#2.23

SMALL SCALE WASTE MANAGEMENT PROJECT

Management of Residental Greywater

by

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March 1978

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MANAGEMENT OF RESIDENTIAL GREY WATER

Robert L. Siegrist

In striving to develop improved methods of onsite wastewater management, increasingly more emphasis is being placed on developing in-house water conservation and waste load reduction strategies. Elimination of potential pollutants at the source or their isolation in a concentrated waste stream are being recognized as possible methods for enhancing conventional disposal practices or facilitating the development and use of alternative management schemes.

A powerful strategy which has evolved is waste segregation and separate treatment. Basically, this strategy involves segregating the individual water-using events which typically occur within a home into three fractions, 1) garbage disposal wastes, 2) toilet wastes and, 3) sink, basin and appliance wastewaters. Processing the garbage wastes as a solid material and using an alternative toilet system, such as a composting or closed-loop recycle unit for the toilet wastes would reduce the wastewater flow volume and pollutant load of residential households to that from the basins, sinks and appliances, often collectively referred to as *Grey Water*.

Although the successful application of alternative toilet systems and segregated treatment strategies requires the handling of all waste fractions,

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the effective management of the grey water fraction has often been disregarded. The purpose of this paper is to present a discussion of the management of residential grey water, including a detailed analysis of its characteristics and an overview of the types of strategies which have been proposed for its management. Also included is a discussion of research and development efforts previously accomplished and presently scheduled at the University of Wisconsin.

CHARACTERISTICS OF RESIDENTIAL GREY WATER

To identify appropriate systems for processing residential grey water prior to disposal and/or reuse, a knowledge of its characteristics is required. Although residential grey water as a whole has not been monitored to any degree, the results of detailed characterization studies involving individual grey water event wastewaters have been used to predict the characteristics of the grey water stream in total.

At the onset, it is important to realize that variations in the characteristics of grey water can occur at a given home and between homes due to a variety of influences. The physical characteristics of the household, particularly the number and characteristics of the basins, sinks and appliances present exert major influences as do the characteristics and habits of the residents. Thus, average or representative grey water characteristics must be used cautiously in light of the fact that at a particular home, substantial variations may be encountered.

Grey Water Flow Volumes

A summary of the average flow volumes determined by several investigators for household grey water events is presented in Table 1. Also presented are the values determined for garbage disposal usage and water-carriage toilet usage.

Table 1. Water-Use Characteristics of Grey Water Events

Fraction	Event	Gal/Use	Use/Cap/Day	Gal/Cap/Day
Grey Water	Bath/Shower	24.5[a] 21.4-27.2[b] (2,4,5)[c]	0.43 0.32-0.50 (2,4,5)	9.2 6.3-12.5 (1-5)
	Clotheswashing	37.4 33.5-40.0 (2,4,5)	0.29 0.25-0.31 (2,4,5)	10.0 7.4-11.6 (1-5)
	Dishwashing	8.8 7.0-12.5 (2,4,5)	0.35 0.15-0.50 (2,4,5)	3.2 1.1-4.9 (2,4,5)
	Miscellaneous	-	-	6.6 5.7-8.0 (2,4,5)
	Total	-	-	29.0 21.6-34.8 (1-5)
Garbage	Garbage Grinding	2.0 2.0-2.1 (2,4)	0.58 0.4-0.75 (2,4)	1.2 0.8-1.5 (2,4)
Black Water	Toilet	4.3 4.0-5.0 (1,2,4,5)	3.5 2.3-4.1 (1,2,4,5)	16.2 9.2-20.0 (1-5)

Note: Litres = 3.8 x gallon. Gal/cap/day may not equal gal/use multiplied by uses/cap/day to difference in the number of study averages used to compute the mean and ranges shown.

[a] Mean of study averages.

[b] Range of study averages.

[c] References included in determining mean and/or range: (1) Wallman and Cohen 1974; (2) Ligman, et al., 1974; (3) Laak, 1975; (4) Bennett and Linstedt, 1975; (5) Siegrist, et al., 1976.

