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SMALL SCALE WASTE MANAGEMENT PROJECT

Onsite Reclamation of Residential Greywater

by

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Presented at the Onsite Sewage Treatment Symposium
Chicago, IL, December 1981

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ONSITE RECLAMATION OF RESIDENTIAL GREYWATER

Robert L. Siegrist William C. Boyle

In conventional approaches to domestic wastewater management, the discrete wastewater flows produced by individual water-using fixtures and appliances are collected jointly and handled as a single combined waste stream. An alternative approach is to segregate the individual waste sources into two or more waste streams and provide appropriate treatment based upon the characteristics of each wastewater and the intended disposal/reuse method. To its proponents, this appeared as a logical strategy which could facilitate water conservation and wastewater recycling as well as enhance wastewater disposal. Based upon intuitive judgments and the results of early characterization studies, the concept of segregating the greywater or wastewaters generated through basin, sink and appliance usage evolved. Since they are not contaminated directly by human excrement, strategies are often proposed involving onsite recycling or casual disposal of greywater. Improved treatment unit response, reduced treatment requirements and a lesser hazard to the environment and public health than that associated with normal domestic wastewater often appear as supporting arguments.

A series of field and laboratory studies were undertaken at the University of Wisconsin in 1977 to investigate greywater management. The objectives of these efforts were to characterize residential greywater and identify the performance capabilities of septic tanks, soil absorption systems, intermittent sand filters, and inhouse recycle units. This paper presents a synopsis of these efforts dealing with the raw waste characterization and the performance of septic tanks, and intermittent sand filters. Additional details regarding these and related studies may be found in Siegrist et al., 1981, Saw, 1981, Anderson et al., 1981 and forthcoming publications.

MATERIALS AND METHODS

Research Facility Characteristics

To enable this investigation, the plumbing systems at four Wisconsin homes were modified so that the greywaters from various fixtures and appliances were transported in newly installed drainage pipes, separate from the toilet wastes. The characteristics of the study homes are shown in Table 1. At each of the four homes, the greywaters were transported to selected treatment units. A brief description of those at each home follows.

Home 1: At home 1, a septic tank, sand filter basin and two sampling wells were installed as shown in Figure 1. The septic tank utilized was a precast concrete tank, approximately 1.7 m in diameter with a liquid depth of 0.9 m and a total liquid volume of 1985 L. The inlet and outlet were baffled with semi-circular fiberglass baffles attached to the tank wall. The characteristics of the sand filter are depicted in Figure 2. The media finally selected was a coarse filter sand with effective size of 1.37 mm and uniformity coefficient of 1.30. The initial saturated hydraulic conductivity of this sand was 520 m/d. The filter was 1.2 m deep and 1.07 m in diameter. A section of

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3.8 cm diameter plastic pipe perforated with 7.9 mm diameter holes served as the underdrain. Approximately 15 cm of 2.5 cm washed hardrock overlain by 10 cm of 0.6 cm pea gravel served as the support media for 68 cm of filter sand. Uniform distribution of greywater over the sand surface was supplied by a rotating aluminum sprinkler arm 4.7 mm in diameter and perforated with 3 mm holes. Two distinctly different strategies were used to apply STE to the sand filter during this study. During the first series of filter runs (Phase I), the daily loading was designed to be applied in intermittent doses of 5 cm, with the actual dosing schedule and daily loading determined by the greywater generation pattern within the home. During Phase II, the daily loading was designed to be applied in hourly doses of 1.35 cm, with a high-level float switch provided to activate extra doses of 4.0 cm during periods of high flow.

During the second phase of operation with the sand filter at home 1, eight sand columns were also employed to evaluate the effects of filter grain size and hydraulic loading on filter performance (Saw, 1981). The cast acrylic columns were 9.5 cm in diameter and contained 9 cm of 2.5 cm gravel, 6 cm of 0.6 cm pea gravel and 68 cm of filter sand (Figure 3). The factorial design used in this experiment consisted of duplicate columns with two sand sizes and two daily loading rates. The sands were a coarse sand with an effective size of 1.02 mm and uniformity coefficient of 1.44 and a medium sand with an effective size of 0.17 mm and a uniformity coefficient of 2.82. The daily loading rates were 15 and 30 cm/day, to be applied in 24 hourly doses/day at the same time the sand filter unit received its hourly dose.

