13.1	16.7	30.6	33.9	46.7	52.2
1971-2000 avg	34.3	21.9	17.6	16.0	19.0	26.1	36.5	47.1	54.9

Snow Depth (inches)

Yr 2007-2008	Oct	Nov	Dec	Jan	Feb	Mar	Apr
	0.1	2.3	2.8	9.8	13.7	9.2	3.3

http://www.nws.noaa.gov/climate/xmacis.php?wfo=pafc

Sampling procedure for collection from advanced onsite wastewater treatment systems, January to June of 2008.

The Aerocell, Reactex, and lined ISF systems had sample ports.

Collection was made w/ ladle (1 L bottle attached to end of telescoping rod;)or a 1 ft piece of pvc pipe, capped, on a rope, lowered into pipe if the diameter was too narrow for the ladle.

In the Biocycle aerated tank systems, effluent collections were made by dipping out of the 4th chamber.

The Advantex units required uncoupling the discharge line in the pump vault if there is no pipe draining into pump chamber. All AX-20 systems included in analysis had this bare pipe from which sample was caught in the ladle. If possible, the sample is collected without using recirc switch. Some have a continuous dribble, others require holding the recirc switch down for 15-20 sec.

Two 1 liter poly bottles were filled and put in an insulated chest toprotect from freezing in winter, keep cool in warmer weather, using ice packs if necessary. Sample temp needs to be in 1-8 degrees C range short term, 1-4 degrees C if delay of over 2 hr.

If possible measurements of pH, temperature, and DO were taken at the site.

Lab procedure for wastewater analysis

The samples arrived at the lab within 2 hous, and never held for more than 3 hours before starting lab work.

First 40 ml of sample was transfered to a 100 liter poly bottle and 3 drops sulfuric acid added to preserve for later batch TN analysis. These are kept in refrigerator. It was reported in procedures that freezing these samples without adding acid is OK, but side by side TN test results didn't come out similar.

BOD_5 procedure

The dilution water must be chilled or fresh distilled water, or boiled and cooled distilled water if it has been in a jug at room temperature for more than a day. Early on it was discovered that distilled water kept in a jug at room temp had a BOD_5 of 5-10 mg/l. There are four chemical solutions described in Standard Methods that must be mixed up and added to the dilution water. I keep the dilution water in a brown 2.5 L jug, chilled. The solution is brought to room temperature at the time of use, and shaken repeatedly to aerate.

BOD dilution for treated effluent must be estimated and adjusted based on previous results. It was necessary to process four dilutions per sample (4 BOD bottles.) If BOD_5 is higher than 40, the dilution is 4%, 6%, 8%, and 10%.

If under 30, then the range is 20-36%. Sometimes it was discovered that the dilution is too strong until after running the first test. If the final DO is 0.4 mg/l or less, the results are not useable. It is usually possible to predict dilution percentage based on sample odor and clarity. After carefully measuring sample into 300 ml BOD bottle, fill with dilution water to near the top, but allowing for DO probe immersion without overflowing bottle. A magnetic pellet is put in bottle, place bottle on stirrer, and insert calibrated DO probe. After sample is measured, retrieve magnet with magnet rod, handling with tweezers to place in next bottle. Tools must be rinsed with distilled water before using in next sample series. BOD bottle is filled to near top with dilution solution and stoppered. The bottles are then placed in a bath. It was unnecessary to turn on water bath heater; room temperature kept bath at 21 degrees.

5 days later, just measure DO in bottles, while stirring with magnetic pellet, then empty and wash.

Then TSS analysis was performed, following Standard Methods.

Nitrate and total nitrogen analysis

Nitrate analysis was done using reagent TNT 836 and DR 2800 Spectrophotometer, from Hach Lab Supplies.

TN was measured using reagent TNT 828 and DR 2800 Spectrophotometer, from Hach Lab Supplies. Acidified samples were kept chilled up to 3 weeks, then neutralized with NaOH prior to analysis. Standard Methods says that acidified samples may be stored in refrigerator up to 4 weeks. Sample tubes were heated 1 hour in a COD reactor.

The TNT 828 reagents include azide, which requires special disposal procedure.

Lab procedure quality control: comparison of means from same samples to SGS Environmental lab results for Aerocell certification.