As shown, the primary contributors to the grey water flow are the activities of bathing (9.2 gal/cap/day or 32%) and clotheswashing (10.0 gal/cap/day or 34%). In total, the grey water generated in a typical residential dwelling was, on the average, 29 gal/cap/day. For a representative dwelling with a garbage disposal and water-carriage toilet, this grey water flow would represent about 62% of the total daily wastewater flow.

Grey Water Quality

Chemical/Physical Constituents--

BOD_5, TSS, N, P--A summary of the average contribution of biochemical oxygen demand (BOD_5), total suspended solids (TSS), Nitrogen (N) and Phosphorus (P), as determined by several investigators, is presented in Table 2. As shown, the grey water does contain significant concentrations of the pollutants measured. However, the mass of pollutants contributed is substantially less than that in a dwelling with a garbage disposal and water-carriage toilet, particularly with regard to total suspended solids and nitrogen.

Grease--Based on the analysis of a limited number of individual event samples, a grease concentration on the order of 125 mg/L was estimated for the grey water (Witt, et al., 1974).

Surfactants--Bennett and Linstedt (1975) reported MBAS contributions for individual grey water events as part of a household wastewater characterization study. Using these results, an average contribution of 3.4 gram/cap/day yielding a concentration of 34 mg/L was calculated for the grey water fraction. Hypes (1975) measured the MBAS concentration in the grey water produced by a family of four utilizing appliances and facilities in a special research facility. A somewhat lower average concentration of 22 mg/L was measured.

pH--Based on the results of characterization studies conducted by Bennett and Linstedt (1975), Olsson, et al., (1968) and Hypes (1975), the pH of residential grey water appears to be slightly alkaline, in the range of 7.2 to 7.6.

Table 2. Average Pollutant Characteristics of Residential Grey Water

Pollutant	Grey Water			Garbage Disposal	Toilet	Approx. Total
	g/cap/day	Mean % of Total	Mean Mg/L	g/cap/day	g/cap/day	g/cap/day
BOD_5	28.5[a] 24.5-38.8[b] (1-5)[c]	45	260[d]	18.0 10.9-30.9 (1-3)	16.7 6.9-23.6 (1-5)	63.2
TSS	17.2 10.8-22.6 (1-4)	24	160[d]	26.5 15.8-43.6 (1-3)	27.0 12.5-36.5 (1-4)	70.7
Tot N	1.9 1.1-2.0 (1,2,4)	17	17[d]	0.6 0.2-0.9 (1-3)	8.7 4.1-16.8 (1-4)	11.2
Tot P	2.8 2.2-3.4 (1,3,4)	70	25[d]	0.1 0.1-0.1 (1-3)	1.2 0.6-1.6 (1,3,4)	4.0

[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. Laak, 1975

[d] Based on a flow volume of 29 gal/cap/day (Refer to Table 1).

<u>Temperature</u>--Certain grey water events such as clotheswashing and dishwashing can utilize relatively high water temperatures (e.g., 60° C). However, when combined with other grey water events and more importantly, after carriage through the appliance and drainage system plumbing, the high temperature flows are likely to be substantially moderated. Based on in-house temperature measurements of individual grey water events by Bennett and Linstedt (1975), an average temperature of about 42° C was calculated for the grey water flow prior to carriage. The results of studies conducted at the University of Wisconsin

indicated an average temperature of approximately 31° C for the grey water flow at the point of discharge from a household (Siegrist, et al., 1976). Similar effluent temperatures have been reported by Olsson, et al., (1968).

Microbiological Characteristics--

When identifying the type of treatment required to render residential grey water suitable for disposal/reuse, the microbiological characteristics of the raw grey water are of prime importance. Specifically, a knowledge of the potential for occurrence and transmission of pathogenic bacteria and virus in the grey water is required. Obviously, a prerequisite to the actual occurrence of any pathogenic organisms in any residential wastewater fraction is that a member of the residence, or a visitor, be shedding pathogens.

