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Waste Segregation to Facilitate Onsite Wastewater Disposal Alternatives

by

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WASTE SEGREGATION TO FACILITATE ONSITE WASTEWATER DISPOSAL ALTERNATIVES

Robert L. Siegrist

The search for improved methods of onsite wastewater management initially centered largely around developing more effective treatment and soil disposal system technology. However, acknowledging the impact of wastewater characteristics on management efforts, increasingly more emphasis is being placed on altering the characteristics of the raw wastewater. Elimination or isolation of potential pollutants at the source, such as flow, BOD_5, suspended solids, nutrients and pathogenic organisms would leave the major volume of wastewater lesser contaminated, thereby enhancing conventional disposal methods or facilitating the development of innovative alternatives.

A powerful strategy for altering typical wastewater characteristics involves in-house waste segregation. As illustrated in Figure 1, waste segregation involves the in-house separation of the individual waste streams produced within a household into three major fractions: (1) the toilet wastes, often referred to as *black water*, (2) the garbage wastes, and (3) the remaining household wastewaters, collectively referred to as *grey water*. The elimination of the garbage disposal and removal of the toilet wastes from the remaining household wastewater stream through use of a non-conventional toilet system (e.g. composting, incinerating, recycle, low volume/flush holding tank) would serve to (1) eliminate unnecessary waterborne wastes, (2) eliminate dilution of concentrated raw waste materials, (3) avoid the co-mingling of wastes of grossly different character and (4) reduce the wastewater flow volume. As a result, major benefits may be realized including, (1) suitable onsite wastewater treatment and disposal in a traditionally unsuitable area, (2) a potential for recycling valuable nutrients to the soil, (3) a reduced nutrient input to groundwater, lakes and streams, and (4) a conservation of water resources.

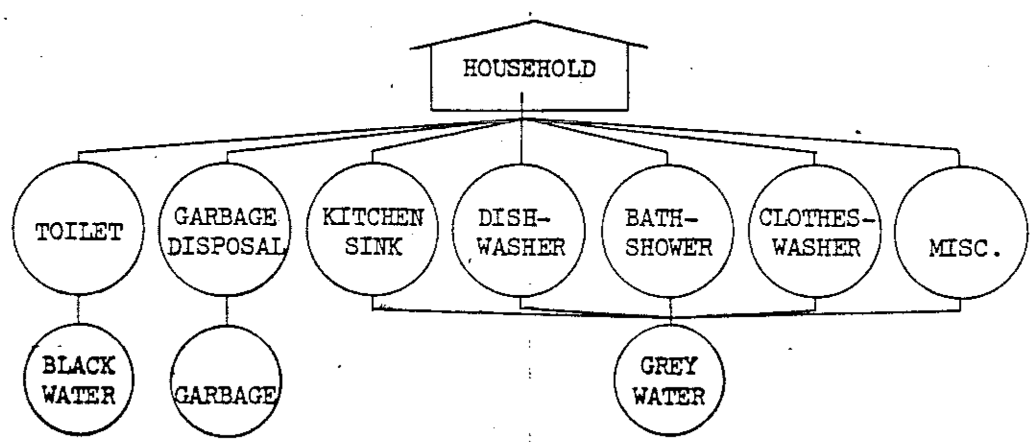

Fig. 1. In-House Waste Segregation

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To effectively develop and evaluate the segregated treatment/disposal system concept, investigations have been undertaken as part of the Small Scale Waste Management Project at the University of Wisconsin. Special emphasis has been directed toward the treatment and disposal of grey water, including the development of a feasible grey water treatment system not dependent on site soil conditions. This paper presents a discussion of the theory and application of segregated treatment to facilitate innovative wastewater management. Included is a discussion of research and development efforts previously accomplished and presently scheduled at the University of Wisconsin.

SEGREGATED WASTEWATER CHARACTERISTICS

The potential efficacy of waste segregation for separate treatment is indicated by the characteristics of each wastewater fraction. Based on the results of recent detailed characterization studies, the individual water-using events which typically occur within the home may be grouped to yield three major waste fractions: (1) garbage disposal wastes, (2) toilet wastes, referred to as *black water*, and (3) sink, basin and appliance wastewater, collectively referred to as *grey water* (Siegrist, et al., 1976; Bennett and Linstedt, 1975; Ligman, et al., 1974; Olsson, et al., 1968; Wallman and Cohen, 1974; Laak, 1975). A summary of the average pollutant contributions identified for these three waste fractions is presented in Table 1. It must be emphasized that the values presented are averages, and considerable day-to-day variation may occur at a given home and between homes.