Home 2: At home 2, a septic tank and two sampling wells were installed. The greywater septic tank was fabricated from a concrete manhole with an inside diameter of 1.2 m and a liquid depth of 0.9 m yielding a liquid volume of 1058 L. The inlet and outlet were baffled with open-ended tees.

Homes 3-4: At both of these homes, proprietary greywater recycle systems were installed within the dwellings. The units, manufactured by Aquasaver, Inc., employed the unit processes of sedimentation, paper cartridge filtration (20 μ) and chlorine disinfection for purifying bathing and laundry greywater for reuse in flushing toilets and lawn irrigation. A discussion of the performance evaluations of these units may be found in Siegrist et al., 1981 and Anderson et al., 1981.

Monitoring Procedures

Volumetric flow data were collected automatically for raw greywater and flow streams associated with each unit process using specially altered water meters and flow indicating switches interfaced with occurrence counters and continuous strip-chart recorders. Data were collected over many multi-day periods and analyzed on an hourly and daily basis. Qualitative characterization was also accomplished through collection of grab and 24-hour flow composited samples with analyses for various parameters performed according to Standard Methods (1976). System operations were monitored with occurrence counters and continuous strip-chart recorders as well as elapsed time indicators and power meters. Maintenance requirements were delineated in a log. With the proprietary recycle units, user acceptance was assessed through recordings in a user log and responses to a final questionnaire. Additional details regarding the monitoring procedure may be found in Siegrist et al., 1981 and Saw, 1981.

RESULTS AND DISCUSSION

Greywater Characteristics

The daily per capita generation of greywater was measured at Homes 1, 3 and 4 yielding the results shown in Table 2. The mean daily flow ranged from 75.7 to 126.7 Lpcd while the maximum daily flow varied from 259 to 364 Lpcd. At the three homes, the greywater flow represented 71.0 to 79.4% of the total wastewater flow.

The qualitative characteristics of the raw greywater at the four homes are summarized in Table 3. These data clearly demonstrate that greywater does contain significant concentrations of potential pollutants including BOD_5, solids, and nitrogen. Comparison of the data for those homes with kitchen sink wastes included (Home 1 and 2) versus those without (Homes 3 and 4) revealed that inclusion of the kitchen wastes significantly increases the contaminant load in the greywater stream. At all four homes, high levels of fecal organisms were routinely measured suggesting that the greywater may have been routinely contaminated by fecal matter. Assuming no bacterial population changes during a 24-hour sampling period, to yield 10^6 fecal coli/100 ml would have required that approximately 1.2 g of wet fecal matter (@ 2.7×10^9 fecal coli/wet gram of human feces), were contributed to a 320 Lpd greywater stream. When compared to total residential wastewater, greywater comprised of all household basins, sinks and appliances possesses lower concentrations of most conventional pollutants with the exception of BOD_5. If the kitchen sinks wastes are excluded, the pollutant concentrations in the greywater are significantly lower than in the total residential waste stream.

A cursory study was also performed to determine the settling properties and size distribution of particles in greywater (Saw, 1981). Results of analyses of two to four samples (24-hour flow composited), from Homes 1 and 2 revealed that little settleable or floatable material was present. After 60 minutes of quiescent settling, the total solids present were reduced by less than 14%. Subjective estimates of particle size distribution were achieved by selective filtration on a variety of membrane and glass fiber filters. Based upon this analysis, over 50 percent of the solids present in the greywater had diameters less than 0.45 microns, while over 25 percent had diameters greater than 20 microns. While limited, these studies suggested that simple sedimentation or mechanical filtration would be relatively ineffective for greywater renovation. Olsson (1968) reported similar findings for individual greywaters from an apartment complex in Sweden.

<u>Septic Tank Performance</u>

The septic tank effluent (STE) characteristics are delineated in Table 4. Septic tank treatment effectively reduced the suspended solids in the greywater by approximately 50 to 70 percent. The other parameters measured were affected to a lesser degree while total and fecal coliform levels were reduced by only a few percent.

The results of this study are compared with those reported by Brandes (1978) and Kristiansen et al.,(1979) in Table 5. In general, the results of this study are similar to those reported previously. When compared to the septic tank effluent quality achieved with total residential wastewater, the effluent quality with greywater is quite similar. The only potentially significant differences exist in the nitrogen and phosphorus concentrations which are lower in greywater STE.