Lab	# samples	BOD_5	TSS	NO_3	TN	TKN
SGS Env	30	10.5	6.7	23	29.8	6.8
EW	10-19	10.1	5.0	21.1	27.2	6.1

Wastewater treatment reactions

Carbonaceous bacteria consumes waste in wastewater for tissue maintenance and growth. This oxidation is represented in the following generalized reaction:

$COHN + 0_2 \rightarrow CO_2 + H_2O + NH_3$ + end products and energy.

COHN represents basic elements in wastewater.
The BOD_5 procedure measures the amount of oxygen used in this reaction in a 5 day period.

Hydrolysis of proteins produces ammonia which goes through the following series of reactions to ultimately be released as nitrogen gas.

Nitrosomonas bacteria converts ammonia to nitrite:

$NH_3 + 0_2 \rightarrow HNO_2 + H_2O$,

Followed by *Nitrobacter* converting nitrite to nitrate:

$HNO_2 + 0_2 \rightarrow HNO_3 + H_2O$.

Further processing of the nitrate in wastewater requires addition of an electron donor. In the case of the trickle filters addressed in this study, this source is carbon accessed by recirculation through the septic tank. The anaerobic environment there allows the nitrate to accept electrons with the end product being nitrogen gas:

$COHN + N0_3 \rightarrow N_2 + CO_2 + H_2O + NH_3$

From Metcalf & Eddy, 2003

analysis of variance (**ANOVA**) tests means from more than 2 sets of independent samples.

The ANOVA produces an F statistic, the ratio of the variance among the means to the variance within the samples.*The higher F is, the greater the difference in variance among sites than within sites.*

- If the group means are more spread out compared to how spread out the individuals are, then conceptually, the means are significantly different from each other.

BOD for household sizes shows high and nearly = F value between 2 size categories.

Analysis of Variance (ANOVA) Input Alaska study TN Data

system	**N (count)**	**Mean**	**Std. Dev.**
Aerocell	38	29.4	11.6
Advantex	30	26	17.4
Reactex	19	29.3	21
Biocycle	22	31.4	14.5

Source of variation	Sum of squares	d.f	Mean square	F statistics	p-value[1]
Between Groups	402.072	3	134.024	0.539	0.66
Within Groups	26112	105	248.686		
Total	26514.1	108			

	Chi square	d.f	p-value
Test for equality of variance	10.1285	3	0.0175

system	Mean	95% CI of individual sample mean range	95% CI assuming equal variance range
Aerocell	29.4	25-33	24-34
Advantex	26	19-32	20-32
Reactex	29.3	19-39	21-37
Biocycle	31.4	25-38	24-38

Analysis of Variance (ANOVA) TSS data

system	N	Mean	St Dev
Aerocell	38	6.3	3.2
Advantex	26	12.5	10.6
Reactex	20	7.3	24.6
Biocycle	22	17.8	22
ISF	13	2	3

Source of variation	Sum of squares	d.f	Mean square	*F*=	P=
Between Groups	2966.7	4	741.674	3.39	0.012
Within Groups	24957.9	114	218.929		
Total	27924.6	118			

	Chi square	d.f	p-value[1]
Test for equality of variance	130.553	4	0.000000000066

		95% CI of individual sample mean		95% CI if equal variance
Group	Mean	range	Upper Limit	range
Aerocell	6.3	5.3-7.3	7.35181	1.4-11
Advantex	12.5	8-17	16.7815	6.5-18
Reactex	7.3	-4-18	18.8131	0.4-14
Biocycle	17.8	8-27	27.5542	11-24
ISF	2	0.2-3.8	3.81287	7-11

Two-Sample Independent *t* Tests

Input BOD5 Data from 2 household categories,
means are avg of independents using data from table 8, p.31

Household size	**Sample size**	**Mean**	**Std. Dev.**
<3 persons	25	21.1	10.3
3+ persons	71	30.4	18.9

2-sided 90% conf. interval

Result	t =	*df*	P=	Mean Dif	range
= variance	2.33	94	0.0216	9.3	2.7-15.9
Unequal variance	3.05	77	0.003	9.3	4.2-14.4
		F =		*df*	P=
Test for equality of variance		3.36		70,24	0.0015

Two-Sample Independent t Test

Input BOD5 Data from 2 household categories:
Households <3 w/o Ax5 or ISFs; households 3+ w/o ISFs.