Olsson, et al., (1968) monitored the grey waters produced in bathrooms and kitchens serving apartment homes in a 25 unit building near Stockholm, Sweden, yielding the results shown in Table 3. As shown, very high levels of coliform

Table 3. Bacteriological Characteristics of Grey Water,[a] Organisms/100 ml (Olsson, et al., 1968).

Fraction	Organism	Arithmetic Mean	Standard Deviation
Bathroom	Total Coliforms	6,100,000	24,500,000
	Fecal Coliforms	970,000	2,470,000
Kitchen	Total Coliforms	30,100,000	32,700,000
	Fecal Coliforms	6,100,000	4,200,000
Kitchens/Bathrooms	Total Coliforms	3,800,000	4,800,000
	Fecal Coliforms	940,000	1,290,000

[a] Based on the results of 18-28 samples of each fraction taken during a one week period from a separated drainage system serving a 25 unit aparment building.

organisms were isolated in the grey waters sampled. The investigators also sampled the wastewaters for the drainage line serving vacuum toilets in each of the apartments. Surprisingly, on the basis of organism/capita/day, the collective contribution of total and fecal coliforms from the kitchens and bathrooms was on the same order of magnitude as that from the toilet wastes. The extremely high average levels reported for the grey waters may have been due, at least in part to the fact that the concentration reported were arithmetic averages, rather than geometric averages, and a certain degree of in-line contamination may have occurred as a result of carriage through the sizable drainage networks prior to sampling.

Hypes and Collins (1974) studied the microbiological characteristics of residential bath and laundry water, at the Langley Research Center in Hampton, Virginia, utilizing a specially constructed experimental facility which included a typical kitchen, laundry and bathroom. The grey waters generated by a subject family of four using these facilities were conveyed through a plumbing system to a collection tank prior to processing through selected prototype recycle systems. During a 12 day test of one system, samples of the grey water in the collection tank were taken daily and analyzed for total coliform organisms. Based on the analyses of nine samples, the mean (geometric) concentration of total coliforms was calculated as 2×10^5/100 mL with the range of values from 1.3×10^4 to 1.5×10^7/100 mL.

At the University of Wisconsin, microbiological analyses were conducted on samples collected directly from bathing and clotheswashing events (Siegrist, et al., 1976, Siegrist, 1977; Small Scale Waste Management Project, 1978). Samples were obtained from each of six households over a two-week period and analyzed for total and fecal coliforms and fecal streptococci. As shown in

Table 4, a wide range of organisms often used as indicators of fecal contamination were isolated.

The characterization of 35 fecal coliforms and 48 streptococcal isolates on the samples obtained from three of the homes, 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. Analyses performed on the samples obtained from the other three study homes for two common pathogens indicated a very low incidence of Pseudomonas aeruginosa (1 of 3 homes, 7 of 47 samples) with concentrations always below 20/100 mL, while Staphylococcus aureus was not isolated in any of the 45 samples analyzed.

An additional sampling effort was conducted at a single home (2 adults, 1 child) to obtain samples of several wastewaters generated through hygienic care

Table 4. Bacteriological Characteristics of Bath and Laundry Wastewaters,[a] Organisms/100 ml (Siegrist, 1977).

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.

of an infant who had just received an oral polio vaccination. In-house samples were obtained by the adult residents from the baby's stools, diaper pail, bath and laundry wastewaters over a twelve day period. Microbiological analyses were conducted yielding the results shown in Table 5.

Although the laundry yielded only a one log reduction in the concentration of organisms measured in the diaper pail by dilution alone, reductions of approximately 8 logs for total and fecal coliforms and 2 logs for fecal streptococci and virus were determined. These reductions were probably due in large part to the "hot" laundry cycles which were routinely used (temperature = 60^{o} C). Of special note, are the very low levels of indicator bacteria and the absence of virus in all of the laundry-wash cycle samples. The analysis of bathing samples yielded concentrations within the range of values determined previously for the selected indicator bacteria. Surprisingly, virus was only isolated in one of five samples at a low level of 5 PFU/mL.

