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Characteristics of Rural Household Wastewater

by

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Characteristics of Rural Household Wastewater

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Introduction

The characteristics of waste flows from individual households can have a profound effect on the performance of individual household treatment and final disposal methods. Various water use events within a home create an intermittent flow pattern of wastes that vary widely in strength and volume. In order to study and improve individual treatment and disposal alternatives effectively, quantitative and qualitative characterization of household wastewater is necessary. To enhance the existing characterization data base, field studies were conducted by the University of Wisconsin as part of the Small Scale Waste Management Project.

Methods

The field analyses on wastewater characteristics were accomplished in two phases: (1) Water use (wastewater production) characterization; and (2) wastewater quality characterization.

Water Use (Wastewater Production) Characterization.—Eleven rural homes were monitored during this phase of the study. These sites offered a wide variety of family types and sizes. A summary of pertinent family characteristics is shown in Table 1.

Within the home, there are basically five major ways in which water is consumed and a substantial volume of wastewater is subsequently produced: (1) Toilet usage; (2) clothes washing; (3) bathing; (4) dishwashing; and (5) water softening. These five water-use events were selected for monitoring during this phase

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TABLE 1.—Family Information

Location (1)	Adults (2)	Children (age) (3)	Bathrooms (4)	Automatic clothes washer (5)	Automatic dish washer (6)	Water softener (7)	Occupation of head of household (8)
A	2	2 (8,18)	2-1/2	yes	yes	yes	Herdsman
B	2	1 (15)	1-1/2	no	yes	no	Earth contractor
C	2	2 (3,5)	1	yes	no	yes	Herdsman
D	2	4 (10,12,17,19)	2	yes	yes	yes	Resort employee
E	2	1 (9 month)	2	yes	yes	no	Pharmacist
F	2	3 (6,8,9)	1-1/2	yes	no	no	Paper mill worker
G	2	5 (4,9,15,17,18)	1-1/2	yes	no	yes	Dairy farmer
H	3	0	1	yes	no	yes	Farm worker
I	2	3 (2,3,5)	1-1/2	yes	yes	no	Meat cutter
J	2	5 (3,7,11,16,17)	1-1/2	yes	no	no	Agronomist
K	2	2 (8,15)	2	yes	no	yes	Agriculture professor

TABLE 2.—Family Information

Location (1)	Adults (2)	Children (age) (3)	Bathrooms (4)	Automatic Clothes washer (5)	Automatic dish washer (6)	Garbage disposal (7)	Occupation of head of household (8)
C	2	2 (3,5)	1	yes	no	yes	Herdsman
G	2	5 (4,9,15,17,18)	1-1/2	yes	yes	no	Dairy farmer
I	2	3 (2,3,5)	1-1/2	yes	yes	no	Meat cutter
C'	2	1 (1)	1	yes	no	yes	Herdsman

TABLE 3.—Frequency and Size of Events

	Toilet		Laundry		Bath or Shower		Dish Wash		Water Softener	
Location (1)	Number per capita per day (2)	Gallons[a] (3)	Number per capita per day (4)	Gallons (5)	Number per capita per day (6)	Gallons (7)	Number per capita per day (8)	Gallons (9)	Number per capita per day (10)	Gallons (11)
A	2.07	4.4	0.36	35.4	0.43	31.5	0.29	17.0	0.08	75.7
B	2.29	3.8	0.19	11.4	0.38	20.9	0.26	10.2	—	—
C	1.70	3.3	0.36	36.3	0.31	23.6	0.31	11.2	0.06	71.7
D	2.79	3.0	0.23	33.2	0.66	20.1	0.41	12.2	0.02	95.2
E	1.71	4.8	0.33	41.9	0.45	19.0	0.24	11.6	—	—
F	1.39	4.5	0.46	27.3	0.26	22.3	0.39	12.8	—	—
G	1.49	4.3	0.15	28.6	0.47	18.5	0.36	10.5	0.05	69.8
H	2.29	4.0	0.32	34.9	0.36	16.3	0.36	7.9	0.24	66.4
I	1.68	4.7	0.59	27.7	0.34	21.3	0.49	12.5	—	—
J	3.10	4.4	0.27	34.9	0.57	21.5	0.40	13.8	—	—
K	2.93	3.7	0.34	38.4	0.55	21.2	0.54	13.3	0.03	144.6
Average (weighted)	2.29	4.0	0.31	33.5	0.47	21.4	0.39	12.5	0.03	81.1