<u>Intermittent Sand Filtration</u>

<u>Sand Filter</u>: During the first phase of operation, the sand filter was dosed intermittently with septic tank effluent beginning on November 27, 1979 (Table 6). Application was continued until the hydraulic conductivity decreased to the point where it was continuously ponded between doses. This occurred after 119 days of operation and after loading to the filter totalled approximately 44.6 m, applied in a total of 784 doses. Application to the filter during this period averaged 6.6 doses per day at 5.7 cm/dose,

yielding a total daily loading of 38 cm/day. Actual individual filter dosings and daily loadings depended on the greywater generation patterns in the home.

Visual observation of the filter with time revealed that the hydraulic conductivity gradually decreased. After 119 days of operation, the surface was continuously ponded and the filter run was terminated. In an attempt to rejuvenate the filter, the sand media was allowed to drain for 24 hours and was then raked to a depth of 10 to 15 cm. The filter surface was smoothed out and a second filter run began. The hydraulic conductivity of the filter after raking was similar to that of clean sand, yet after only 27 days of operation the filter surface was continuously ponded and the filter run was terminated. The filter was again rejuvenated by raking and a third run of 28 days was achieved. During the initial filter run, the filter air temperature varied from 2 to 10°C while that of the STE ranged from 8 to 10°C.

The effluent quality achieved with the sand filter during the first filter run is summarized in Table 7. Removals were very poor and virtually no nitrification occurred. The limited pollutant removals in the filter were most likely due to the coarse media employed and the application method utilizing only 6 to 7 doses per day. It seems reasonable that the coarse media and loading regime were not amenable to physical and chemical removal processes and the potentially short contact times and relatively cool temperatures did not favor biological activity. The cool temperatures during start up undoubtedly hindered the development of a healthy biomass during this run. In light of the coarse media and the limited pollutant removals, a filter run of only 119 days was unexpectedly short.

To enhance the poor performance exhibited by the sand filter during phase I, a new mode of operation was selected. During phase II, the filter was to receive 1.35 cm doses each hour of the day with additional 4.0 cm doses during periods of high flow. The daily loading was to be approximately the same. Prior to initiation of this phase, the top 25-30 cm of the filter bed were removed and the underlying media was dosed with 10% H_2O_2. After flushing with tapwater, 25-30 cm of new sand were added. The sprinkler arm, underdrain, and filter effluent pump basin were also cleaned with 5% H_2O_2.

Operation of the filter during phase II began on July 15, 1980 (Table 6). Application to the filter continued until the hydraulic conductivity decreased to the point where continuous ponding occurred. This occurred after 149 days of operation during which time the loading to the filter totalled approximately 58.3 m applied in a total of 3,348 hourly doses (1.35 cm/dose) and 326 high-level doses (4 cm/dose) (Table 6). The total daily loading to the filter during this period averaged approximately 39 cm/day. This loading was applied in an average of approximately 22.5 hourly doses/day and 2.2 high-level doses/day. Actual individual filter doses and daily loadings depended on the home greywater generation patterns.

After the first filter run, a combination of surface raking and hydrogen peroxide treatment was used to rejuvenate the filter. Immediately after termination of the filter run, approximately 50% of the ponded surface was raked vigorously to a depth of 15 cm. The 7 to 10 cm of ponded water slowly drained through the filter during the next 30 min. The unraked sand surface was black and malodorous and covered with a thin (1 to 2 mm) mat of black solids. The raked area indicated a black discoloration to approximately 10 cm into the bed. After smoothing the sand bed, 5.7 liters of 15% H_2O_2 were dosed on the filter. The filter was placed back into service approximately 45 minutes after this treatment. Subsequent measurements indicated that the hydraulic conductivity of the sand bed apparently had not been significantly rejuvenated by the raking and the level of H_2O_2 treatment employed. This was supported by the fact that a succeeding filter run lasted only 45 days until continuous ponding reoccurred. During this period, the filter air temperature ranged from 10 to 20°C and the STE temperature ranged from 8 to 10°C.

The sand filter effluent quality achieved is summarized in Table 8. Effluent quality was consistently high with BOD_5 and TSS concentrations of 6 and 10 mg/L, representing removal efficiencies of 97 and 83 percent, respectively. In addition to near complete nitrification of the influent, approximately 43% of the applied nitrogen was removed in the filter with a significant fraction apparently due to mechanisms other than simple retention or assimilation in biomass.(Siegrist et al., 1981). Total and fecal coliform concentrations were reduced by 97 and 99%, respectively, but concentrations in the filter effluent remained relatively high.