Biological Decomposition Characteristics--

As part of the Small Scale Waste Management Project, in-house sampling was conducted at each of three households to characterize the biological decomposition of three grey water event wastewaters - dishwashing, bathing and clotheswashing (wash cycle). The residents of each of the homes (Table 6) involved were responsible for taking samples of each event according to prescribed procedures. Basically, after occurrence of an event, the wastewater generated was thoroughly mixed and a 1 litre sample was obtained prior to discharge of the basin or appliance contents. The samples were refrigerated until they were picked up and transported back to the University of Wisconsin laboratories (within 24 hours) where analyses were performed according to procedures outlined in Standard Methods (1971) for COD and BOD_5 as well as BOD versus time (24 day period).

Table 5. Microbiological Characteristics of Infant Related Wastewaters[a]

Event	Total Coliforms Log no./ 100 mL	Fecal Coliforms Log no./ 100 mL	Fecal Strep. Log no./ 100 mL	Pseudomonas aeruginosa Log no./ 100 mL	Virus Infectivity PFU/mL
Diaper Pail	8.71 (6) 7.43-9.98	8.67 (6) 7.40-9.94	2.65 (6) 1.58-3.73	< 1.30 (6) -	2.55 (7) 2.17-2.93
Bathing	3.93 (4) 1.95-5.92	3.93 (4) 1.95-5.92	4.48 (4) 3.25-5.71	< 1.30 (4) -	1 sample - 0.70 4 samples - ND[b]
Laundry	0.38 (5) 0.15-0.60	0.38 (5) 0.15-0.60	< 1.0 (5) -	< 1.30 (4) -	6 samples - ND
Stool Sample[c]	11.01 (7) 10.17-11.86	10.94 (7) 10.16-11.72	11.64 (7) 11.39-11.88	<2.08 (6) -	5.86 (8) 5.36-6.35

[a] Log normalized data; mean (number of samples)
95% CI

[b] ND = none detected

[c] Stool sample values expressed per wet gram.

To enable conversion of the concentration values measured to mass per event occurrence values, wastewater flow volumes were identified. For bathing and dishwashing, depth versus volume relationships were utilized for each basin of interest. For clotheswashing, the characteristics of the clotheswasher (e.g., make and model) allowed the determination of the waste flow volumes. As a sample

Table 6. Family Characteristics

Family Unit	Adults	Children (Age)	Bathrooms	Automatic Clothes Washer	Automatic Dish Washer	Garbage Disposal	Occupation of Head of Household
L	2	2 (4 mo., 7)	1	Yes	Yes	No	Poultry Man
M	2	0	1	No	No	No	Poultry Man
N	2	0	1 1/2	Yes	Yes	Yes	Engineer

was only obtained from the wash cycle of each clotheswashing event, the mass contributed by the event in total was estimated as the wash cycle mass divided by a factor of 0.7 (Siegrist, et al., 1976).

The average concentrations and mass contributions of BOD_5 and COD for each of the three events studied are presented in Table 7. In Table 8, the COD/BOD_5 ratios obtained in this study are compared to the results of previous investigators. As shown, the results for the individual events are quite consistent between investigators as well as the different grey water events.

The ratio of the COD/BOD is sometimes used as a gross indicator of the fraction of organic material in a wastewater which is readily amenable to biological decomposition. The BOD measurement provides an estimate of the quantity of oxygen required to biologically stabilize the organic matter present whereas the COD measurement provides an estimate of the oxygen equivalent of the organic matter that can be chemically oxidized. In general, the COD is greater than the BOD and the lower the COD/BOD ratio, the greater the percentage of biologically oxidizable organic matter present. Although considerable variation occurs, a COD/BOD_5 often reported for typical domestic sewage is on the order of 2.5