Note: 1 gal = 3.8 l.

of the study. In monitoring water use within each of the 11 homes, every effort was made to avoid interruption of the normal activity within the home. A chart recorder, driven by the water meter in the home, was chosen to make a record of water use versus time. Charts were changed on a weekly basis, thus eliminating much of the homeowner's involvement. From the charts, individual household events were identified and the corresponding volume for each event was measured. To aid in the event identification, a preliminary questionnaire was completed by each home, counters were installed on the toilets, and any large extraordinary flows were checked by talking with the homeowner. Details of the methods used may be found in a paper by the second writer (15).

Efforts were made to obtain approx 4 weeks or more of data at each site, with the data being collected in segments no smaller than seven continuous days. Winter to summer comparisons were made at three of the homes with at least 5 weeks of summer data and 4 weeks of winter data at each of the three. Data were collected for a total of 434 days and were tabulated by each hour of the day and by each day of the week for each home studied and the five major water-use events.

Wastewater Quality Characterization.—Wastewater quality studies were conducted at three of the residences studied in the water use (wastewater production) phase. Since one of the three residences was occupied by a second family during the course of the wastewater quality study, it was treated as two residences. Thus, four families were involved in the study. Their pertinent characteristics are given in Table 2.

From the many wastewater producing events that can occur in the home, eight were selected for qualitative characterization: (1) Fecal toilet flush; (2) nonfecal toilet flush; (3) garbage disposal usage; (4) kitchen sink usage; (5) automatic dishwasher; (6) clothes washer-wash cycle; (7) clothes washer-rinse cycle; and (8) bath/shower. To facilitate this characterization, yet minimize the involvement of the homeowner, a unique portable automatic wastewater sampler was designed, constructed, and tested.

When installed at one of the study homes, the system would homogenize and take an individual 1-1/2-qt (1.4-l) sample of any wastewater flow of 3-1/2 gal (13.2 l) or more and store the sample on ice. The system also provided a record of flow volume and temperature versus time of day by means of a monitoring system and two continuous chart recorders. This sampling and monitoring was accomplished automatically without any participation from the residents of the site. The event that produced each sample obtained was identified by means of a home-owner questionnaire, the flow characteristics recorded by the flow recording monitor, and visual inspection of each sample. Details of the sampling procedures may be found in a previous paper by the first writer (11).

The samples obtained each day were transported back to the Sanitary Engineering Laboratory where analyses were performed using procedures outlined in Ref. 12 with the following modifications. Filtered BOD_5 and TOC values were obtained by filtering the samples through Whatman No. 2 filter paper. The TOC was determined using a Beckman Model 915 Total Carbon Analyzer. Suspended solids analyses were performed using 2.1-cm glass fiber filter disks. The Olson Modification (3) of the semimicro kjeldahl procedure was used to determine total organic nitrogen. Ammonia and nitrate nitrogen were determined by using the steam distillation-titration procedure outlined by Bremner and Keeney (4). Total and orthophosphorus were analyzed by the vanadomolybdate yellow color method described by Jackson (6).

The sampling system was used at each of the four sites for several 3-day to 4-day sampling periods during the spring and summer of 1974. The data collected for each of the eight selected events were subsequently tabulated.

During the summer of 1974, an ancillary wastewater quality study was conducted to determine the microbiological characteristics of three household events: (1) Bath/shower; (2) clothes washer-wash cycle, and (3) clothes washer-rinse cycle. The automatic sampling system was not used to obtain samples for this characterization due to the high degree of in-line contamination that would have been present. Samples were taken by the individual homeowner and refrigerated until they were picked up by project personnel. Each sample taken was analyzed for fecal streptococci, fecal coliforms and total coliforms according to procedures outlined in Ref. 10. Coliform and streptococcal isolates were taken during the foregoing analyses and subsequently characterized.

Results and Analysis

Water Use (Wastewater Production) Characterization.—A summary of the results for the individual water use events and all 11 homes is tabulated in Tables 3 and 4.