Household size	**Sample size**	**Mean**	**Std. Dev.**
<3 persons	31	21.8	12.5
3+ persons	71	24.7	23.3

2-sided 90% conf. interval

Result	*t* statistics	*Df*	p-value[1]	Mean Dif	range
= variance	0.65	100	0.52	2.9	-4.4-10.3
Unequal variance	0.81	96	0.42	2.9	-3-8.8

T test comparing household size categories

Advantex systems' effluent BOD5: households having less than 3 vs. those with 3 or more.

	Sample size	Mean	Std. Dev.
Ax <3	15	19	48
Ax 3+	13	39	26

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Diff**	**Lower and Upper Limits**	
Equal variance	1.339	26	0.19	20	-5.5	45.5
Unequal variance	1.395	22	0.18	20	-4.6	44.6

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	3.40828	14,12	0.0397027

[1] p-value (two-tailed)

T test comparing household size categories

Biocycle systems' effluent BOD5: households having less than 3 vs. those with 3 or more.

	Sample size	Mean	Std. Dev.
Biocycle <3	9	15	5.6
Biocycle 3+	11	30	24.2

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Difference**	**Lower and upper Limits**
Equal variance	1.81178	18	0.087	15	0.6 to 29.3
Unequal variance	1.99162	11	0.072	15	1.5 to 28.5

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	18.6747	10,8	0.00035

[1] p-value (two-tailed)

T test comparing household size categories. Reactex systems' effluent BOD5: households having less than 3 vs. those with 3 or more.

Two-sided confidence interval	90%		
	Sample size	**Mean**	**Std. Dev.**
<3	12	29	10.2
3+	8	49	21.5

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Difference**	**Lower and**	**Upper Limits**
Equal variance	2.80893	18	0.01	20	7.6	32.3
Unequal variance	2.45346	9	0.04	20	5.1	34.9

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	4.443	7,11	0.03

[1] p-value (two-tailed)

T test comparing household size categories

Advantex systems' effluent TN: households having less than 3 vs. those with 3 or more.

	Sample size	**Mean**	**Std. Dev.**
Ax <3	15	20.5	13
Ax 3+	16	38	18

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Difference**	**Lower and**	**Upper Limits**
Equal variance	3.0847	29	0.0044	17.5	7.9	27.1
Unequal variance	3.11722	27	0.0043	17.5	7.9	27.1

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	1.91716	15,14	0.23

[1] p-value (two-tailed)

T test comparing household size categories.
Reactex systems' effluent TN: households having less than 3 vs. those with 3 or more.

Two-sided confidence interval	90%		
	Sample size	**Mean**	**Std. Dev.**
Group-1	11	36	5.2
Group-2	7	43	22

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Difference**	**Lower and Upper Limits**	
Equal variance	1.028	16	0.32	7	-4.9	18.9
Unequal variance	0.83	6	0.44	7	-9.5	23.4

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	17.9	6,10	0.0002

[1] p-value (two-tailed)

T test comparing household size categories.
Biocycle systems' effluent TN: households having less than 3 vs. those with 3 or more.

	Sample size	**Mean**	**Std. Dev.**
Group-1	9	22	5.7
Group-2	13	36	16.2

Result	***t* statistics**	***df***	**p-value[1]**	**Mean Difference**	**Lower and**	**Upper Limits**
Equal variance	2.47285	20	0.02	14	4.2	23.8
Unequal variance	2.86986	16	0.01	14	5.5	22.5

	***F* statistics**	***df*(numerator,denominator)**	**p-value[1]**
Test for equality of variance[2]	8.07756	12,8	0.00622685

http://www.openepi.com/Menu/OpenEpiMenu.htm

correlation coefficients comparing BOD_5 to TSS.
As cor.coeff. approaches +1, it indicates stronger positive correlation.