Sand Columns: The sand column studies were initiated in July, 1980 in parallel with the phase II filter run. The length of filter run for each column are presented in Table 6 along with the average dosing frequency and daily loading. Within one month after startup, all medium sand columns were continuously ponded. In the two replicate coarse sand columns loaded at 30 cm/d some ponding was noted after 220 days of loading and continuous ponding was present at the end of the 316 day study period. No ponding was observed in the two coarse sand columns loaded at 14 cm/d and final measurements indicated the infiltration rates of these two columns remained high after 316 days of operation. During the study period column air temperature ranged from 4 to 28°C and the STE temperatures varied from 7 to 12°C.

The effluent quality achieved during the column studies is delineated in Table 9. The effects of sand size and hydraulic loading on effluent quality were not pronounced except in the case of the high loaded medium sand columns where a lower quality effluent was produced. The effluents from all four coarse sand columns were of relatively high quality with the lower loaded columns producing only a slightly better effluent. Nitrification was prevalent in all but the high loaded medium sand, but was greatest with the low loaded coarse sand. From 26 to 55% of the applied nitrogen was not accounted for in the column effluents. This is similar to the experience with the sand filter. Two to three log reductions in fecal coliforms through the column still resulted in high effluent concentrations.

Operation of the sand columns differed from the sand filter in two distinct ways: the average daily loadings to the columns were lower and there were no surge doses during periods of high greywater production. While it is difficult to say for certain, these operational differences may have been responsible for the increased filter runs and volumes of STE processed in the coarse sand columns compared to the filter. The effluents from the coarse sand columns and the sand filter were comparable and of a high quality.

Sand Filtration Synopsis: It is difficult to directly compare the sand filtration results of this study to those of previous investigations due to the type of effluent applied and/or the method of application. Experience to date with intermittent sand filtration of domestic wastewater has been primarily associated with treatment of total domestic wastewater, typically from primary settling tanks, septic tanks or lagoons. Under these circumstances, high quality effluents are produced and filter runs vary depending on influent wastewater quality, loading rate and sand media size (U.S. EPA, 1980). Filtration of 20 cm/d of household STE applied in 4 to 6 doses/day typically yields filter run lengths of 3 to 6 months. The filter runs observed with greywater STE in this study suggested that multiple loading of wastewater to the filter may enhance effluent purification and run length of coarse sand filters. The sand filter loaded 24 times daily at 39 cm/day produced a significantly longer filter run than that loaded 6.6 doses/day at approximately the same daily loading. Effluent quality was also substantially better in the filter receiving more frequent doses. These findings were further corroborated in the coarse sand column filter runs at 14 and 30 cm/day. Similar results with primary treated residential wastewater have been reported previously (Furman et al., 1955). There is little doubt that intermittent sand filtration of greywater STE can yield a high quality effluent similar to that produced with total household STE. Questions remain however concerning whether longer filter runs and/or higher loading rates can be achieved with greywater STE as compared to total household wastewater STE. A study is in progress at the University of Wisconsin addressing these issues.

SUMMARY AND CONCLUSIONS

Field studies were conducted by the University of Wisconsin at four Wisconsin homes (Table 1) to investigate the characteristics of untreated greywater and the performance capabilities of septic tanks and intermittent sand filters. The following conclusions are developed from the results of these efforts.

1) The average greywater flow measured at each of three homes ranged from 75.7 to 126.7 Lpcd (Table 2).

2) Household greywater from four homes was found to contain sufficient concentrations of organic materials, solids, nutrients and fecal bacteria to warrant management on a par with that for total household wastewater (Table 3).

3). At two homes, treatment of raw greywater through septic tanks with average detention times of 6 days yielded 52 and 73% reductions in the suspended solids concentrations and conversion of nitrogen in an organic form to an ammonia form. Impacts on the other measured parameters were minimal (Table 4).

4) The septic tank effluent (STE) quality produced with greywater and total wastewater is quite similar, the only notable exceptions being reduced nutrient concentrations in the greywater STE (Table 5).

