SMALL SCALE WASTE MANAGEMENT PROJECT

Pump Chambers Effluent Quality Following Aerobic Units and Sand Filters Serving Residences

by

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PUMP CHAMBER EFFLUENT QUALITY FOLLOWING AEROBIC UNITS AND SAND FILTERS SERVING RESIDENCES[1]

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ABSTRACT

Pump chamber effluents from 20 single pass, membrane lined, buried sand filters (Unit A), 21 suspended growth media units (Unit B) with vertical fabric filters to retain solids, and 10 suspended growth media units (Unit C) incorporating a septic tank, aeration chamber and settling chamber with a fine mesh screen covering a plate filter to retain solids were evaluated for various wastewater parameters. In addition, three other systems (two Unit Bs and one Unit A) were evaluated individually and not averaged with the above units because the number of samples collected from these three units were considerably greater than from the other units which would have biased the results. All units were full sized serving households. A total of 573 samples were collected by periodically sampling the pump chamber. Samples were also collected from the septic tank pump chamber serving the sand filters. The data were compiled and analyzed for median and average values, standard deviation, and minimum and maximum values for each type of unit.

The median BOD of the pump chamber effluent was 4, 4.4 and 27 for Units A, B and C, respectively. The median and average fecal coliform concentrations were 3 and 280, 530 and 10,000, and 24,000 and 150,000 col./100 mL in the pump chambers serving Units A, B and C, respectively. The median TKN and nitrates were 3.4 and 28, 3.3 and 24, and 40 and 0.9 mg N/L in the pump chambers serving Units A, B and C, respectively. A frequency analysis showed that the pump chamber effluent serving the sand filter (Unit A) provided the most consistent effluent for fecal coliform and BOD concentrations. The sand filter reduced the total nitrogen by about 43 and 34%, based on median and average values, respectively.

INTRODUCTION

On-site wastewater treatment has relied on the septic tank soil absorption unit to treat and disperse wastewater to the environment. With increased interest in rural development, sites suitable for septic tank soil absorption systems, including mounds, are becoming limited, and many of the remaining sites suitable for traditional treatment methods may be of more value to society than rural housing development. From a land use planning perspective, it is essential that numerous on-site treatment technologies be available to meet the needs for most sites and not control land use by restricting the use of these technologies.

With the traditional septic soil absorption system, the soil provides most of the treatment and final dispersal to the environment. With the advent of newer technologies, pretreatment units, such

as sand filters, aerobic units, bio filters and peat filters, provide most of the treatment with the soil providing final polishing and dispersal to the environment. Since the soil's primary function is dispersal and not treatment, the separation distance, from the bottom of the soil dispersal unit to limiting condition, can be less than if it received septic tank effluent (Converse and Tyler, 1997). Also, it may be possible to downsize the soil dispersal unit when using high quality effluent, as clogging mat development is highly unlikely. Thus, design can be based on soil hydraulic conductivity and linear loading rate and not on a clogging mat/soil morphology interaction.

However, before these "newer" technologies can be fully implemented, it is essential that extensive field testing be undertaken to determine how well the units perform under actual operating conditions. Standard 40 (NSF, 1990) was developed to test aerobic units under quasi-field conditions, but actual field conditions can be considerably different. There are no standard testing procedures for other system types such as sand filters and peat filters.

An experimental program was initiated to evaluate the effect of highly pretreated (aerobically treated) effluent on soil absorption units with emphasis on establishing a suitable soil separation distance to adequately polish the treated effluent and disperse the effluent into the soil. The program criteria were that: 1) the units served typical households, 2) effluent is aerobically treated using a sand filter or aerobic units, and 3) effluent is dispersed into a soil dispersal unit such as a shallow in-ground trench, at-grade unit or modified mound. Converse and Tyler (1998) reported on the suitable soil separation for soil dispersal units receiving aerobically treated effluent.

The objective of this study was to evaluate the field performance of single pass sand filters and aerobic units serving households. This paper will concentrate on the effluent quality from single pass sand filters and two types of aerobic units.

METHODS AND MATERIALS

Sampling Procedure

The components of each system consisted of a pretreatment unit, a pump chamber, and a soil dispersal unit. The pretreatment unit was either a single pass sand filter with a septic tank and pump chamber/vault preceding it or an aerobic unit with or without a septic tank/trash tank preceding it. All samples were taken from the pump chamber or from the septic pump vault located in the septic tank. Samples were also taken from the mixed liquor of the aeration units.

No attempt was made to obtain a 24-hour composite sample except that the pump chamber, in essence, served as a sample compositor. The amount of effluent in the pump chamber varied, depending on the time between pump chamber discharge and sampling. Samples were taken by attaching a one-liter plastic bottle to a sampler, inserting it below the surface, and allowing the bottle to fill. Samples collected for fecal coliform analysis were collected first in sterile bottles. Samples used for chemical analysis were collected next. For the sand filter sites, samples were collected from the sand filter pump chamber and then from the septic tank vault to minimize bacterial contamination, since fecal coliform counts are much higher in the septic tank than in the sand filter effluent. Temperature and pH were measured in the chemical analysis sample immediately after taking the sample. Dissolved oxygen was measured using a YSI dissolved oxygen probe. Samples were placed on ice during the return trip to the laboratory.