	Corel. Coeff.
Advantex	0.75
Aerocell	0.40
Biocycle	0.90
Reactex	-0.01
ISF	-0.15

Test data Standard Error (SE), Coefficient of Variation(CV), Standard Deviation (SD)

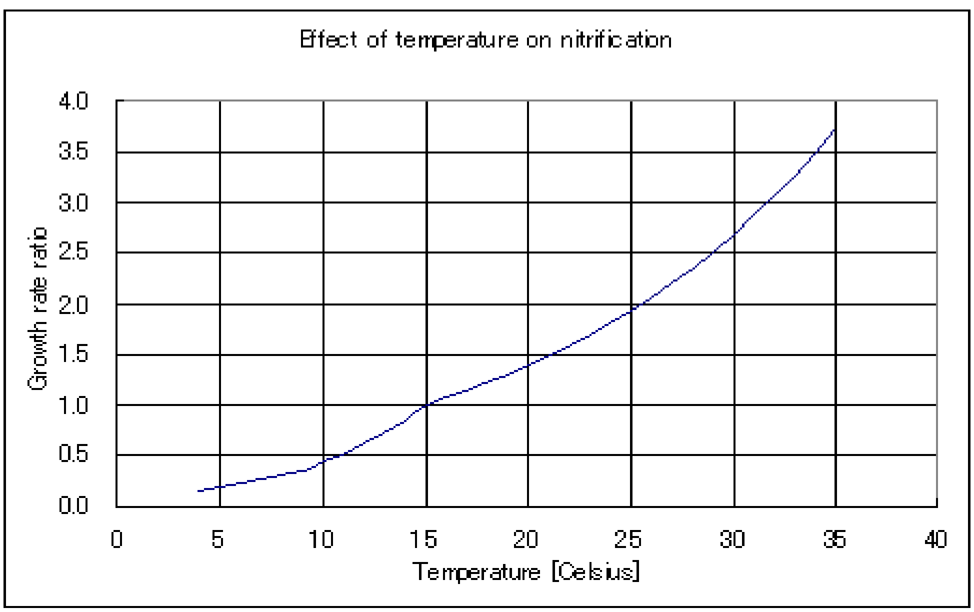
System type, test	SE	CV	SD
Advantex BOD_5	7.56	1.0	38.5
Advantex TSS	2.08	0.8	10.6
Advantex TN	3.17	0.7	17.4
Aerocell BOD_5	0.89	0.53	5.5
Aerocell TSS	0.50	0.51	3.2
Aerocell TN	1.67	0.39	11.6
Biocycle BOD_5	3.20	0.65	13.97
Biocycle TSS	2.48	0.96	10.80
Biocycle TN	3.09	0.46	14.51
Reactex BOD_5	4.27	0.51	19.07
Reactex TSS	5.51	1.50	24.63
Reactex TN	4.95	0.72	20.99
ISF BOD_5	1.54	0.61	5.56
ISF TSS	0.86	1.65	3.09
ISF TN	2.41	0.20	7.99

D-1

System type	#sites /#samples	Temp ◦C	TN/ median or % removal	NO_3	BOD_5	TSS
Reactex[1]	1/15	7.0	54/ 26%	43	5	2
RSF[2]		>20	17	13		
		<5	20	12		
ISF[3]	47/1	6	81/36	65	6	4
	47/1	18	41/ 38	33	3	3

Temperature effects on packed bed trickling filters
[1]McCarthey et al., 2001; [2]Urynowicz, 2007; [3]Converse & Converse, 1999.

D-2



Effect of temperature on population growth rate of nitrifying bacteria.
From Geyser Pump Tech. Co., 2007.

D-3

Municipality of Anchorage selected portions from building code.
Chapter 15.65 WASTEWATER DISPOSAL
PART III. ADVANCED WASTEWATER TREATMENT STANDARDS
15.65.300 Baseline system standards.
A. A passive dual compartment septic tank, …. should have anticipated effluent concentrations …
1. CBOD5 . . . 300 mg/l.
2. TSS . . . 250 mg/l.
3. TN . . . 60--80 mg/l.
4. TP . . . 15 mg/l.
5. Fecal Coliform--1.5× 106 col./100 ml.