An average flow of 42.6 gal/capita/day (161.0 l/capita/day) was calculated for all data collected over the 434-day sampling period with a 90% confidence interval of 40.8 gal/capita/day–44.4 gal/capita/day (154.2 l/capita/day–167.8 l/capita/day). This average flow is comparable to that found by earlier investigators as shown in Table 5.

The use of water within the home has changed greatly in recent years due to the ever increasing number of modern appliances that have been introduced. Trends have developed which indicate greater usage in the kitchen and laundry relative to total usage. This can be explained by the introduction of automatic dishwashers, garbage disposals, and clothes washers, which use more water for permanent press fabrics. Changes in the habits of people probably have also affected the volume of water and the way it is used in the home.

In order to illustrate water use patterns in a home, daily and weekly flow plots were constructed for each of the sites as well as summary plots for all 11 sites combined. The summary plots are given in Figs. 1 and 2. As would be expected, the fluctuations in the 11 site summary plots were highly attenuated. The fluctuations in a single household pattern were far more extreme than the fluctuations presented in these figures. Detailed data for each site can be found in Ref. 13.

The hourly flow pattern (Fig. 1) shows two major times of high water usage in the morning and evening hours with lower demands during late night, early morning, and afternoon periods of the day. The miscellaneous or other flow is quite constant from 6 a.m. to midnight with lower flow during the early morning hours. Toilet flushing followed a similar pattern with a slight increase between 6 a.m. and 8 a.m. Laundry was largely concentrated in the morning, with 63% of it occurring between 7 a.m. and 2 p.m. Baths and showers were

TABLE 4.—Water Usage, in Gallons per capita per day

Location (1)	Toilet (2)	Laundry (3)	Bath or shower (4)	Dish wash (5)	Water softener (6)	Other (7)	Total (8)	90% confidence interval (9)	Days (10)
A	9.1	12.6	13.5	5.0	6.1	10.4	56.7	48.9-64.8	28
B	8.7	2.2	8.0	2.7	—	4.0	25.4	20.0-30.9	14
C	5.6	13.1	7.3	3.5	4.0	5.4	38.9	34.5-43.2	77
D	8.4	7.6	13.3	5.0	2.3	4.5	41.0	37.9-44.2	42
E	8.2	14.0	8.6	2.8	—	7.9	41.5	32.2-50.8	28
F	6.2	12.7	5.7	5.0	—	4.1	33.7	27.9-39.6	28
G	6.5	4.2	8.7	3.7	3.4	3.3	29.8	26.4-33.1	35
H	9.2	11.2	5.9	2.9	15.7	4.9	49.7	44.8-54.6	24
I	7.9	16.2	7.1	6.1	—	4.4	41.8	36.8-46.8	28
J	13.8	9.5	12.2	5.5	—	4.2	45.1	42.8-47.4	68
K	10.9	13.0	11.7	7.1	4.7	9.5	56.9	50.7-63.2	62
Average (weighted)	9.2	10.5	10.0	4.9	2.6	5.4	42.6	40.8-44.4	434

Note: 1 gal/capita/day = 3.8 l/capita/day.

TABLE 5.—Water Usage Comparison, as a percentage

Usage	U.S. Geological Survey, 1962 (10)	Haney and Hamann, 1967 (5)	Laak, 1975 (7)	Ligman, 1972 (8)	Wallman, 1972 (13)	Ontario research, 1973 (2)	Bennett, 1975 (1)	This study
Toilet	41	45	47	41	27-45	38	33	22
Laundry	4	5	18	19	18	12	27	25
Bath	37	30	21	26	18-36	34	24	23
Kitchen	6	6	9	10	13	10	16	11
Cleaning	3	4	—	1	—	3	—	—
Drinking	5	3	—	3	—	3	—	—
Miscellaneous	4	7	5	0	6	0	—	13 other 6 water softener
Flow, in gallons per capita per day	—	—	41	45	30-50	—	44.5	43