BOD, fecal coliform analysis, COD, chlorides and EC analysis were conducted within 24 hours of sampling. The nitrogen series were either done immediately, refrigerated for a short time, or frozen for later analysis depending on time. TOC samples were stored in a refrigerator and analyzed later. The sample was preserved with a small amount of acid placed in the brown bottle prior to adding the effluent.

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All analyses, except chlorides, were conducted according to procedures in Standard Methods for the Examination of Water and Wastewater (APHA, 1985). Chloride analysis was conducted using an automatic coulometric/amperametric chloride titrator.

Unit A

Unit A consisted of a commercial single pass buried sand filter. The septic tank was either: 1) a single compartment tank with a screened pump vault in the tank, 2) a double compartment tank with an effluent filter in the first compartment, or 3) a single compartment septic tank with an effluent filter followed by a pump chamber. The pump, dosing the sand filter distribution network using time dosing, was either a turbine pump or an effluent pump. The sand filter consisted of either a 5.5 × 6.1 m (18 × 20 ft) or 3 × 11 m (10 × 36 ft) membrane lined filter. The sand filters all had pump vaults contained within the sand filter. The distribution network consisted of 31.75 mm (1/8 in.) holes spaced on 60 cm (2 ft) spacing with orifices located upward. Several had the holes located downward. The sand filter effluent was pumped to either a shallow in-ground trench, at-grade, or modified mound. Sampling was done in the septic tank pump vault/chamber (after effluent had passed through the screen) and in the sand filter pump chamber.

Unit B

Unit B was a suspended growth aeration unit located in a fiber glass spherical container with a removable cover. An aeration pump, running continuously, dispersed air throughout the mixed liquor. As influent entered the mixed liquor compartment, effluent moved through cylindrical filters, over a weir, and by gravity to a pump chamber. Solids were retained in the unit by the filters with solids pumped out when they reached 40 to50% by volume. Some units had trash traps upstream of the aeration unit, and some had pumps installed in the trash trap to time dose small amounts of wastewater into the aeration unit. There was no attempt to retain the solids in the trash tank other than to elevate the pump on a concrete block. Samples were collected from the pump chamber and from the mixed liquor in the aeration section. The mixed liquor was analyzed for D.O., temperature, pH and % settleable solids measured on the mixed liquor. Units were sized according to number of bedrooms served or number of gallons of wastewater processed daily.

Unit C

Unit C was a suspended growth aeration unit located in a 3-compartment concrete tank. The first compartment served as the septic tank. The second served as the aeration section with a motor, suspended above the mixed liquor, connected to a hollow shaft with an aspirator that extended into the mixed liquor, drawing in air and dispersing it into the mixed liquor. The aeration pump ran continuously. The third compartment served as the settling chamber which contained a plate filter surrounded by a fine screen. The filtered effluent flowed by gravity to an external pump chamber. Samples were collected from the pump chamber and from the mixed liquor in the aeration section. The mixed liquor was analyzed for D.O., temperature, pH and % settleable solids measured on the mixed liquor. Units were sized based on the number of bedrooms or number of gallons of wastewater processed daily.

RESULTS AND DISCUSSION

The pumping chamber effluent of 51 pretreatment units (20 systems of Unit A, 21 systems of Unit B and 10 systems of Unit C) was evaluated based on 345 samples. All the data for each unit were summarized by median, average, standard deviation, and minimum and maximum values as the number of samples collected from each system within a unit were similar. In addition, three sites (one Unit A and two Unit Bs) are presented separately based on long term performance and/or large

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number of samples collected in relation to the number of samples collected from the other 51 sites. Not all laboratory tests were run on all samples. Median values are used in the discussion as they are more representative than averages as several large numbers can skew average values. However, averages are presented for those who want to use the more traditional method of reporting data.

The effluent sample represented what was pumped into the soil absorption unit and not necessarily the effluent quality of the pretreatment unit. However, the more samples collected, the more the analysis represented the effluent quality of the pretreatment unit. If the aerobic unit spilled solids over to the pump chamber, it was possible that the spill still had some influence the next time that unit was sampled, resulting in higher values, such as BOD and suspended solids, than normal had the spill not occurred. During the time the seasonal saturation was high, some pump chambers leaked around the riser which diluted the pump chamber contents.

Unit A

Table 1 is a summary of the pump chamber effluents serving the 20 septic tanks and sand filters. The sand filter provided a very high quality effluent by reducing the median BOD from 186 mg/L to 4.0, a reduction of 98%. COD and TOC reductions were 94 and 85%, respectively. Others found similar reductions in BOD and COD (Ronayne et al., 1982; Darby et al., 1996). The septic tank effluent parameters were considerably lower in Darby et al. (1996) study than this study. In a field evaluation, Cagle and Johnson (1993) found BOD reductions of 98%.

The median and average fecal coliform count in the sand filter effluent was 3 and 280 col./100 mL, respectively, a reduction greater than 99.97% or a 5 and 3 log reduction, respectively. The count ranged from less than 1 to 7200 col./100 mL.