15.65.310 Category I, Wastewater Treatment Standards.
A. A Category I system design (type) using advanced treatment technology is a system
which fails to meet the requirements of a Category II system.
15.65.320 Category II Standards
15.65.330 Category III Standards
15.65.340 Nitrogen reducing system Standards

Cat. II parameters:	Yearlong (12x)	Monthlong (4x)	Weeklong (7x)
$CBOD_5$ & TSS	30 mg/l	40 mg/l	45 mg/l
Fecal Coliform	50,000 col/ 100 ml	75,000 col/ 100 ml.	100,000col/ 100 ml.
Cat. III parameters:			
$CBOD_5$ & TSS	10 mg/l	20 mg/l	30 mg/l
Fecal Coliform	10,000 col/ 100 ml	20,000 col/ 100 ml.	30,000col/ 100 ml.
N reducing system	20 mg/l	30 mg/l	40 mg/l

ISF sites

Site	date/2008	time	BOD5	TSS	NO3	TN	TKN	pH	temp,C	DO
ISF-5	1/26	1430	10.5	1	25.3	26.3	1	7.3	1	
ISF-5	2/17	1300	3.6	3	31.6	39.2	7.6	7.2		9.8
ISF-5	2/27	930	21.20	1.2	15.2	34.5	19.3	7.1	4	9.6
ISF-6	2/2		2.3	0.2	57.6	48.6		6.9		
ISF-6	2/12		5	11.8	35.1	37.8	2.7	7.3	3	6.8
ISF-6	2/22		6	0.4	34.9	40.9	6	5.2	4	9.8
ISF-6	2/28	1000	3.6	0.3	24.1		-24	6.2	3	10.5
ISF-6	3/21	1000	10.6	0.3	29.7	41.8	12.1	7.3	3	9.6
ISF-7	1/28	830	8	0.5	32.9			7.8	1	
ISF-7	2/14	1200	15.5	1.7	37.4	51	13.6	7.1	4	6.4
ISF-7	2/22	1130	13.9	2	36.5	43.4	6.9	5	3.8	7.6
ISF-7	2/28	1130	14	1	23	50.7	27.7	5	5	4.2
ISF-7	3/21	930	9.6	1	20	30.4		6.8	3.5	6.9

Advantex										C-2
	date /2008	time	BOD5	TSS	NO3	TN	TKN	pH	temp,C	DO
Ax-2	5/12	1130	28.3	8.2	17.5	27.1	9.6	6.8	10.5	6.1
Ax-2	5/19	900	40.4	6	23.2	30.2	7			
Ax-2	5/28	900	25	4.8	26.6	35.1	8.5	7.1	10	6.8
Ax-2	6/4	1030	6.7	1.8	17.8	21.6	3.8	7.2	9.7	5
Ax-2	6/19	1330	16.2	1.6	33.4	35.3	1.9	6.7	13	4.8
Ax-3	5/12	1130	13.2	2.5	8.4	15.2	6.8			
Ax-3	5/19	900	15.5	2.7	7.9	15.5	7.6			
Ax-3	5/28	1000	27.1	3.8	12.6	17	4.4	7.2	12	4.6
Ax-3	6/4	1030	8.8	2	13.5	21.9	8.4	7.7	13	5.3
Ax-3	6/19	1330	10.8	3.2	9.7	14.5	4.8	7.2	13.5	3.2
Ax-4	5/12	1200	6.3	0.8	9.7	12.6	2.9			
Ax-4	5/19	930	17.4	6.9	5.7	12.6	6.9			
Ax-4	5/28	900	15.3	17.1	5.7	9.9	4.2	7.1	7	6
Ax-4	6/4	1000	13.3	10.7	4.2	11.1	6.9	7.7	8	8.3
Ax-4	6/19	1300	9.1	2.9	4.5	9.2	4.7	6.9	9	2.8
Ax-5	5/12	1200	57.4	31.2	1.4	49.9	48.5			
Ax-5	5/19	930	118	28.7	0.3	51.1	50.8	5.5		
Ax-5	5/28	900	165	27.1	0.3	28.1	27.8	6.5	14	1.5
Ax-5	6/4	1000	54	8.2	0.4	11.7	11.3	6.8	9.4	1.5
Ax-5	6/19	1300	88	11.1	0.4	20.2	19.8	6.4	13	0
A1ef-1	3/19/2008	900	45	18.2	11.7	25.3		7.2	6	7
A1ef-1	3/26/2008	1100	16	11	22	73.1		6.8	7	8.7
A1ef-1	4/2/2008	1000	72	28.3	14.2	81.5				
A1ef1	4/8/2008	1130		12.3	14.7	32.1				
A1-1	6/20/2008	1030	77	22.5	7.7	25		6.8	12.5	5.5
A1-1	6/26/2008	900	94	52.3	4.3	34.1		6.7	14	2.8
A1ef-2	3/19/2008	900		25.2	9.4	21.9				7.1
A1ef-2	3/26/2008	1100	23	26.8	11.4	28.1				
A1ef-2	4/2/2008	1000	51	25.8	16.7	39.2		7.1	7	3.1
A1ef-2	4/9/2008	1130	48	24.3	9.5	32		7.1	5	5.7