Table 1. Average Pollutant Contributions of Major Residential Wastewater Fractions, grams/capita/day

Fraction	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Approximate Total Contribution
BOD_5	18.0[a] 10.9 - 30.9[b] (1,2,3)[c]	16.7 6.9 - 23.6 (1,2,3,4,6)	28.5 24.5 - 38.8 (1,2,3,4,6)	63.2
Suspended Solids	26.5 15.8 - 43.6 (1,2,3)	27.0 12.5 - 36.5 (1,2,3,4)	17.2 10.8 - 22.6 (1,2,3,4)	70.7
Nitrogen	0.6 0.2 - 0.9 (1,2,3)	8.7 4.1 - 16.8 (1,2,3,4)	1.9 1.1 - 2.0 (1,2,4)	11.2
Phosphorus	0.1 0.1 - 0.1 (1,2,)	1.2 0.6 - 1.6 (1,3,4)	2.8 2.2 - 3.4 (1,3,4)	4.0
Approximate Flow[d] gal/c/d	2 (1,2,3)	16 (1 - 6)	29 (1 - 6)	47

[a]Mean of Study Average Values.

[b]Range of Study Average Values.

[c]References used in mean and range calculations as follows;

1. Siegrist, et al., 1976
2. Bennett and Linstedt, 1975
3. Ligman, et al., 1974
4. Olsson, et al., 1968
5. Wallman and Cohen, 1974
6. Laak, 1975

As presented in Table 1, the use of a garbage disposal may contribute significant quantities of BOD_5 (28%) and suspended solids (37%) to the household wastewater load while adding little nitrogen (5%), phosphorus (2%) or flow volume (4%). Further, it has been shown that the use of a garbage disposal may increase the rate of sludge and scum accumulation and produce a higher failure rate for conventional disposal systems under otherwise comparable conditions (Bendixen, et al., 1961). For these reasons as well as the fact that most wastes handled by a garbage disposal could be handled as solid wastes, the elimination of this appliance is felt to be advisable.

Comparison of the remaining two waste fractions, the toilet wastes (black water) and the basin, sink and appliance wastewaters (grey water), indicates that elimination of the toilet wastes from the onsite wastewater stream through use of an alternative toilet system would serve to remove major quantities of BOD_5 (37%), suspended solids (61%), nitrogen (82%) and phosphorus (30%) and reduce the wastewater flow volume by approximately 35% (Table 1).

Although the chemical/physical characteristics discussed previously are of importance, the microbiological characteristics of the segregated waste fractions, and in particular the grey water, are of equal or perhaps greater concern. The obvious concern regards the potential for occurrence of pathogenic organisms in the grey and/or black water streams. Obviously, a prerequisite to encountering any pathogenic organism in either waste fraction is that a member of a household, or visitor thereof, be shedding pathogens. Intuitively, one would expect the majority of any pathogens shed to be contributed in the toilet wastes with the grey water being comparatively innocuous. To evaluate this intuitive hypothesis, microbiological studies have been conducted at the University of Wisconsin (Siegrist, 1977; Small Scale Waste Management Project, 1977). In-house samples of the wastewater produced by two key grey water events, bathing and clothes washing, were obtained from each of six households over a two-week period and analyses were performed for total and fecal coliforms and fecal streptococci. In addition, coliform and streptococcal isolates were taken for further characterization.

The summarized results of the indicator bacteria analyses are presented in Table 2. As shown, the results demonstrate that a wide range of indicator organisms can be expected in the raw bath and laundry wastewaters.

Table 2. Bacteriological Characteristics of Bath and Laundry Wastewaters[a]

Event	Organism	Samples	Mean[b] No./100 ml	95% Confidence Interval - No./100 ml
Clotheswashing[c]	Total Coliforms	41	215	65 - 700
	Fecal Coliforms	41	107	39 - 295
	Fecal Streptococci	41	77	27 - 220
Bathing	Total Coliforms	32	1810	710 - 4600
	Fecal Coliforms	32	1210	450 - 3240
	Fecal Streptococci	32	326	100 - 1050

[a]The results shown are from in-house sampling at each of six residences.