5) Filtration of greywater STE through 68 cm of a coarse sand (E.S. = 1.37 mm, U.C. = 1.30) was accomplished at an average daily loading of 38 cm/day (8.7 gpd/ft^2) applied in an average of 6.6 doses/day (Phase I). After 119 days of operation, the filter was continuously ponded (Table 6). Rejuvenation of the filter by vigorous raking to a 10 cm depth and reloading resulted in subsequent runs of only 27 and 28 days.

6) During the first filter run (Phase I), removal of BOD_5 averaged only 61% and suspended solids removals were near zero (Table 7). Although no nitrification occurred, 33% of the applied nitrogen was removed in the filter. Coliform concentrations were reduced by less than one log. The poor performance was attributed to the coarse media used, the application method (only 6 to 7 doses/day) and cool operating temperatures (2-10°C).

7) During Phase II, intermittent filtration of greywater STE through 68 cm of a similar coarse sand was accomplished at an average daily loading of 39 cm/day (9.0 gpd/ft^2) applied in an average of 22.5 hourly doses/day and 2.2 high-level doses/day (Table 6). After 149 days of operation the filter surface remained continuously ponded. Analyses of the filter media with depth indicated that a buildup of organic materials had occurred not only at the surface but with depth (Siegrist et al., 1981). Rejuvenation of the filter by raking to a 10 cm depth and treating with H_2O_2 (0.7 cm of 15% H_2O_2) yielded a subsequent filter run only 30% as long as the first.

8) The effluent quality achieved with hourly filter dosing was significantly better than that with six to seven random doses per day. Concentrations of BOD_5 and suspended solids averaged only 6 and 10 mg/liter, respectively, representing removals of 97 and 83% (Table 8). In addition to near complete nitrification, approximately 43% of the applied nitrogen was removed in the filter with a large fraction apparently due to mechanisms other than simple retention or assimilation in biomass. The enhanced performance of the filter during phase II was presumable due largely to the smaller dose volumes which provided for longer contact times. Also, fluctuations in daily loading and short-term peak loading were reduced during phase II.

9) Sand columns operated in parallel with the sand filter during phase II yielded filter runs of 316 days at 30.2 cm/d and runs in excess of this at 14.4 cm/d on a similar coarse-grained sand (E.S. = 1.02, U.C. = 1.44)(Table 6).

In contrast, medium sand columns (E.S. = 0.17 mm, U.C. = 2.82) loaded at these rates were all ponded continuously within 30 days of startup. During these studies dosing also occurred at 1 hour intervals, but no extra high-level doses occurred during periods of high flow.

10) Effluent quality with the coarse sand columns was very good and similar to that of the phase II sand filter run. Unexpectedly, the medium sand columns exhibited poorer effluent quality (Table 9).

ACKNOWLEDGMENTS-

This study was supported in part by funds from the State of Wisconsin administered by the Small Scale Waste Management Project at the University of Wisconsin-Madison. Substantial funding was also provided by U.S. Office of Water Research and Technology, Proj. OWRT B-105-WIS. The generous support of these funding agencies and the efforts of project staff are gratefully acknowledged. A special thank you is given to the residents at each of the participating homes.

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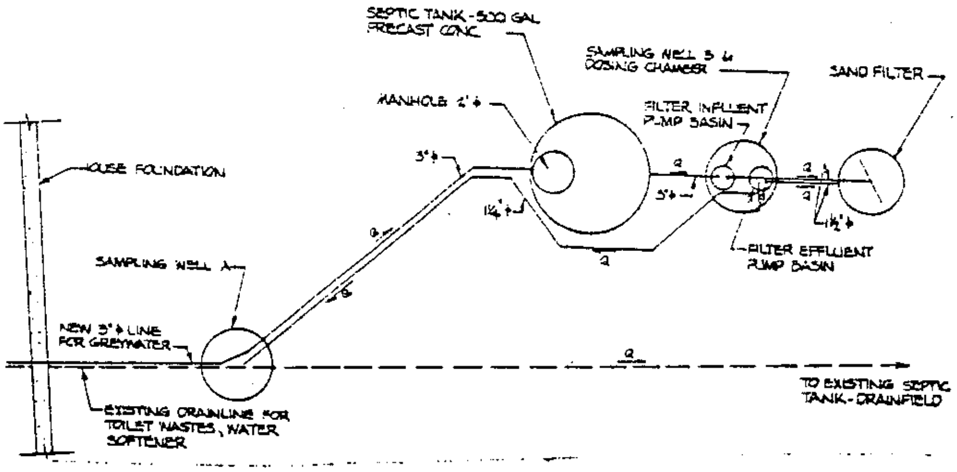