The sand filter reduced the TKN from 55 mg N/L to 3.4 mg N/L, a reduction of 94%, which is less than the 97% found by Ronayne et al. (1982) and 99 % removal found by Darby et al. (1996). The total nitrogen reduction through nitrification, denitrification and organic nitrogen synthesis averaged 43% based on median values and 34% based on average values.

The septic tank effluent and sand filter effluent median chloride concentration was 130 and 98 mg/L, respectively. This represents a 24.6 and 19.8% reduction in chlorides based on median and average concentrations. Since chlorides are conservative ions, the difference is dilution, sampling error or a combination of both. If the difference is due to dilution, the soil absorption unit is accepting from 19 to 25% more effluent than is entering the sand filter via septic tank assuming no ground water leakage into the septic tank. Thus, part of the nitrogen and other reductions may be partly due to dilution. Obviously, dilution will take place only during rain events.

The pH decreased from 7.3 to 6.7, and the median dissolved oxygen was 3.6 mg/L, with a range of 0.4 to 8.4 mg/L, indicating sufficient aeration taking place in the sand filter. The median temperature in the septic tank was 10.2°C with a range of 2.7 to 23.2°C. The median sand filter temperature, as measured by the effluent temperature was 6.5°C with a range of 1.9 to 21.4°C, a reduction of 36%.

Table 2 gives the results for the second longest operating sand filter in the study. It was singled out and not grouped with the other sand filters because of the large number of samples collected which would have influenced the results in Table 1. This unit served a family of 6 people with an average loading rate of 662 L/D (175 gpd). The BOD reduction was 98% based on median values. Median and average fecal coliform counts were 3 and 125 col./100 mL, a 6 and 4 log reduction. Nitrogen reductions were 23 and 25% based on median and average values, respectively.

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Table 1. Pump chamber effluent of 20 septic tanks with screen vaults and 20 single pass sand filters serving residences (Unit A). Effluent was time dosed to the sand filters.

Parameter	Units	Septic Vault Effluent						Sand Filter Effluent					
		No.[†]	Median	Average	S.D.	Min.	Max.	No.[†]	Median	Average	S.D.	Min.	Max.
Total Solids	mg/L	78	876	1090	497	280	2468	80	979	1170	562	250	2821
Volatile Solids	mg/L	77	247	261	78	120	440	80	164	188	112	30	845
BOD	mg/L	69	186	215	95	36	548	71	4.0	6.0	5.4	0.9	23
COD	mg/L	73	450	461	205	50	990	80	25	28	12	10	70
TOC	mg/L	16	86	107	59	29	234	18	12.7	15	10	5.8	40
TKN	mg N/L	70	55	58	23	9.7	144	75	3.4	10	14	<0.1	73
Ammonia	mg N/L	73	45	47	20	9.3	129	76	2.3	9.0	13	<0.1	73
Nitrate	mg N/L	67	0.5	0.7	0.8	0.0	6.1*	78	28	29	17	<0.1	87
Chloride	mg/L	74	130	378	441	17	1974	80	98	303	432	1.7	2611
EC	mos/cm	74	1425	1821	943	400	4100	79	1350	1826	1115	490	5500
Total Coliforms	col./100 mL	74	2.3E07	1.8E08	3.4E08	8.0E04	1.7E09	74	1.8E03	9.5E05	5.7E06	7	4.8E07
Fecal Coliforms	col./100 mL	74	2.5E05	9.0E05	1.9E06	1.7E03	8.5E06	79	3	280	950	<1	7200
Total Alkalinity	mg CaCO₃/L	5	501	433	112	297	562	63	360	380	115	117	753
Eff. pH	-	69	7.3	7.4	0.5	6.2	8.9	74	6.7	6.7	0.3	6.0	7.3
Eff. D.O.	mg/L	-	-	-	-	-	-	61	3.6	4.0	2.5	0.4	8.4
Eff. Temp.	°C	69	10.2	10.8	4.9	2.7	23.2	74	6.5	8.6	5.6	1.9	21.4
Amb. Temp.	°C	69	3.8	6.1	10.7	-18.4	28.9	74	3.7	6.0	11.0	-18.4	28.9

[†] Number represents the total number of samples collected and analyzed. The data are the compiled results of all samples collected from the 20 sites. Number of samples ranged from 2 to 13 samples/site with sampling periods ranging from 1 to 28 months.

* Excessive ground water leaking into septic tank resulting in D.O. of 5.2 mg/L (March, 1997).

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Table 2. Performance of one single pass sand filter over an 18-month period with a 3-month interruption.