[b]Log-normalized data.

[c]Samples were obtained from the middle of the wash cycle. Samples taken from 15 rinse cycles were consistently lower than the corresponding wash cycle values.

Coliform and streptococcal isolates were taken from the bath and laundry samples obtained at three of the study households for further characterization. This characterization of 85 fecal coliform and 48 streptococcal isolates indicated that much of the bacterial contamination in the wastewaters was probably from the natural environment or skin flora of man. However, the incidence of certain enterobacteriaciae did indicate possible fecal contamination. Further analyses were performed on the samples obtained from the other three study homes for two common pathogens, Pseudomonas aeruginosa and Staphylococcus aureus. The results indicated a very low incidence of Pseudomonas aeruginosa (1 of 3 homes, 7 of 47 samples) and in those samples where it was isolated, the concentrations were always below 20/100 ml. Staphylococcus aureus was not isolated in any of the 45 samples analyzed.

Bathing and clotheswashing represent the two major residential activities which possess the potential for yielding pathogenic contamination of the residential grey water fraction. The result of these microbiological studies have demonstrated that the bath and laundry wastewaters possess a potential for containing enteric organisms, as well as non-enteric organisms. However, this potential appears substantially lower than that of either the toilet wastes or combined household wastewaters.

SEGREGATED TREATMENT AND DISPOSAL STRATEGIES

The successful application of waste segregation and separate treatment requires the effective management of both the black water and grey water fractions.

Black Water Management

Various strategies have been proposed to enable segregation and separate management of the toilet wastes. Those strategies which appear most feasible for residential use at present, have been outlined in Figure 2. A discussion of these strategies has been presented elsewhere (Rybczynski and Ortega, 1975; Orr and Smith, 1976; Milne, 1976; Siegrist, et al., 1977).

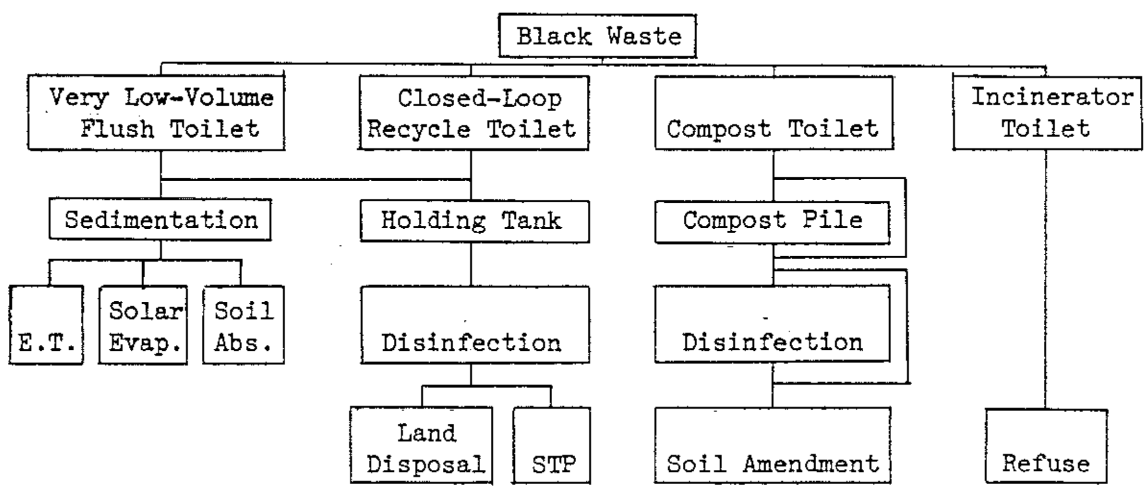

Fig. 2. Strategies for Black Waste Management

Grey Water Management

Typically, when segregated systems have been suggested with the toilet wastes handled through use of an alternative toilet system, grey water disposal has involved a conventional septic tank - soil absorption system. However, more innovative management schemes may be feasible based on the reduced pollutant load and contamination of the grey water. Several potential strategies for grey water management are outlined in Figure 3 and a brief discussion follows.