Fig. 1 Greywater Treatment Facilities

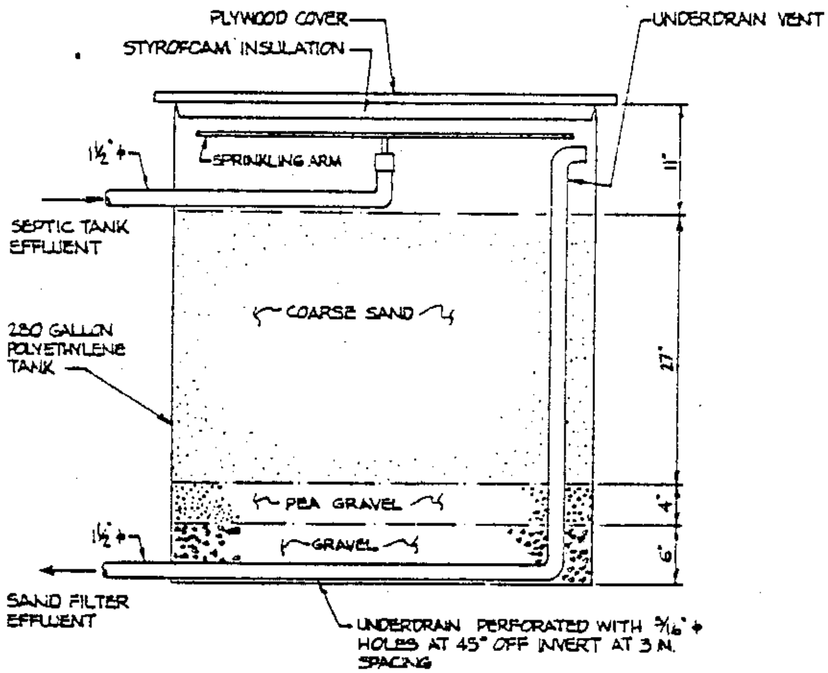

Fig. 2 Greywater Sand Filter Detail

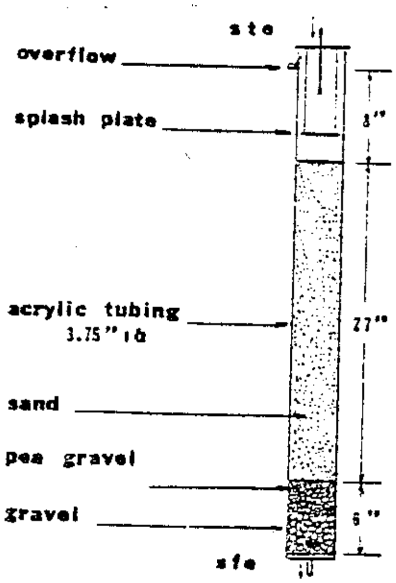

Fig. 3 Greywater Sand Column Detail

Table 4. Septic Tank Effluent Quality[a]

Parameter	Unit	Home 1 No.	Home 1 Mean	Home 1 Range	Home 2 No.	Home 2 Mean	Home 2 Range
BOD_5	mg/L	25	216	7-330	11	139	74-290
COD	mg/L	21	502	159-749	8	409	181-761
TS	mg/L	23	659	534-899	9	2584	1126-3694
TVS	mg/L	23	279	120-648	9	227	92-660
TSS	mg/L	21	52	18-95	5	38	22-50
TVSS	mg/L	19	37	0-72	4	23	18-33
TKN	mgN/L	22	18.6	12.4-27.7	9	13.1	8.4-19.9
NH_4-N	mgN/L	20	10.3	3.6-18.0	7	5.5	4.1-6.9
NO_3-N	mgN/L	20	0.2	0-1.2	7	0.6	0-2.7
TP	mgP/L	14	3.2	1.0-7.8	4	5.5	3.2-7.4
Alkalinity	$mgCaCO_3$/L	16	342	128-408	8	422	363-568
Turbidity	NTU	18	52	34-75	6	51	30-68
pH	-	5	-	6.8-7.6	4	-	6.4-7.5
Total Coliform	Log #/L	20	7.96	7.32-8.88	4	8.96	7.90-9.76
Fecal Coliform	Log #/L	22	7.09	6.00-8.60	10	7.31	6.70-8.15

[a]Home 1: Tank volume = 1984 L; Detention time ≈ 6.2 days; Data Period = Nov.'79-Feb.'81. Home 2: Tank volume = 1058 L; Detention time ≈ 6.9 days; Data Period = Sept.'79-Nov.'80.