Reactex

Site	date/2008	time	BOD5	TSS	NO3	TN	TKN	pH	temp,	DO
Rx3	2/21	1230	67	8.5	0.1	54	53.9	5.5	10	1.3
Rx3	2/27		76	11	66	54.3		6.3	10	1.1
Rx3	3/16	1500	61	19	0.6	69.6	69	6.5	8.5	1
Rx3	4/2	1130	41.7	17	0.1	75	74.9	7.1	7.7	1.6
Rx3	4/10	1000	86	9.6	0.03	67.1	67.07	6.9	8	2
Rx6	3/16	1400	40	7.5	3.6	28.9	25.3	6.7	7	0.9
Rx6	3/26	1130	22.7	4.6	1.3	24.5	23.2	6.8	6	2.1
Rx6	4/2	1100	21.8	5.5	0.7	27	26.3	7.5		2.5
Rx6	4/8	1030	40	3.5	0.5	22.1	21.6	7.3	5.5	2.3
Rx6	4/10	1100	38	5.6	0.3	22.7	22.4	7.5	6	2.5
Rx5	2/14		52	77	0.3	23.7	23.4	6.9	8	1.6
Rx5	2/6	1300	34	16	0.2			7.1	5	3.2
Rx5	2/27	1000	23	96	0.1	20	19.9	6.4	6	0.9
Rx14	2/8	1200	22	2	0.4	24.1	23.7	7	4	2
Rx14	2/21	1130	14	2	1.2	17.4	16.2	4.4	8.5	0.8
Rx22	2/14		39	11	0.2	12	11.8	6.8	8	3.2
Rx22	2/7	1100	28	9.1	0.2			7.2	6.5	3.3
Rx22	2/22	1100	41	9.2	1.5	14.7	13.2	5.2	7.5	2.6
Rx22	2/28	1100	32	5.5	2	13.8	11.8	6.1	6	1.7
Rx22	3/19	1000	47	8.7	1	16.9		6.8		2.1

Quanics Aerocell data

											C-4
Q1	date/2(	time	Lab	BOD5	TSS	NO3	TN	TKN	FC	pH	temp,C
Glenview N											
Lt5 Blk2	12/12	900	SGS	7.1	5.9	30.3	39.5	9.2			
	1/11	900	SGS	5.5	10.3	35.2	45.2	10			
	1/12	2230	SGS	11.5	6.8	31.3	42.8	11.5			
	1/13		SGS	8.6	9	33	43.4	10.4	43.4		
	1/14		SGS	9.5	7.4	18.4	29.3	10.9	29.3		
	1/15		SGS	12.6	7.2	24.8	38	13.2	38		
	1/16		SGS	7.5	8	33.6	45	11.4	45		
	1/17		SGS	22.5	8.6	35	47.5	13.5	48.5		
	1/24		SGS	8	7.4	37	49.6	12.6	49.6		
	2/1		SGS	9.7	8	36.3	52	15.8	52.1		
			EW			39.8	55.9	16.1			
			EW				48.1				
			EW				17.6				
			EW			18.8	16.4				
			EW			26.3	45	18.7			
			EW	17		17.5	29.3	11.8	29.3		
			EW	7.6	5.9	19.2	37.3	18.1	37.3		
	1/24		EW	7.2	7.1		32.1	32.1	32.1	5.2	6.7
	2/1		EW	11.5	7.2	39.8	36.8			5	
Q2,											
Fischer	12/12		SGS	13.5	4.6	25.8	29.4	3.6			
Lt3A,Blk1	1/11		SGS	13.8	12.6	16.3	21.4	5.1			
	1/12		SGS	11.4	11.1	16.5	19.7	3.2			
	1/13		SGS	15.2	14	15.4	19.4	4			
	1/14		SGS	12.2	9.4	15	23.7	8.7			
	1/15		SGS	13.3	13	0.3		4.1			
	1/16		SGS	8.6	7.8	14.5	18.4	3.9			
	1/17		SGS	17.7	6.7	15.4	18.6	3.2			
	1/24		SGS	10.3	5.8	14.4	18.8	4.4			
	2/1		SGS	5.7	3.8	10.4	13.5	3.1			
			EW				24.2				
			EW				18.2				
			EW	10.7		29.4					
			EW			11.9					
			EW		6.1	13.4	21.3	7.9			
			EW		4.5	19.1	22.2	3.1			
			EW	13.4	4.9	11.4					
	2/1		EW	5.4	2	2.7	12.2	9.5			