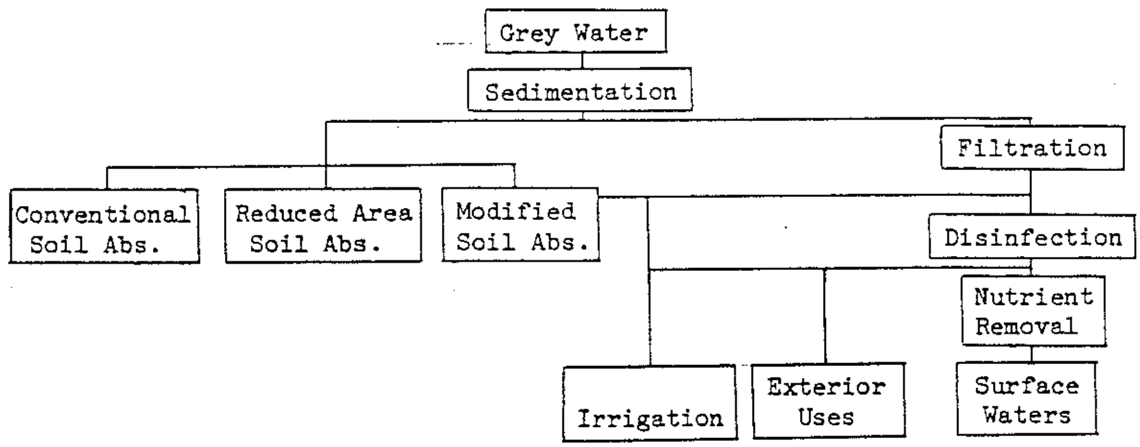

Fig. 3. Strategies for Grey Water Management

Reduced-Size Soil Absorption System: An obvious method of treatment and disposal consists of a septic tank and soil absorption field. Further, due to the reduced wastewater volume and pollutant mass encountered in grey water, suitable reductions in the size of this system have been suggested. Several states are allowing soil absorption fields for household grey water to be sized at 2/3 or even 1/2 that typically required (e.g. Maine and Oregon). The reduction in system size is typically restricted to the soil absorption field. This reduced size would seem reasonable due to a lower hydraulic loading; grey water, on the average, comprises about 65% of the normal wastewater flow volume. Additionally, waste segregation provides for the reduction in quantity and concentration of certain pollutants, which would appear to further support a reduced sizing. Although most efforts to correlate soil clogging with household wastewater characteristics have been generally unsuccessful, especially in structured soils (Small Scale Waste Management Project, 1977), the results of preliminary laboratory studies have indicated that grey water septic tank effluent is relatively more acceptable to non-structured sandy soils than combined wastewater septic tank effluent (grey water treatment and disposal studies, this paper). As yet, the effects of grey water on soil absorption systems, either beneficial, detrimental, or of no consequence, have not been well delineated and any reduction in field sizing must be attributed to the reduced hydraulic loading.

Surface Discharging Systems: The surface disposal of an effluent produced by a small-scale wastewater treatment system is a very complex subject. Major concerns relate not only to the technological aspects, but to the institutional and regulatory aspects as well. A detailed analysis of the institutional/regulatory aspects of surface discharging systems has been conducted previously (Stewart, 1976; Small Scale Waste Management Project, 1977). Thus, the present discussion has been restricted to the technical aspects of grey water surface discharging systems.

Any small-scale wastewater treatment system which includes surface disposal of its effluent must be reliable in producing a consistently high quality effluent to ensure protection of the public health and the environment. For most applications, the pollutants of concern will include BOD_5, suspended solids and pathogenic organisms and, in many applications, nitrogen and phosphorus. As discussed previously, the black waters contain the majority of pathogenic organisms, nitrogen and suspended solids and significant quantities of BOD_5 and phosphorus. Thus, if the black waters and their share of pollutants were segregated through use of an alternative toilet system, the grey water should be more amenable to an alternative onsite treatment system employing surface disposal.

A treatment system which has proven its technical feasibility in regard to the treatment of combined household wastewater for surface disposal consists of septic tank pretreatment followed by sand filtration and some form of disinfection (dry feed chlorination or ultraviolet light irradiation) prior to surface disposal (Sauer, 1976; Sauer and Boyle, 1977). Although this system has not been thoroughly evaluated for the treatment of household grey water, a preliminary analysis has indicated that waste segregation may greatly enhance the technical feasibility of this alternative (Siegrist, 1976; Grey Water Treatment and Disposal Studies, this paper).