Table 7. COD and BOD_5 Characteristics of Grey Water Event Wastewaters

EVENT	BOD_5		COD		COD / BOD_5	
	mg/L	g/event	mg/L	g/event	mg/L	g/event
Dishwashing	970 (11)[a]	11.5 (11)	2060 (11)	22.5 (11)	2.1	2.0
Clotheswashing	400 (24)	30.0 (20)	1070 (20)	115.0 (16)	2.7	3.8
Bathing	310 (18)	9.2 (18)	540 (18)	18.7 (18)	1.7	2.0

[a] Mean value, with no. of data points given in parenthesis.

Table 8. COD / BOD_5 Ratios for Grey Water Event Wastewaters - Investigator Summary

Event	Olsson, Karlgren & Tullander (1968)	Laak (1974)	Bennett & Linstedt (1975)	This Study
Kitchen Sink	2.0[a]	2.0	1.5	-
Dishwash		-	1.8	2.0
Bathroom Sink	1.4	1.7	1.9	-
Bathing		1.5	2.2	2.0
Clotheswasher	2.3	2.6	2.8	3.8
Toilet	3.6	2.9	9.4	-
Combined Wastewater[b]	2.7	2.5	3.5	-

[a] Values shown were calculated on a mass per event basis.
[b] Excludes garbage disposal contribution.

(Metcalf and Eddy, Inc., 1972). When compared to the values presented for toilet wastewaters and domestic sewage, the ratios for grey water event wastewaters are somewhat lower.

Analyses for BOD were conducted over a 24 day period on a limited number of samples of each of the three events obtained at two of the study homes. The reaction rate constants, K, for $BOD_t = BOD_1 (1-10^{-Kt})$ over a 14-day period were calculated using the Thomas Method (Metcalf and Eddy, Inc., 1972). The results of this characterization are graphically presented in Figure 1.

The biological decomposition of the wastewaters generated by all three events progressed in a similar manner. A moderately rapid decomposition phase was noted during the first three-to-five day period followed by a relatively stable period through day 14. The calculated rate constants were between 0.075 and 0.110 day^{-1} for this 14-day period. Surprisingly, a rather significant