Parameter	Units	Septic Vault Effluent						Sand Filter Effluent					
		No.[†]	Median	Average	S.D.	Min.	Max.	No.[†]	Median	Average	S.D.	Min.	Max.
Total Solids	mg/L	23	818	813	38	724	890	23	857	853	63	705	958
Volatile Solids	mg/L	23	277	270	52	191	378	23	199	195	52	82	295
BOD	mg/L	18	91	102	38	46	196	19	2.0	2.2	1.6	0.5	6.9
COD	mg/L	23	260	267	43	160	350	23	12.0	13.4	3.6	9.0	20
TOC	mg/L	17	74	71	26	15	133	19	6.0	9.3	11.7	1.4	57
TKN	mg N/L	23	62	64	13	43	92	22	0.3	2.3	5.6	0	26
Ammonia	mg N/L	23	51	52	12	32	78	22	0.2	1.5	2.9	0	10.4
Nitrate	mg N/L	23	0.4	0.4	0.3	<0.1	1.0	23	48	46	6.6	31	60
Chloride	mg/L	23	97	103	44	58	300	23	92	87	18	41	117
EC	mos/cm	23	1350	1335	102	1200	1520	22	1200	1216	112	1000	1450
Total Coliforms	col./100 mL	23	5.1E07	1.3E08	2.1E08	1.9E06	9.9E08	22	750	5.4E04	2.3E05	70	1.1E06
Fecal Coliforms	col./100 mL	23	1.4E06	2.1E06	2.1E06	1.1E05	8.5E06	22	3	125	422	<1	2000
Total Alkalinity	mg CaCO$_3$/L	6	603	578	69	438	648	16	336	335	32	283	410
Eff. pH	-	20	8.3	8.0	0.6	6.9	8.8	20	6.9	7.0	0.3	6.7	8.3
Eff. D.O.	mg/L	-	-	-	-	-	-	13	5.0	5.2	1.3	3.1	7.5
Eff. Temp.	°C	19	16.2	14.4	5.2	4.6	21.4	20	15.4	12.8	6.7	1.4	21.2
Amb. Temp.	°C	19	14.5	11.2	13.9	-19.6	29.7	19	14.5	11.1	13.9	-19.6	29.7

[†] Number represents the total number of samples collected and analyzed. Data presented in this table is not included in Table 1. Sampling period was 8/95 to 3/97, with 3 mo. interruption from 2/96 to 4/96.

Unit B

Table 3 is the summary of the pump chamber effluent serving Unit B aerobic systems. The median BOD, COD and TOC were 4.4, 39 and 16 mg/L, respectively. It is difficult to measure reduction since the influent concentrations are unknown. Since this system may or may not have a trash tank in front of the unit, the unit processes more organic matter than those with a septic tank proceeding the unit.

Table 3. Pump chamber effluent quality of 21 aerobic units serving residences (Unit B).

Parameter	Units	Number[†]	Median	Average	S.D.	Min.	Max.
Total Solids	mg/L	197	695	859	479	200	3013
Volatile Solids	mg/L	197	193	223	125	2.5	776
BOD	mg/L	151	4.4	10.8	16	0.5	76
COD	mg/L	188	39	55	52	5.0	400
TOC	mg/L	118	16	23	41	3.3	429
TKN	mg N/L	191	3.3	8.0	12	0.1	85
Ammonia	mg N/L	189	1.0	5.2	9.1	<0.1	74
Nitrate	mg N/L	193	24	28	20	0.1	97
Chloride	mg/L	187	75	254	392	14	1955
EC	mos/cm	187	930	1243	852	280	4500
Total Coliforms	col.100 mL	181	3.0E04	3.0E06	2.5E07	22	2.8E08
Fecal Coliforms	col.100 mL	185	530	10,000	41,000	1	4.5E05
Total Alkalinity	mg CaCO$_3$/L	66	195	186	117	10	621
Eff. pH	-	173	7.2	7.1	0.6	4.1	8.2
Aerator pH	-	151	7.1	6.8	1.1	3.2	8.3
Eff. D.O.	mg/L	164	4.6	4.4	2.3	0.1	10.0
Aerator D.O.	mg/L	142	8.2	7.9	1.9	0.3	11.6
Eff. Temp.	°C	178	13.1	13.3	5.9	2.3	26.5
Aerator Temp.	°C	157	16.6	17.2	5.8	7.4	31.4
Amb. Temp	°C	177	9.8	10.6	10.8	-12.9	31.4

[†] Number represents the total number of samples collected and analyzed. The data are the compiled results of all samples collected from the 21 units. Number of samples/site ranged from 7 to 15 with sampling periods ranging from 6 to 56 months.

The median TKN, ammonia and nitrate concentrations were 3.3, 1.0 and 24 mg N/L, respectively, indicating that the unit is doing a reasonable job of converting the organic and ammonia nitrogen to nitrates. Again, it is difficult to measure the percent reduction and conversion since the influent was not measured.

The median and average fecal coliform concentration was 530 and 10,000 col./100 mL, respectively, indicating there is considerable variability in the unit's ability to reduce fecal coliforms consistently. The range was less than 1 to 4.5 E+05 col./100 mL. There was also similar variability in total coliform concentrations.

The median aeration unit pH of 7.1 was slightly less than the chamber effluent of 7.2. The median aeration unit temperature of 16.6 °C was slightly higher than the chamber effluent of 13.1 °C which is reasonable as the submerged aerator adds heat to the unit and some of it is dissipated in the chamber. The dissolved oxygen in the aeration unit was about twice as high as in the chamber, 8.2 vs. 4.6 mg/L, indicating the bacteria continues to respire in the pump chamber.

Table 4 presents data for two Unit B systems not included in Table 3 because of their longevity and the number of samples collected. The sampling periods for these units were 9.4 and 7.2 yrs.

Table 4. Long-term performance of two units (Unit B) serving residences.