Modified Subsurface Disposal: Typically, three feet or more of suitable, unsaturated soil must exist between the bottom of a soil absorption field and a limiting layer such as high groundwater or poroused/creviced bedrock to ensure adequate purification and drainage. It is conceivable that for a lesser contaminated effluent such as grey water, the required value of three feet may be reduced somewhat and still provide adequate purification and drainage. This would seem particularly feasible if the grey water were treated prior to subsurface disposal, for example by a septic tank - sand filter system as previously described. Unfortunately, data is presently lacking to either support or refute this alternative.

System Application

The actual application of a segregated treatment system will depend on several factors, including (1) adequate performance capabilities, (2) ensurances of reliable performance by proper operation and maintenance, (3) cost-effectiveness, (4) user acceptance, (5) available alternatives (especially for an existing problem), and (6) regulatory confidence and approval. To properly address these issues and provide a sound basis for decision, for the homeowner as well as regulatory officials and agencies, detailed investigations are necessary in the treatment and disposal of grey water as well as black water.

GREY WATER TREATMENT AND DISPOSAL STUDIES

To enhance the limited data base regarding the treatment and disposal of household grey water as previously described (Figure 3), preliminary laboratory investigations were conducted and field studies are being initiated at the University of Wisconsin.

Laboratory Study

A preliminary laboratory study was conducted from April, 1976 to April, 1977 to (1) identify the comparative performance of septic tank - sand filtration of grey water versus combined wastewater, (2) identify the comparative performance of a 2.0 m^3 (500 gal) versus 4 m^3 (1000 gal) septic tank, and (3) identify further areas of research. To provide a controlled environment for this preliminary study and facilitate the above types of comparisons, this effort was accomplished in a rather unique research laboratory. At this laboratory, the wastewater generated by typical household events was simulated utilizing conventional appliances as well as specially designed equipment and consumer materials/waste products (both off-the-shelf and substitute materials). Utilizing an electronic control system, the simulated household events were made to occur intermittently during the day, yielding a loading pattern representative of that generated by a family of four. By staggering the schedule of events, the same event sequence and daily loading could be applied to each of several treatment units. A discussion of this study follows; additional details regarding the study have been presented elsewhere (Small Scale Waste Management Project, 1977).

Influent Wastewater: The events simulated included toilet use, bathing, dish-rinsing, dishwashing, clotheswashing, and miscellaneous. The day-to-day loading was constant for all events with the exception of the laundry, which varied from none to three occurrences per day. The grey waters were directed to each of two septic tanks of 2.0 m^3 (500 gal) and 4.0 m^3 (1000 gal) size. A third septic tank of 4.0 m^3 (1000 gal) size received the same grey waters as well as toilet flush wastewaters. The average characteristics of the simulated influents are shown in Table 3.

Table 3. Simulated Raw Wastewater Characteristics - Daily Averages

	Grey		Combined	
Parameter	Volume or Mass	Concentration (mg/L)	Volume or Mass	Concentration (mg/L)
Flow	484 L	-	711 L	-
BOD_5	108 g	220	186 g	260
COD	203 g	420	519 g	730
TS[1]	396 g	820	874	1230
TSS	52 g	110	295 g	410
TN	5.6 g	12	57 g	80
TP	21.5 g	44	40 g	57

[1]Includes 300 mg/L total solids contribution from the tap water.

Septic Tank Operation: During a preceding study, the septic tanks had received simulated combined wastewater similar to that used in this study for 15 months. The 4 m^3 (1000 gal) tanks were simply switched over to their new wastewaters while the 2 m^3 (500 gal) tank was pumped down and cleaned out except for a small quantity of diluted residual material. For three months prior to the start of this evaluation, the septic tanks received their respective "new" wastewaters to stabilize their performance.

Sand Filter Operation: Eight sand filter lysimeters were established specifically for this study. Each filter was about 0.3 m^2 (1 ft^2) in surface area, with .30 m (1 ft) of freeboard, .60 m (2 ft) of sand, .13 m (.40 ft) of pea gravel, and .18 m (.60 ft) of coarse stone. A summary of the experimental design for the filtration research is presented in Table 4.