Note: 1 gal/capita/day = 3.8 l/capita/day

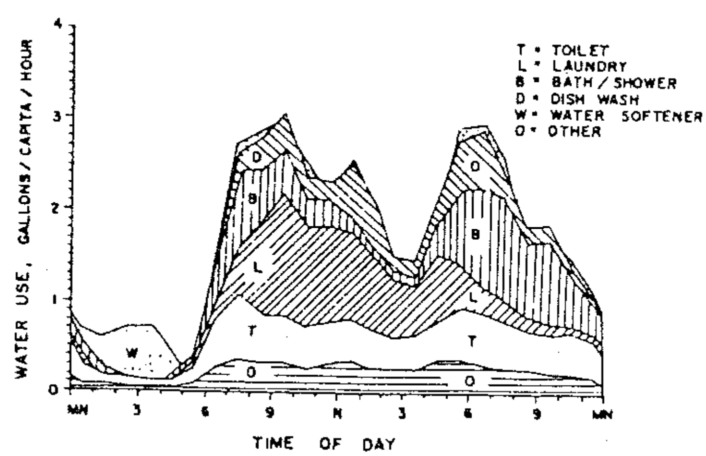

FIG. 1.—Average Daily Flow Pattern

most often found in the evening hours between 5 p.m. and midnight, althoug the morning hours of 6 a.m.-9 a.m. also showed an increase from this event Dishwashings were measured in three peaks following mealtimes, with the larges

TABLE 6.—Mean Wastewater Concentrations from Household Events, milligrams per liter

Parameter (1)	Event							
	Fecal toilet flush (2)	Nonfecal toilet flush (3)	Garbage disposal (4)	Kitchen sink usage (5)	Automatic dish washer (6)	Clothes washer-wash (7)	Clothes washer-rinse (8)	Bath/shower (9)
BOD_5 U	610	330	1,030	1,460	1,040	380	150	170
BOD_5 F	330	200	240	800	650	250	110	100
TOC U	500	220	690	880	600	280	100	100
TOC F	220	160	370	720	390	190	72	61
TS	1,500	910	2,430	2,410	1,500	1,340	410	250
TVS	1,090	610	2,270	1,710	870	520	180	190
TSS	880	320	1,490	720	440	280	120	120
TVSS	720	260	1,270	670	370	170	69	85
TOT-N	210	140	60	74	40	21	6	17
NH_3-N	84	27	0.9	6	4.5	0.7	0.4	2
NO_3-N	0.9	1.1	0	0.3	0.3	0.6	0.4	0.4
TOT-P	38	14	12	74	68	57	21	2
ORTHO-P	16	10	8	31	32	15	4.0	1
Temperature	66° F	66° F	71° F	80° F	101° F	90° F	83° F	85° F
Flow[a]	4.3	4.3	3.8	4.8	12.0	15.7	14.4	13.0
Number of samples	32-40	24-37	4-7	7-11	13-15	24-27	24-28	18-24

[a] Flow values were determined in the wastewater quality study and are in gallons.
Note: 1 gal = 3.8 l.

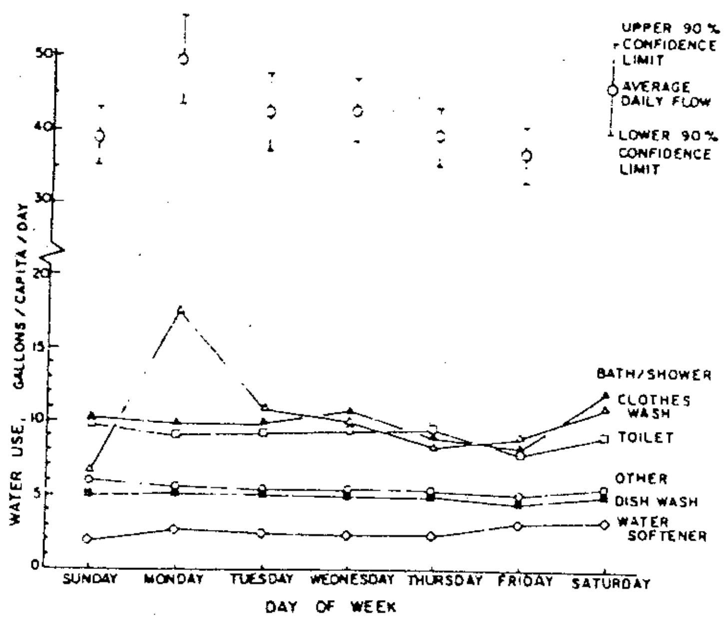

FIG. 2.—Average Weekly Flow Pattern

flow between 5 p.m. and 7 p.m. As would be expected, the water softene was concentrated between midnight and 5 a.m.