Parameter	Units	System P						System W					
		No.[†]	Median	Average	S.D.	Min.	Max.	No.[†]	Median	Average	S.D.	Min.	Max.
Total Solids	mg/L	146	1029	1196	633	460	3489	59	813	959	393	522	2112
Volatile Solids	mg/L	146	247	277	135	102	982	59	326	334	129	145	947
BOD	mg/L	101	2.8	3.2	2.2	0.5	11	50	2	2.6	1.8	1	10.1
COD	mg/L	125	30	37	27	6	234	55	28	29	10.6	6	66
TOC	mg/L	47	7.9	10.4	6.7	4	37	39	10	11	6.6	1	34
TKN	mg N/L	141	2.0	2.6	3.0	0.1	23	57	1.0	1.6	2.3	0.5	17
Ammonia	mg N/L	138	0.5	1.1	2.3	0.1	18	55	0.5	0.8	1.8	0.1	14
Nitrate	mg N/L	137	26	26	8.8	3	54	56	40	39	16	9	77
Chloride	mg/L	125	378	596	589	50	3937	47	83	240	372	35	1348
EC	mos/cm	125	1700	2152	1376	730	8500	48	1130	1415	673	950	3500
Total Coliforms	col./100 mL	118	2.6E04	9.5E04	3.2E05	730	3.4E06	41	1.4E04	5.3E04	1.6E05	110	1.0E06
Fecal Coliforms	col./100 mL	120	2550	1.8E04	5.3E04	<1	4.0E05	41	420	3118	7904	5	3.9E04
Total Alkalinity	mg CaCO$_3$/L	23	196	200	39	90	281	5	351	365	86	250	509
Eff. pH	-	83	7.2	7.2	0.3	6.7	8.2	50	7.8	7.8	0.3	7.12	8.3
Aerator pH	-	58	7.0	7.1	0.3	6.3	8.2	14	7.5	7.6	0.5	7.0	8.6
Eff. D.O.	mg/L	87	4.7	4.9	1.7	0.2	8.6	46	6.3	6.2	1.3	2.7	8.6
Aerator D.O.	mg/L	57	7.0	6.8	1.5	2.3	9.8	15	7.2	6.8	2.1	3.0	10.4
Eff. Temp.	°C	87	15.3	15.3	6.0	5.3	26.0	55	14.0	14.0	5.5	60	25.0
Aerator Temp.	°C	64	19.0	18.8	4.8	10.0	28.0	49	23.0	22.7	4.5	11.8	30.0
Amb. Temp.	°C	71	12.0	10.6	11.6	-20.4	31.0	41	9.7	8.9	12.1	-19.0	31.0

† Number represents the total number of samples collected and analyzed. Data presented in this table is not included in Table 3. Sampling period for System P 9.4 years and 7.2 years for System W.

These systems have operated with no septic tank preceding the unit. The effluent quality has been consistently good with median and average BODs of 2.8 and 3.2 mg/L, respectively. The two systems converted the nitrogen to nitrates with TKN less than 2.6 mg N/L and nitrates averaging 26 and 39 mg N/L. The median and average fecal counts were 2550 and 18,000 and 420 and 3118 col./100 mL for Systems P and W, respectively. System W served a family of 4 people with an average loading rate of 870 L/d (230 gpd; average of last two years). These systems were maintained on 6-month intervals. System P had to have additional maintenance as it would generate excessive solids on occasion with solids being forced out around the lid. The cause of the excessive solids generation may have been due to medication taken by a family member.

Unit C

Table 5 is the summary of the pump chamber effluent serving Unit C aerobic systems. The median BOD, COD and TOC were 27, 142 and 44 mg/L, respectively. It is difficult to measure reduction since the influent concentrations are unknown. This unit has a septic tank for solids settling prior to effluent entering the aeration section.

Table 5. Pump chamber effluent quality of 10 aerobic units serving residences (Unit C).

Parameter	Units	Number[†]	Median	Average	S.D.	Min.	Max.
Total Solids	mg/L	68	750	937	579	300	2949
Volatile Solids	mg/L	68	206	209	74	75	436
BOD	mg/L	50	27	36	25	0.5	103
COD	mg/L	66	142	169	103	31	425
TOC	mg/L	34	44	54	32	12	133
TKN	mg N/L	66	40	39	25	2.5	89
Ammonia	mg N/L	68	28	30	21	0.5	70
Nitrate	mg N/L	68	0.9	5.2	7.9	0.1	36
Chloride	mg/L	67	71	275	517	33	2053
EC	mos/cm	66	1135	1513	1094	550	5000
Total Coliforms	col./100 mL	67	8.1E05	8.8E06	2.2E07	240	1.1E08
Fecal Coliforms	col./100 mL	66	2.4E04	1.5E05	3.5E05	<1	1.6E06
Total Alkalinity	mg CaCO₃/L	32	337	372	146	132	658
Eff. pH	-	63	7.3	7.3	0.4	6.5	8.4
Aerator pH	-	46	7.2	7.2	0.5	6.1	8.7
Eff. D.O.	mg/L	51	0.9	1.7	1.7	0.1	6.4
Aerator D.O.	mg/L	35	7.0	7.2	2.3	2.5	11.4
Eff. Temp.	°C	64	9.7	11.3	5.7	3.1	25.6
Aerator Temp.	°C	46	14.6	15.6	4.4	8.4	23.1
Amb. Temp.	°C	64	9.0	8.5	12.3	-13.3	33.0

[†] Number represents the total number of samples collected and analyzed. The data are the compiled results of all samples collected from the 10 units. Number of samples per site ranged from 4 to 10 with sampling periods ranging from 15 to 27 months.