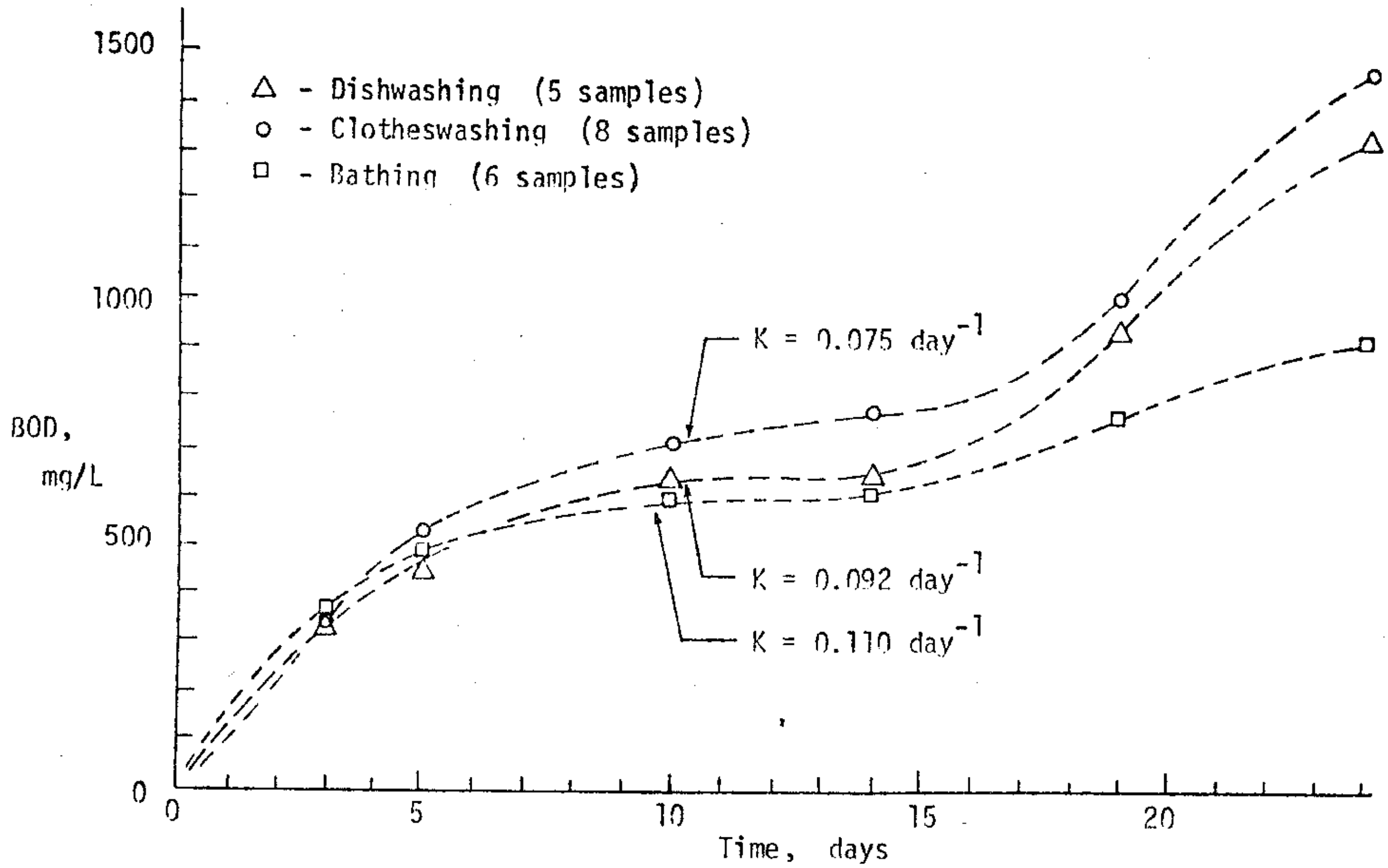

Figure 1. Average BOD progression curves for grey water event wastewaters.

decomposition phase subsequently occurred. This subsequent phase may have been due, in part, to a nitrogenous oxygen demand. Although the nitrogen concentrations were not measured, based on the results of related characterization efforts, the oxygen demand affected in this phase appears to be substantially higher than could be attributed to nitrogenous demand alone. When compared to the biological decomposition of typical domestic wastewater, the biological decomposition of these grey water event wastewaters progressed in a relatively similar manner (Metcalf and Eddy, Inc. 1972).

As part of the characterization study conducted by Olsson, et al., (1968), the progression of BOD with time for grey water event wastewaters was studied. Six samples of wastewater were obtained from each of the drainage lines serving the bathroom, kitchen, and kitchen plus bathroom groups, and periodic BOD measurements were made (in most cases, over a 32 day period). In all samples, two stages of decomposition were noted, a relatively rapid decomposition occurring during the first 3 to 5 days followed by a much slower decomposition phase. The average rate constants determined for these two stages were approximately 0.45 and 0.05 day^{-1}, respectively. BOD exerted during the first rapid phase was about 50 to 60% of the estimated ultimate BOD and little or no nitrogenous demand was exerted in any of the samples.

Bennett and Linstedt (1975) studied the rate of decomposition of grey water event wastewaters individually and in combination under aerobic and anaerobic conditions using one gallon batch reactors. One set of wastewaters were aerated with the dissolved oxygen contents maintained above 1 mg/L, while the second set was not aerated. Based on an initial set of tests, the investigators found that seeding did not appreciatively affect the rate or the constant of the biological decomposition. The wastewater in all batch aerators were sampled periodically (aliquots removed without stirring the reactor contents) and analyses were performed for COD, BOD and total and dissolved solids concentrations. All of the wastewaters were found to degrade in a similar manner. Under aerobic conditions, the BOD concentrations were reduced by approximately 60% in four days. After that, the rate was drastically reduced. Two distinct stages of decomposition were noted, a rapid initial rate followed by a slower rate. The non-aerated wastewaters were not as completely decomposed, as indicated by the BOD analysis; a 40% reduction in BOD was found after four days. No odors were noted during decomposition under anaerobic conditions.