Little day-to-day variation in the flow existed for any of the events excep the bath and laundry (Fig. 2). The bath showed a significant difference betweer Friday at 8.0 gal/capita/day (30.2 l/capita/day) and Saturday at 12.1 gal/capita/day (45.7 l/capita/day). The laundry demonstrated a significantly highei concentration on Monday, when compared to all days except Tuesday. Wher considering daily flow, however, no one day was significantly different fron the average.

Winter-summer water use comparison at three homes indicated no significant seasonal differences at the 90% level of confidence. The differences between households were more important in determining water usage than the season of the year.

Wastewater Quality Characterization.—Quality characteristics are reported as contributions by event and per capita. The carriage water contributions of the measured parameters were removed from the results of each sample basec on the analysis of tap water samples obtained from each home. These correctec

TABLE 7.—Mean Wastewater Contributions from Household Events, in milligrams per event

	Event							
Parameter (1)	Fecal toilet flush (2)	Nonfecal toilet flush (3)	Garbage disposal (4)	Kitchen sink usage (5)	Automatic dish washer (6)	Clothes washer-wash (7)	Clothes washer-rinse (8)	Bath/shower (9)
BOD_5 U	10,000	5,360	14,600	26,800	47,500	22,900	8,210	8,230
BOD_5 F	5,390	3,340	3,430	14,700	29,500	14,900	5,820	4,980
TOC U	8,160	3,520	9,800	16,000	27,300	16,400	5,330	4,680
TOC F	3,640	2,660	5,240	13,200	17,600	11,400	3,920	3,010
TS	24,600	15,000	34,500	44,200	68,300	79,800	22,500	12,200
TVS	17,900	10,100	32,200	31,200	39,600	31,200	9,840	9,560
TSS	14,400	5,280	21,200	13,200	19,800	16,900	6,260	6,020
TVSS	11,700	4,300	18,100	12,300	16,700	10,000	3,750	4,190
TOT-N	3,460	2,230	850	1,350	1,820	1,250	330	840
NH_3-N	1,380	440	13	110	210	42	22	99
NO_3-N	15	18	0	6	14	36	22	20
TOT-P	620	230	170	1,350	3,090	3,400	1,140	99
ORTHO-P	260	160	110	560	1,460	900	220	49

milligram per liter concentrations of pollutants for each sample were ther converted to milligram per event values by multiplying each concentration by the measured flow. In order to determine milligram per capita per day contributions, the frequency of occurrence for each of the eight household events was needed on a per capita per day basis. As part of the first phase of this study the frequencies of occurrence for the bath/shower, automatic clothes washe and toilet were determined. Other needed frequency data were obtained fron earlier studies. The toilet event frequencies were divided into fecal toilet flusl frequencies and nonfecal flush frequencies by using information presented by Perry (unpublished report). An average frequency for the garbage disposal was obtained from Ligman (6). The kitchen sink usage and automatic dishwashe frequencies were based on information presented by Ligman (9) along witl consultation with the homeowners. The milligram per capita per day value were then calculated by multiplying the milligram per event values for eacl sample times the appropriate frequency of occurrence. The mean values deter mined for each event and the measured parameters are presented in Tables 6-9.

The results shown in the mean value tables (Tables 6-9) indicate how the mean concentrations and mass loadings contributed by the household events

TABLE 8.—Mean Wastewater Contributions from Household Events, milligrams per capita per day

Parameter (1)	Event							
	Fecal toilet flush (2)	Nonfecal toilet flush (3)	Garbage disposal (4)	Kitchen sink usage (5)	Automatic dish washer (6)	Clothes washer-wash (7)	Clothes washer-rinse (8)	Bath/shower (9)
BOD_5 U	4,340	6,380	10,900	8,340	12,600	10,800	4,010	3,090
BOD_5 F	2,340	3,980	2,570	4,580	7,840	6,970	2,840	1,870
TOC U	3,530	4,250	7,320	5,000	7,280	7,700	2,610	1,750
TOC F	1,580	3,170	3,910	4,110	4,690	5,380	1,910	1,130
TS	10,700	17,800	25,800	13,800	18,200	37,500	10,900	4,590
TVS	7,760	12,000	24,000	9,730	10,500	14,700	4,800	3,600
TSS	6,240	6,280	15,800	4,110	5,270	7,930	3,040	2,260
TVSS	5,090	5,120	13,500	3,840	4,460	4,700	1,810	1,580
TOT-N	1,500	2,640	630	420	490	580	150	310
NH_3-N	590	520	9.6	32.3	54	19.4	11.4	40
NO_3-N	6.3	21.1	0.2	1.8	4.1	17	10.3	7.4
TOT-P	270	280	130	420	820	1600	550	36
ORTHO-P	120	190	90	180	380	410	110	20