Table 5. Comparison of Septic Tank Effluent Quality

Parameter	Unit	Greywater Home 1[a]	Greywater Home 2[a]	Greywater Brandes (1978)	Greywater Kristiansen[b] et al(1979)	Total SSWMP (1978)
BOD_5	mg/L	216	139	149	107-160	138
COD	mg/L	502	409	366	307-370	327
TSS	mg/L	52	38	162	28-43	49
TKN	mgN/L	18.6	13.1	11.3	13-26.2	45
NH_4-N	mgN/L	10.3	5.5	1.7	5.9-17.9	31
TP	mgP/L	3.2	5.5	1.4	-	13
pH	-	6.8-7.6	6.4-7.5	6.8	-	-
Total Coliform	Log #/L	7.96	8.96	8.38	-	-
Fecal Coliform	Log #/L	7.09	7.31	7.15	5.27-6.70	6.7

[a]Refer to Table 4.
[b]Range of mean values for three systems. Multi-chambered tanks. BOD_7 value.

Table 6. Greywater Sand Filtration Characteristics

Unit	Media E.S. (mm)	Media U.C.	Doses No/d	Doses Volume (cm)	Loading Daily (cm/d)	Loading Total (m)	Run Length (days)
Filter-I	1.37	1.30	6.6	5.7	37.4	44.6	119
-II	1.37	1.30	22.5 (2.2)[a]	1.35 (4.0)[a]	39.2	58.3	149
Column 1	1.02	1.44	24.0	1.26	30.2	95.4	316
2	1.02	1.44	24.0	1.26	30.2	95.4	316
7	1.02	1.44	24.0	0.60	14.4	>45.5	>316
8	1.02	1.44	24.0	0.60	14.4	>45.5	>316
3	0.17	2.82	21.0	1.33	28.0	10.6	38
4	0.17	2.82	22.3	1.33	29.7	25.6	86
5	0.17	2.82	22.3	0.64	14.2	12.2	86
6	0.17	2.82	21.6	0.64	13.8	0.6	43

[a]High level doses, in addition to hourly doses, in parentheses.

Table 1. Characteristics at Study Residences

Characteristic	Home 1	Home 2	Home 3	Home 4
Residents				
Adults	2	2	2	2
Children (Age)	2(5,2)	1(2)	3(4,6,14)	2(17,19)
Water-Using Fixtures				
Toilets	1	1	2	1
Bathtubs	1	1	1	1
Showers	1	1	1	1
Bath basins	1	1	2	1
Clotheswasher	1	1	1	1
Dishwasher	-	1	-	-
Kitchen Sink	1	1	1	1
Garbage Disposal	-	-	-	-
Water Softener	1	1	1	1
Water Supply	Well	Well	Well	Well
Waste Disposal	STSAS[a]	STSAS[a]	HT[b]	STSAS[a]

[a]Septic tank - soil absorption system; [b]Holding tank.

Table 2. Daily Greywater Flow Characteristics

Parameter	Unit	Home 1	Home 3	Home 4
Mean	LPCD	80.6	75.7	126.7
S.D.	--	52.2	67.6	58.1
95% C.I.	LPCD	71.2-90.1	56.8-94.6	112.8-140.4
Range	LPCD	7.6-259.3	14.2-274.2	47.3-364.3
Fraction	%	71.0	73.8	79.4
Data Points	Days	121	51	69
Data Period	--	11/79-12/80	8/80-6/81	12/79-10/80
Greywater Events[a]	--	KS,BS,B/S,CW,LS	KS,BS,B/S,CW,LS,	KS,BS,B/S,CW,LS WS

[a]Events included in greywater stream: KS = kitchen sink; BS = bathroom sink; B/S = bath or shower; CW = clotheswasher; LS = laundry sink; WS = water softener.