Summary

In summary, the results of various characterization studies, primarily involving individual grey water event wastewaters, have demonstrated that grey water is indeed a wastewater. Grey water can be expected to contain appreciable quantities of oxygen demanding substances, suspended solids, phosphorus and grease in a flow volume of approximately 29 gal/cap/day. Its temperature as it leaves the residence should be slightly higher than combined wastewater (including black water) and in the range of 31° C with a pH slightly on the alkaline side. The organic materials in the grey water appear to degrade at a rate not significantly different from those in combined residential wastewater. With regard to health hazards associated with the management of grey water, microbiological studies have demonstrated that raw grey water does possess a potential for containing pathogenic organisms. However, this potential appears substantially lower than that of either the toilet waste or typical combined household wastewater.

GREY WATER TREATMENT AND DISPOSAL/REUSE

Overview

The most commonly employed method of grey water treatment and disposal perhaps because it has been the sole method recognized by many regulatory agencies, has involved a conventional septic tank-soil absorption field. However, more innovative management schemes may be feasible in light of the reduced flow and pollutant load of the grey water. In recognition of this, a diverse array of management strategies, including innovative techniques, devices and systems are under various stages of development and/or application. A summary of several grey water management alternatives which have been conceived, promoted and/or applied by various individuals and organizations is presented in Figure 2.

Figure 2. Example grey water management alternatives[a]

I. Conventional Septic Tank - Soil Absorption Systems

II. User-Contrived Low Technology Systems

III. Modified Conventional Septic Tank - Soil Absorption Systems
   A. Modified Pretreatment
      1. Reduced Septic Tank Sizing
      2. Alternatives
         a. Coarse Stone Filter
         b. Septic Tank-Anaerobic Upflow Filter
   B. Modified Soil Disposal
      1. Reduced Soil Absorption Area Sizing
      2. Shallow Subsurface Irrigation

IV. Surface Disposal/Reuse Systems
   A. User-Contrived Low Technology Systems
   B. Sedimentation - Irrigation
   C. Septic Tank - Sand Filter Systems

[a] The list presented is for illustrative purposes only. It is by no means all-inclusive and the inclusion of a particular alternative or the lack thereof should not be construed as a positive or negative recommendation by the author.

While innovative strategies such as those outlined in Figure 2 have been proposed for management of grey waters, and although operation and performance characteristics have often been predicted, no well-conceived field evaluations have been conducted. Publications are available describing the experience of hopeful inventors and homeowners who have designed and installed grey water systems for their use. However, the types of systems involved are often of limited application and/or the experiences gained tend to fall far short of sufficiently delineating the operation and performance characteristics of the systems involved. To provide the necessary operation and performance information to support a refute the feasibility of a particular alternative, rigorous field investigations are needed.

University of Wisconsin Studies

To enhance the limited data base regarding the treatment and disposal of household grey water, preliminary laboratory investigations were conducted and field studies are being initiated at the University of Wisconsin. As details of these studies have been presented elsewhere (Siegrist, 1977; Small Scale Waste Management Project, 1978), only a brief discussion is included herein.

Laboratory Study--

A preliminary study was conducted from April, 1976 to April, 1977 to accomplish several objectives: 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 patterns 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.

The events simulated included toilet use, bathing, dishrinsing, dishwashing, clotheswashing and miscellaneous with a constant day-to-day loading 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 500 gal and 1000 gal size, while a third septic tank of 1000 gal size received the same grey waters as well as toilet flush wastewaters.