The median TKN, ammonia and nitrate concentrations in the chamber were 40, 28 and 0.9 mg N/L. The high TKN and low nitrate concentration indicates that a reasonable degree of nitrification had not occurred. The low nitrate level does not signify significant denitrification since the TKN is high.

The median and average fecal coliform concentrations in the chamber were 24,000 and 150,000

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col./100 mL, indicating considerable variability from sample to sample. The range was less than 1 to 1,600,000 col./100 mL.

The median aeration unit pH of 7.2 was slightly less than the chamber effluent of 7.3. The median aeration unit temperature of 14.6°C was higher than the pump chamber effluent of 9.7°C as some of the heat is dissipated in the pump chamber. The dissolved oxygen in the aeration section was about seven times higher than in the pump chamber (7.0 vs. 0.9 mg/L). The dissolved oxygen reduction is the result of increased bacterial activity due to the high BOD and SS in the pump chamber.

Comparison of Units and Pump Chambers A, B and C

Table 6 gives a summary of the medians and averages for selected parameters from Tables 1, 3 and 5 for easier comparison among units. The organic matter concentration in Chamber A, as measured by median and average BOD, COD and TOC concentrations, was consistently better than the concentrations in Chamber B with the least quality effluent in Chamber C.

Table 6. Summary of Tables 1, 3 and 5 comparing Units A, B and C.

Parameter	Units	Median			Average		
		Unit A	Unit B	Unit C	Unit A	Unit B	Unit C
Total Solids	mg/L	979	695	750	1170	859	937
Volatile Solids	mg/L	164	193	206	188	223	209
BOD	mg/L	4.0	4.4	27	6.0	10.8	36
COD	mg/L	25	39	142	28	55	169
TOC	mg/L	12.7	16	44	15	23	54
TKN	mg N/L	3.4	3.3	40	10	8.0	39
Ammonia	mg N/L	2.3	1.0	28	9.0	5.2	30
Nitrate	mg N/L	28	24	0.9	29	28	5.2
Chloride	mg/L	98	75	71	303	254	275
EC	mos/cm	1350	930	1135	1826	1243	1513
Total Coliforms	col./100 mL	1.8E03	3.0E04	8.1E05	9.5E05	3.1E06	8.8E06
Fecal Coliforms	col./100 mL	3	530	2.4E04	280	10,000	1.5E05
Total Alkalinity	mg CaCO$_3$/L	360	195	337	380	186	372
Eff. pH	-	6.7	7.2	7.3	6.7	7.1	7.3
Aerator pH	-	-	7.1	7.2	-	6.8	7.2
Eff. D.O.	mg/L	3.6	4.6	0.9	4.0	4.4	1.7
Aerator D.O.	mg/L	-	8.2	7.0	-	7.9	7.2
Eff.Temp.	°C	6.5	13.1	9.7	8.6	13.3	11.3
Aerator Temp.	°C	-	16.6	14.6	-	17.2	15.6
Amb. Temp.	°C	3.7	9.8	9.0	6.0	10.6	8.5

The TKN and ammonia concentrations in Chamber B (3.3 and 1.0 mg N/L) were slightly lower than in the Chamber A (3.4 and 2.3 mg N/L), both of which were significantly lower than found in Chamber C (40 and 28 mg N/L). Nitrate concentration in Chambers A was slightly higher than in Chamber B (28 and 24 mg N/L) and significantly greater than found in Chamber C (0.9 mg N/L) which indicates nitrification had not occurred in Chamber C. The total nitrogen concentration (TKN + nitrate) in Chamber B was 13% lower than in Chamber A and 33% lower than in Chamber C.

Median and average fecal coliform counts in Chamber A (3 and 280 col./100 mL) were much lower than found in the Chamber B (530 and 10,000 col./100 mL) which is much better than found in Chamber C (24,000 and 150,000 col./100 mL). Based on differences between the median and average values, there was much greater variability in Chambers B and C than in Chamber A.

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The median pH in Chamber A (6.7) was lower than in Chamber B (7.2) and Chamber C (7.3) while the median pH in the Aeration Unit B (7.1) and Aeration Unit C (7.2) was slightly lower than in the chambers. The median total alkalinity in Chamber A (360 mg/L) and Chamber C (337 mg/L) was considerably higher than in Chamber B (195 mg/L). All units had sufficient alkalinity for nitrification. The lower concentration in Chamber B may have been due to increased nitrification occurring in the unit (lower TKN) and no septic tank to retain solids and nitrogen.

Median effluent dissolved oxygen in Chamber B (4.6 mg/L) was higher than in Chamber A (3.6 mg/L) which was higher than in Chamber C (0.9 mg/L). The dissolved oxygen in Unit B (8.2 mg/L) and Unit C (7.0 mg/L) was higher than in the chambers as the dissolved oxygen was continuing to be consumed in the chambers. More oxygen appeared to be consumed in Chamber C than in Chamber B probably because the BOD in Chamber C was greater than in Chamber B, and the bacteria will continue to respire and consume oxygen especially if food is available.