Table 3. Average Raw Greywater Quality

Parameter	Unit	Home 1	Home 2	Home 3	Home 4
BOD_5	mg/L	291	271	147	125
COD	mg/L	622	600	276	242
TS	mg/L	686	925	810	794
TVS	mg/L	274	289	179	128
TSS	mg/L	136	139	92	36
TVSS	mg/L	90	122	38	33
TKN	mgN/L	18.4	17.4	5.7	5.8
NH_4N	mgN/L	4.5	1.6	1.2	0.6
NO_3N	mgN/L	0.6	0.1	0.4	0.5
TP	mgP/L	4.8	11.9	0.3	1.0
Turbidity	NTU	58	67	-	42
Total Coliform	Log #/L	7.90	9.91	7.44	7.21
Fecal Coliform	Log #/L	7.28	7.78	6.68	5.54
Greywater Events[a]		KS,BS,B/S, CW,LS	KS,BS,B/S, CW,LS,	BS,B/S,CW, LS,	B/S,CW,

[a]Events included in total greywater stream: KS = kitchen sink; BS = bathroom sink; B/S = bath or shower; CW = clotheswasher; LS = laundry sink;

Table 7. Greywater Sand Filter Effluent Quality - Phase I

Parameter	Unit	Sand Filter Effluent[a] No.	Mean	Range	Removal Influent[b]	%R
BOD_5	mg/L	7	83	35-147	215	61
COD	mg/L	8	232	201-313	473	51
TSS	mg/L	4	45	13-80	41	0
TVSS	mg/L	3	4	0-8	22	82
TKN	mgN/L	8	14.6	6.0-24.2	22.0[c]	33[c]
NH_4N	mgN/L	7	8.5	0.7-16.9	-	-
NO_3N	mgN/L	7	0.2	0-0.4	-	-
Turbidity	NTU	8	20	8-32	52	62
Total Coliform	Log#/L	6	7.25	6.41-8.45	8.08	85
Fecal Coliform	Log#/L	8	6.55	5.30-7.89	7.27	81

[a]37 cm/d in 6.6 doses/day through 68 cm of coarse sand, E.S. = 1.37 mm, U.C. = 1.30. [b]Mean septic tank effluent during filter run. [c]Total nitrogen.

Table 8. Greywater Sand Filter Effluent Quality - Phase II

Parameter	Unit	Sand Filter Effluent[a] No.	Mean	Range	Removal Influent[b]	%R
BOD_5	mg/L	6	6	2-9	216	97
COD	mg/L	7	112	11-313	528	78
TSS	mg/L	7	10	4-17	60	83
TVSS	mg/L	7	5	0-14	46	89
TKN	mgN/L	7	3.0	1.2-5.2	15.5[c]	43[c]
NH_4N	mgN/L	7	0.3	0-1.0	-	-
NO_3N	mgN/L	7	5.9	2.6-12.8	-	-
Turbidity	NTU	5	2	1-4	54	96
Total Coliform	Log#/L	6	6.34	5.30-6.95	7.84	97
Fecal Coliform	Log#/L	3	4.78	3.18-6.18	6.91	99

[a]39 cm/d through 68 cm of coarse sand, E.S. = 1.37 mm, U.C. = 1.30. [b]Mean septic tank effluent during filter run. [c]Total nitrogen.

Table 9. Sand Column Mean Effluent Quality

Parameter	Unit	STE	Coarse Sand[a] 1	2	7	8	Medium Sand[a] 3	4	5	6
BOD_5	mg/L	243	18	13	13	10	54	60	15	14
COD	mg/L	519	51	49	30	35	180	206	70	37
TSS	mg/L	58	15	13	11	11	27	39	24	10
TVSS	mg/L	46	7	6	6	7	11	24	13	3
TKN	mgN/L	15.2	3.5	3.7	2.4	2.0	10.6	12.0	8.3	7.0
NH_4N	mgN/L	6.6	0.8	1.0	0.3	0.3	6.3	6.9	4.1	2.2
NO_3N	mgN/L	0.3	3.9	3.4	6.5	5.8	0.3	0.4	3.0	3.0
Total Coliforms	Log#/L	8.30	6.17	5.68	5.87	5.65	5.83	6.78	5.88	4.51
Fecal Coliforms	Log#/L	6.90	4.38	4.48	4.34	4.20	4.43	5.08	4.89	3.00
Loading	cm/d	-	30.2	30.2	14.4	14.4	28.0	29.7	14.2	13.8

[a]Coarse sand: E.S. = 1.02 mm, U.C. = 1.44 Medium sand: E.S. = 0.17 mm, U.C. = 2.82.