Eight sand filter lysimeters were established specifically for this study. Each filter was about 1 ft^2 in surface area, with 1 ft of freeboard, 2 ft of sand, 0.4 ft of pea gravel and 0.6 ft of coarse stone. A summary of the experimental design for the filtration research is presented in Table 9. 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.

The results of selected chemical/physical analyses on daily flow-composited samples of each septic tank effluent are presented in Table 10. The effluent from the 500 gal septic tank treating grey water was significantly higher in BOD_5 and COD than the 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 COD_5 and COD reductions. Also, the circular, 500 gal tank effluent could have been

Table 9. Sand Filter Experimental Design

Filter Number	Septic Tank Effluent Applied	Application		Media Size	
		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

Table 10. Septic Tank Effluent Quality, mg/L

Parameter	Grey Water			Combined Wastewater	
	Influent[a]	500 gal STE	1000 gal STE	Influent	1000 gal STE
BOD_5[b]	220	101 (44)[c] 88-144	62 (57)[d] 56-68	260	55 (60)[d] 50-61
COD	420	236 (42)[d] 220-252	171 (55)[d] 159-183	730	169 (58)[d] 155-185
TSS	110	47 (41)[d] 42-53	46 (56)[d] 41-51	410	46 (58)[d] 41-52[d]
VSS	-	37 (40)[d] 32-41	34 (55)[d] 32-37	-	33 (58)[d] 30-37
Tot N	12	6.5 (22) 6.1-7.0	7.7 (22) 7.0-8.4	80	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	44 (28) 41-47	40 (30) 37-42	57	43 (27) 40-45
Ortho P	-	34 (27) 29-38	34 (26) 31-37	-	36 (27) 33-39
Flow (L/day)	484			711	

[a] Based on periodic analyses of the simulated wastewater constituents as well as daily flow composited samples.

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

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

[d] Log-normalized data.

influenced by surge loadings more so than the cylindrical 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, the characteristics of the effluents from the two 1000 gal septic tanks were essentially the same.

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 without a fecal input, analyses of grab samples of each septic tank effluent yielded very high levels of fecal coliforms. If, as the limited results of the study would seem to indicate, the traditional indicator bacteria can 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.

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. Of these, the grey water filters yielded run lengths over twice those of the combined wastewater filters, (275 days versus 124 days, respectively) accepted about twice as much wastewater, and effectively removed about 140% more BOD_5 and 60% more suspended solids.

Analyses for selected chemical/physical parameters on daily flow composited samples of the effluents from each of the eight sand filters demonstrated that a high quality effluent was produced with regard to BOD_5 and volatile suspended solids with values consistently less than 5 mg/L and 10 mg/L, respectively (Table 11). Further, the nitrogen in the septic tank efluents, largely as ammonia, was almost completely nitrified while there was no significant effect on the phosphorus forms or concentrations.

The results of this preliminary laboratory study may be summarized as follows:

1. The reductions in BOD_5 and COD are considerably greater in grey water

Table 15. Sand Filter Effluent Characteristics, mg/L

Parameter	Grey water 1	Grey water 2	Grey water 3	Grey water 4	Grey/Black water 5	Grey/Black water 6	Grey/Black water 7	Grey/Black water 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.

when treated with a 1000 gal septic tank as compared to a 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 output.

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 objectives 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 objectives 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 be a possible method 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 from the remaining household wastewater stream (grey water) through use of a non-conventional toilet system would reduce the wastewater flow volume and pollutant load of residential households to that of the grey water. Characterization studies have demonstrated that the grey water fraction is not innocuous and must be properly managed. However, the management of the grey water may be simplified over that of total household wastewater due to a reduced flow volume; a reduced mass of pollutants to be removed, particularly suspended solids and nitrogen; and a reduced potential for pathogenic contamination. Although diverse strategies have been proposed for grey water management, rigorous research/development and field evaluations to properly assess the feasibility of most have not yet been conducted. To enhance the limited data base, preliminary laboratory studies have been conducted and field studies are being initiated at the University of Wisconsin.

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