TABLE 9.—Mean Wastewater Contributions from Household Events, as a percentage

Parameter (1)	Event							
	Fecal toilet flush (2)	Nonfecal toilet flush (3)	Garbage disposal (4)	Kitchen sink usage (5)	Automatic dish washer (6)	Clothes washer-wash (7)	Clothes washer-rinse (8)	Bath/shower (9)
BOD_5 U	8.8	12.9	—	16.8	25.5	21.7	8.1	6.2
BOD_5 F	7.7	13.1	—	15.0	25.8	22.9	9.3	6.2
TOC U	11.0	13.2	—	15.6	22.7	24.0	8.1	5.4
TOC F	7.2	14.4	—	18.7	21.4	24.5	8.7	5.1
TS	9.4	15.7	—	12.1	16.0	33.1	9.6	4.1
TVS	12.3	19.0	—	15.4	16.7	23.3	7.6	5.7
TSS	17.8	17.9	—	11.7	15.	22.5	8.7	6.4
TVSS	19.1	19.3	—	14.4	16.8	17.7	6.8	5.9
TOT-N	24.6	43.5	—	7.0	8.0	9.5	2.4	5.0
NH_3-N	46.7	41.0	—	2.5	4.2	1.5	0.9	3.2
NO_3-N	9.3	31.0	—	2.6	6.0	25.	15.2	10.9
TOT-P	6.8	7.0	—	10.6	20.6	40.3	13.8	0.9
ORTHO-P	8.2	13.4	—	12.6	27.2	29.2	7.9	1.5

Note: Garbage disposal results are not included.

vary from event to event. This variation in individual event wastewater quality is as expected, based on the nature and origin of the wastewaters. Based upon a statistical analysis of each event and the measured parameters, the dispersions about the mean values were found to be significant as evidenced by large standard deviations and wide ranges. For example, the mean milligram per capita per day unfiltered BOD_5 loading from the bath/shower event based on 22 samples was 3,090 with a standard deviation of 2,140 and a range of 790 mg/capita/day-6,940 mg/capita/day. But, this is as expected in light of the variation in day to day habits at a given home and the variation in lifestyles between homes, which in turn cause variation in the wastewater quality produced by the individual household events. Further details may be found in Ref. 11.

The results of this study were reviewed on an individual event basis and

TABLE 10.—Toilet Flush Wastewater Comparison, in milligrams per capita per day

Parameter (1)	Ligman (9) (2)	Laak (7) (3)	Bennett (1) (4)	This study (5)
BOD_5	23,600	23,500	6,900	10,700
SS	30,900	—	36,500	12,500
Total N	16,800	14,500	5,200	4,140
Total P	1,360	2,110	—	550

TABLE 11.—Toilet Flush Wastewater Comparison, in milligrams per event

Parameter (1)	Ligman (9) (2)	Laak (7) (3)	Bennett (1) (4)	This study (5)
BOD_5	6,380	4,360	1,920	6,740
SS	8,340	—	10,100	7,870
Total N	4,540	2,680	1,470	2,600
Total P	370	390	—	340
Frequency of occurrence	3.7	5.4	3.6	1.6

TABLE 12.—Dishwashing Wastewater Comparison, in milligrams per capita per day

Parameter (1)	Ligman (9) (2)	Laak (7) (3)	This study[a] (4)
BOD_5	5,900	9,200	21,000
SS	2,720	—	9,380
Total P	450	—	1,240

[a]Results presented based on dishwashing in kitchen sink combined with automatic dishwashing.

compared to the results obtained by earlier investigators. The comparisons were rather scant in many cases, since many of the parameters measured in this study were not reported in the earlier studies.