The median effluent temperature in Chamber A (6.5°C) was considerably lower than in Chamber B (13.1°C) and Chamber C (9.7°C). The temperature in Unit A (sand filter) was assumed to be the same as the sand filter effluent temperature (6.5°C) since the pump chamber was enclosed within the sand filter. The temperature in Unit B (16.6°C) and Unit C (14.6°C) was considerably higher than in Unit A (6.5) and in the chambers. The higher temperature in Unit B can be attributed partially to the submerged pump giving off heat. The sand filter temperature was lower than the temperature in the aerobic units as the surface area of the sand filter is much larger than the aerobic units.

Seasonal Changes in Effluent Quality

Table 7 gives the effluent quality based on cold weather (December - April) and warm weather (May - November) for a number of the parameters. This summary includes the data represented in Tables 1, 2, 3, 4 and 5. For Chamber A the median effluent temperature (assumed temperature of sand filter) was 4.2°C during the cold weather period and 14.9°C during the warm weather period. The colder environment did impact the ability of the sand filter (Unit A) to treat the effluent. The BOD, COD and TOC values were higher during colder weather than during warmer weather. For Chambers B and C, where the effluent temperatures were higher, there were fewer seasonal differences, based on percentages, except for COD in Chamber C.

For Chamber A the TKN was higher and the nitrates lower during cold weather than during warm weather. This is understandable as the nitrification process is sensitive to cold temperature. There was essentially no seasonal difference in nitrification for Chamber B because the cold weather temperature in Unit B was above the temperatures that effect nitrification. However, the TKN was higher and nitrate concentration lower in Chamber C during cold weather than during warm weather even though the aerator temperature for both Unit B and Unit C were similar. Factors other than seasonal temperature differences apparently controlled the nitrification process which produced a high TKN and low nitrate in Chamber C.

The TKN, ammonia and nitrate data for each chamber and the corresponding unit temperatures were plotted to see if there was any correlation between concentration and temperature. The best fit line was plotted with R^2 values reported in Table 8. Although all the R^2 values are generally below accepted levels (greater than 0.5-0.6), the values tend to confirm the temperature affect. Chamber A had higher R^2 values (0.2-0.3) than did Chamber B (less than 0.1), and the cold weather temperature in Unit A (4.2°C) was much lower than in Unit B (13.3°C). Unit C had similar R^2 values to Chamber A which is hard to justify as, based on temperature, those values should have been similar to values in Chamber B.

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Table 7. Pump chamber effluent quality of sand filters (Unit A) and aerobic units (Units B and C) during warm and cold seasons.

Parameter	Units	Median[†] Cold[‡]	Median Warm	Median Cold	Median Warm	Median Cold	Median Warm
		------Unit A------		------Unit B------		------Unit C------	
Sample Size	-	10-54	27-49	29-169	63-208	14-40	11-29
BOD	mg/L	4.5	1.9	3.0	3.0	29	26
COD	mg/L	25	19	34	31	200	105
TOC	mg/L	11	8.9	12	12	44	44
TKN	mg N/L	6.5	1.1	2.0	2.0	45	32
Ammonia	mg N/L	5.7	0.4	0.8	0.5	36	23
Nitrate	mg N/L	27	42	24	29	0.5	3.7
Chloride	mg/L	90	95	135	122	69	72
Total Coliforms	col./100 mL	1.8E03	1.2E03	3.6E04	1.8E04	1.4E06	3.1E05
Fecal Coliforms	col./100 mL	3.3	1.0	1300	810	48,000	17,000
Total Alkalinity	mg CaCO$_3$/L	367	340	192	209	303	348
Eff. pH	-	6.7	6.9	7.3	7.3	7.3	7.2
Aerator pH	°C	-	-	7.1	7.1	7.2	7.1
Eff. D.O.	mg/L	4.0	4.8	5.8	4.5	0.9	0.7
Aerator D.O.	mg/L	-	-	8.8	6.9	8.2	6.1
Eff. Temp.	°C	4.2	14.9	8.6	18.6	7.1	17.6
Aerator Temp.	°C	-	-	13.4	22.9	12.7	20.7
Amb. Temp.	°C	-1.2	18.3	1.4	19.3	2.4	21.1

[†] Median of all samples collected during that period including data in Table 1, 2, 3, 4 and 5.
[‡] Cold season from December through April and warm season from May through November.

The fecal coliform count was higher during cold weather than during warm weather for Chambers B and C with very little seasonal effect noted in Chamber A (Table 7). Due to the variability difference between chambers, it is difficult to determine how temperature affected fecal coliform die off or if other factors such as filtering through the sand played a bigger role.

Table 8. The R^2 value for a 7th order polynomial best fit of TKN, ammonia and nitrates vs. effluent temp. (Unit A) or aerator temp. (Units B and C).