Quanics Aerocell continued

Q3	12/12	SGS	8.6	3.1	15.7	22.4	6.7		
Elmore #1	1/11	SGS	15.4	3.7	25.3	29.4	4.1		
Lt13, Blk6	1/12	SGS	5.8	2.5	27	31.2	4.2		
	1/13	SGS	6.5	2.2	28.4	31.6	3.2		
	1/14	SGS	19.5	5	32.2	35.4	3.2		
	1/15	SGS	6.5	2.3	31.7	35.2	3.5		
	1/16	SGS	6.9	3	19.6	23.1	3.5		
	1/17	SGS	5.5	3.1	18.4	21.9	3.5		
	1/24	SGS	7.5	5.6	16.6	20.4	3.8		
	2/1	SGS	8.5	2.4	14.5	18.9	4.4		
		EW	12			19.7	19.7		
		EW				30.8	30.8		
		EW				32.1	32.1		
		EW			19.4	14.5			
		EW			19.4	24.4	5		
		EW		8.3	31.1				
		EW		dq	10.1	15.6	5.5		
		EW	5.1	1	16.8				7
	2/1	EW	11.3	3	14.9				7.1

Biocycle	date/2008	time	BOD5	TSS	NO3	TN	TKN	pH	temp C	DO	C-5
B1	5/30	900	30.8	28.4	8.7	30.2		7.4		5	
B1	6/5	1100	92	32	14.3	40.3		7.7	14.5	6	
B1	6/20	1200	24.6	15.6	34.3	38.8		6.3		5.7	
B1	6/26	800	35	22.5	6.4	38.8		7.6	15	4.9	
B1	7/11	830	58	25.8	16.7	31		7.3	16	4.7	
B2	5/30	900	17.4	5.3	8.1	19.6		7.4		4	
B2	6/4	930	24.8	5.4	14.3	29.6		8.2	14.5	5.7	
B2	6/5	1100	17.5	5.7	11	33.9		7.4	15	5	
B2	6/20		10	4.7	9.9	17.7		7.3	15		
B2	6/26	800	8.6	7.5	15	19.9		7.6	15	5.3	
B4	6/4	930	44.5	42	0.2	61.6		8.1	12	1.5	
B4	6/20	1230	98	69	0.1	64.1		8	15	3.2	
B4	6/26	830	97	82.8	0.5	58.4		7.7	13	1.8	
B4	7/11	830	36.5	14.1	2.4	36.4		7.7	12	5	
B-3	2/21	1030	14.5	2.2	16.5	21.3	4.8	5.3		7.4	
B-3	2/29	900	8.2	2.8	11.9	21.9	10	7.3	5.5	6.8	
B-3	4/16	800	14	11.4	11.3	18	6.7				
B-3	5/14	900	8	6.6	15.7	27.6	11.9				
B-6	2/29	930	7.8	4.9	6.7	13.3	6.6	6.8	8	6.5	
B-6	2/21	1100	17	4.3	11.1	21.1	10	5.5		7.8	
B-6	4/16	830	10	4.8	6.5	17	10.5				
B-6	5/14	930	22	5.2	5.6	29.8	24.2		9	6.7	