Table 4. Sand Filter Experimental Design

		Application		Media Size	
Filter Number	Septic Tank Effluent Applied	Doses/Day	cm/Day	Effective Size (mm)	Uniformity Coefficient
1, 2	Grey Water	5	30	.28, .30	3.2, 2.9
3, 4	"	5	15	.30, .28	2.9, 3.2
5, 6	Combined	6	15	.28, .30	3.2, 2.9
7, 8	"	6	30	.30, .28	2.9, 3.2

After the first two months of operation at the prescribed loading, the loading was discontinued, and the top 15 centimeters of sand were replaced. The filters were rested for nine days prior to the start of actual data collection.

Septic Tank Performance: The results of selected chemical/physical analyses on daily flow-composited effluent samples are presented in Table 5. The effluent from the 2 m^3 (500 gal) septic tank treating grey water was significantly higher in BOD_5 and COD than the 4 m^3 (1000 gal) septic tank also treating grey water, while there was virtually no difference for the other measured parameters. The increased residence time in the larger tank may have been responsible for the greater BOD_5 and COD reductions. Also, the circular, 2 m^3 (500 gal) tank effluent could have been influenced by surge loadings more than the longer, cylindrical 4 m^3 (1000 gal) tank. Although the concentrations of BOD_5, COD and suspended solids were considerably higher in the raw combined wastewater as compared to the raw grey water (Table 3), the characteristics of the effluents from the two 4 m^3 (1000 gal) septic tanks were essentially the same (Table 5).

Table 5. Septic Tank Effluent Comparison, mg/L

Parameter	Grey water 2 m^3 (500 gal)	Grey water 4 m^3 (1000 gal)	Combined Wastewater 4 m^3 (1000 gal)
BOD_5[a]	101(44) 88-144[b]	62(57) 56-68[c]	55(60) 50-61[c]
COD	236(42) 220-252[c]	171(55) 159-183[c]	169(58) 155-185[c]
TSS	47(41) 42-53[c]	46(56) 41-51[c]	46(58) 41-52[c]
VSS	37(40) 32-41[c]	34(55) 32-37[c]	33(58) 30-37[c]
Tot-N	6.5(22) 6.1-7.0	7.7(22) 7.0-8.4	79(22) 75-84
NH_3-N	1.4(25) 0.9-1.8	2.1(39) 1.7-2.5	54(43) 49-59
Tot-P	44(28) 41-47	40(30) 37-42	43(27) 40-45
Ortho-P	34(27) 29-38	34(26) 31-37	36(27) 33-39

[a]Based on 10 sample analyses, soluble BOD_5 to total BOD_5 equal to 0.8 for all units.

[b]Mean (no. of samples) 95% Confidence Interval.

[c]Log-normalized data.

The results of bacteriological analyses on several grab samples of each septic tank effluent are presented in Table 6.

Table 6. Bacteriological Characteristics of Septic Tank Effluents, Log no./100 mL

Organism	Sample date	Grey water 2m^3 (500 Gal)	Grey water 4m^3 (1000 Gal)	Combined Wastewater 4m^3 (1000 Gal)
Total Coliform	7-76	NS	5.52	6.69
	11-76	5.18	5.08	5.08
	5-77	NS	6.73	6.70
Fecal Coliform	7-76	NS	5.52	6.69
	11-76	4.53	4.69	4.49
	5-77	NS	6.56	6.15
Fecal Streptococci	7-76	NS	NS	NS
	11-76	<2.00	4.26	3.68
	5-77	NS	3.36	5.53
Total Bacteria	7-76	NS	8.49	9.04
	11-76	7.60	6.61	7.20
	5-77	NS	8.52	10.20

NOTE: NS = No Sample

It was anticipated that indicator bacteria would be present in the grey water septic tank effluents initially as a result of pre-study operations with combined wastewaters, but that with time and the dilution affected by the influent grey waters the concentrations would decrease to low levels. However, even after seven and thirteen months of operation, very high levels of indicator bacteria were found. If the traditional indicator bacteria do actively reproduce in a grey water septic tank environment, one must question the value of using the effluent concentrations of these organisms as indicators of potential pathogenic contamination of the grey waters.