Parameter	Unit A	Unit B	Unit C
TKN	0.253	0.056	0.120
Ammonia	0.317	0.068	0.130
Nitrate	0.267	0.062	0.060

Frequency of Occurrence

Performance consistency is important if less emphasis is placed on soil treatment and more on the pretreatment unit such as sand filters and aerobic units. Converse and Tyler (1997) recommend less separation distance if the pretreatment unit consistently produces effluent with low fecal coliform counts. Downsizing is possible if effluent BOD and suspended solids concentrations are less. Table 9 shows that there is a considerable difference in chamber effluent concentrations for fecal coliforms, BOD and suspended solids. Chamber A had the least variable effluent while Chambers B and C had greater variability. For example, 79% of the time the fecal coliform counts in Chamber A effluent was below 100 col./100 mL, but it was below this value only 17.6 and 3% of the time for Chambers B and C, respectively. Thus, the risk of fecal coliform detects exceeding

suggested separation distance (Converse and Tyler, 1997) is much less with Chamber A effluent than Chamber B and C effluent.

Table 9. Frequency at which numbers were below a given value for fecal coliforms, BOD and suspended solids for the three units.

	FECAL COLIFORM COUNT		
Number	Unit A 101	Unit B 346	Unit C 66
Col./100 ml		------ % Less Than ------	
1	45.0	1.2	1.5
10	66.0	3.8	3.0
100	79.0	17.6	3.0
1000	94.0	50.9	15.1
10,000	100.0	80.6	34.8
100,000	-	97.4	77.3
1,000,000	-	100.0	93.9
more	-	-	100.0
	BOD		
Number	90	302	50
BOD - mg/L		------ % Less Than ------	
1	10.1	17.5	2.0
5	66.8	71.9	2.0
10	83.4	85.8	6.0
15	93.4	90.1	12.0
20	97.9	93.0	26.0
25	100.0	94.4	48.0
30	-	95.0	56.0
50	-	97.0	78.0
75	-	99.0	90.0
100	-	100.0	98.0

BOD concentrations below 30 mg/L occurred 100, 95 and 56% of the time in Chambers A, B and C, respectively. The Standard 40 (NSF, 1990) uses 30 mg/L for BOD. It is difficult to compare Standard 40 criteria to this study because of the sampling criteria and the loading regimes required for Standard 40 was not done in this study.

Maintenance

Maintenance is an essential component to overall performance of theses systems. Some systems, such as the aerobic units, may require more maintenance than the sand filters. However, no attempt was made to quantify that aspect. Unit B systems have been installed the longest with an average sampling period of 38 months, followed by Unit C systems with an average sampling period of 20 months, followed by Unit A with an average sampling period of 8 months. Longer term evaluation is required, especially for Unit A systems, before a fair analysis on maintenance requirements can be made. However, some of the aerobic units became upset occasionally with solids being forced out the top of Unit B or solids accumulated in Chamber C on occasion. This study will continue to obtain long term performance and maintenance requirements will be included.

SUMMARY AND CONCLUSIONS

Effluent samples were collected 21 single pass sand filters (Unit A), 23 aerobic units (Unit B) and 10 aerobic units (Unit C). The wastewater source was from residences. A total of 573 samples were collected with evaluation periods ranging from 1 month to 9.2 years. The samples were taken from the pump chamber which had accumulated effluent over time, so the sample could be considered a composite of unknown length which represented the effluent being pumped to the soil absorption unit.

The single pass, buried, membrane lined sand filter (Unit A) with an internal pump chamber received time dosed, screened effluent from either a septic tank with screen vault or a pump chamber following the septic tank. One of the aerobic units (Unit B) consisted of a single compartment unit with a pump drawing air into the mixed liquor. Effluent exited the mixed liquor section through a series of vertical cylindrical fabric filters and flowed by gravity to a pump chamber. Some units had a small trash tank proceeding the unit with a pump dosing the unit. Another aerobic unit (Unit C) consisted of a 3-compartment concrete tank with a septic tank section, an aerated section with a motor with a hollow shaft with aspirator extending into the mixed liquor, and a clarifier section which contained a plate type filter covered with a fine screen. The effluent flowed by gravity to a pump chamber.

The sand filter (Unit A) provided a high quality effluent with BOD, COD and TOC reductions of 98, 94 and 85%, respectively based on median values. The median and average coliform counts were 3 and 280 col./100 mL, respectively, a 5 and 4 log reduction, respectively. Of the 101 samples collected, 79% had fecal coliform concentration less than 100 col./100 mL. The median TKN and nitrate concentrations were 3.4 and 28 mg N/L resulting in a 43 and 34% nitrogen reduction based on median and average values, respectively. Temperature did affect nitrification as the TKN concentration was less in warm weather than in cold weather. Based on chloride concentration, there was about a 20 to 25% dilution effect due to precipitation.

The effluent quality in the pump chamber served by Unit B had a median BOD of 4.4 mg/L. The median TKN and nitrate concentration was 3.3 and 24 mg N/L. The median and average fecal coliform count was 530 and 10,000 col./100 mL, respectively with considerable variability. Of the 346 samples collected, 17.6% had fecal coliform concentrations less than 100 col./100 mL.

The effluent quality in the pump chamber served by Unit C had a median BOD of 27 mg/L. The median TKN and nitrate concentration was 40 and 0.9 mg N/L. The median and average fecal coliform count were 24,000 and 150,000 col./100 mL. Of the 66 samples collected, 3% had fecal coliform concentrations less than 100 col./100 mL. Some of these systems require more maintenance than others. Since many of these systems are relatively new, maintenance requirements are not reported in this study.

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