Sand Filter Performance: Each of the eight sand filters was operated until ponding above the sand surface occurred and reached a height of about 0.25 m (10 in). Only the four high-rate filters (1,2,7,8) failed during the course of this study. A summary of the operational data for each of these four filters is presented in Table 7.

Table 7. High-Rate Filter Operation

	Effluent Application			Run Days to -		Total Application/m^2		
Filter	Type	Doses/day	cm/day	Ponding	Failure	Liters	Grams BOD_5	Grams SS
1	Grey	5	29, 26-32[a]	226	264	6610	4410	3230
2	Grey	5	29, 26-32	260	285	7110	4740	3550
7	Combined	6	31, 28-33	104	124	3330	1940	2040
8	Combined	6	31, 28-33	108	124	3310	1940	2040

[a]Mean followed by 95% Confidence Interval for run length.

The grey water filters yielded run lengths over twice those of the combined wastewater filters accepted about twice as much wastewater, and effectively removed about 140% more BOD_5 and 60% more suspended solids (Tables 7,8).

Table 8. Sand Filter Effluent Characteristics, mg/L

	Grey water				Grey/Black water			
Parameter	1	2	3	4	5	6	7	8
BOD_5[a]	1(17)[b] 1-3	1(18) 1-3	1(17) 1-3	1(18) 1-2	2(19) 1-3	1(13) 1-3	4(15) 2-7	4(20) 2-6
COD	26(6) 13-39	17(7) 7-27	21(7) 7-35	16(7) 12-20	16(9) 10-23	18(9) 10-25	25(6) 9-40	57(9) 29-86
SS[a]	12(19) 9-16	14(19) 10-19	11(16) 7-16	8(20) 6-10	8(20) 5-12	15(13) 9-23	18(14) 11-31	17(20) 12-25
VSS	8(19) 6-9	7(19) 5-9	7(16) 5-9	5(20) 4-6	5(20) 3-6	6(13) 4-9	10(15) 6-14	8(20) 5-10

[a]Log-normalized data.

[b]Mean (samples) over 95% Confidence Interval

Conclusions

1. The reductions in BOD_5 and COD are considerably greater in grey water when treated with a 4 m^3 (1000 gal) septic tank as compared to a 2 m^3 (500 gal) septic tank.

2. Bacteria used as indicators of fecal contamination were found to maintain high concentrations in the effluents from septic tanks receiving just grey water after as much as thirteen months of operation without a fecal input.

3. Sand filters receiving 30 cm/day of grey water septic tank effluent yielded filter run lengths over twice as long, processed over twice as much

wastewater, and removed over 140% more BOD_5 and 60% more suspended solids than did similar filters receiving combined wastewater septic tank effluent.

4. Intermittent sand filtration of grey water septic tank effluent through 60 cm of medium sand at application rates of about 15 and 30 cm per day, produced effluents low in BOD_5 and suspended solids, almost completely nitrified, with the phosphorus largely unchanged.

Future Field Studies

Two major grey water studies are planned in the areas of (1) soil absorption and (2) sand filtration for surface disposal. The overall objective of the soil absorption study is to evaluate the comparative acceptability and purification of grey water and combined wastewater in both structured and non-structured soils. To accomplish this, *in situ* lysimeters as well as soil columns are being utilized. The overall objective of the sand filtration study is to extend the preliminary laboratory research into the field. To facilitate this, a segregated waste treatment facility is being installed at a three-bedroom home.

SUMMARY

In-house waste segregation appears to offer a means of enhancing conventional disposal methods and facilitating the development of alternatives by isolating or eliminating potential pollutants at the source. The elimination of the garbage grinder, and removal of the toilet wastes (black wastes) from the remaining household wastewater stream (grey water) through use of a non-conventional toilet system, could yield major benefits, including (1) suitable onsite wastewater treatment and disposal in a traditionally unsuitable area, (2) a potential for recycling valuable nutrients to the soil, (3) a reduced nutrient input to groundwater, lakes and streams, and (4) a conservation of water resources. To reap these potential benefits, diverse strategies have been proposed for management of the two waste fractions. Further research and development and field investigations are necessary to properly evaluate the proposed strategies.

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