The separation of the toilet flush event into a fecal flush and a nonfecal flush was possible through visual inspection of the toilet flush samples. The fecal flush contributed lower mass per capita per day loadings than the nonfecal flush. The principal reason for this was the fact that the frequency of occurrence of the nonfecal flush was approx 2.6 times as great as that of the fecal flush.

The total output from the toilet based on combining the fecal and nonfecal flushes was found to contribute 21.7% of the unfiltered BOD_5, 35.7% of the suspended solids, 68.1% of the total nitrogen, and 13.8% of the total phosphorus produced daily by a given home (Table 9).

The results of this study for the fecal and nonfecal flushes combined are compared with the results of earlier investigators (Table 10). The mean milligram per capita per day values reported by Ligman (9) and Laak (7) are very similar to each other, but are substantially higher than the results determined by this study. The values reported by the earlier investigators were based largely on small-scale analyses of individual samples of urine and feces and the information available in the literature regarding human waste products. The mass per capita per day contributions determined, represented the total daily quantity of pollutants generated by an average adult. The mean milligram per capita per day contributions determined in this study were based on actual on-site sampling of toilet wastewater from rural homes. The results represent the mean daily quantity of pollutants to be expected from an average resident of a rural home through the use of the toilet facility in the home. Since the average resident in this study (including children, teenagers, and adults) most likely produced less waste than an "average adult" and since a portion of this waste was most likely disposed of through the use of toilet facilities outside of the home, the milligram per capita per day values obtained in this study were expected to be lower than those determined by Ligman and Laak. The results of this study were found to be similar to values obtained by the earlier investigators when the comparison was made on a milligram per event basis (Table 11).

In this study, the wastewater produced by the kitchen sink usage was the result of manual dishwashing and major dish rinsing in the kitchen sink of homes that also have automatic dishwashers. Thus, the total mass per capita per day contributions from dishwashing and rinsing as a whole are represented by the sum of the kitchen sink and automatic dishwasher contributions. Dishwashing and rinsing as a whole, based on the addition of the kitchen sink usage and automatic dishwasher results, proved to be a major contributor of pollutants, generating 42.3% of the unfiltered BOD_5, 26.7% of the suspended solids, 15% of the total nitrogen, and 31.2% of the total phosphorus. The results obtained for dishwashing (kitchen sink and automatic dishwashing combined) in this study are compared to the values reported by earlier investigators (manual dishwashing in the kitchen sinks of homes without automatic dishwashers) in Table 12. Based on a comparison of mean values, the results of this study were found to be significantly higher than the results of earlier studies. However, most of the reported values of earlier investigators are within the range of values determined in this study. The discrepancy in the BOD_5 results, as well as the discrepancies in the results for the other parameters, were most likely caused by the differences in the lifestyle and dishwashing habits of the two homes sampled in this study, as compared to the homes in earlier studies.

The garbage disposal results presented in this study are based on the analysis of samples taken from the garbage disposal wastewaters produced by homes without automatic dishwashers. The garbage disposal results obtained in this study were lower than expected, based on earlier analyses performed by Ligman (Table 13). Ligman (8) reviewed several extensive studies on garbage characteristics and generation rates and collected the garbage from two graduate student

TABLE 13.—Garbage Disposal Wastewater Comparison, in milligrams per event

Parameter (1)	Ligman (9) (2)	Bennett (1) (3)	This study (4)
BOD_5	41,200	12,300	14,600
SS	58,100	20,200	21,100
Frequency of occurrence	0.75	0.40	0.75

TABLE 14.—Laundry Wastewater Comparison, in milligrams per event

Parameter (1)	Ligman (9) (2)	Laak (7) (3)	Bennett (1) (4)	This study (5)
BOD_5	28,000	31,600	29,200	31,100
SS	21,400	—	11,400	23,100
Total P	6,680	—	—	4,540
Frequency of occurrence	0.25	0.30	0.30	0.48

TABLE 15.—Bath/Shower Wastewater Comparison, in milligrams per event

Parameter (1)	Ligman (9) (2)	Bennett (1) (3)	This study (4)
BOD_5	20,600	10,300	7,910
SS	12,400	2,780	5,800
Frequency of occurrence	0.44	0.32	0.39

TABLE 16.—Daily Household Pollutant Contribution Comparison, in pounds per capita per day

Pollutant (1)	Ligman (9) (2)	Laak (7) (3)	Bennett (1) (4)	This study (5)
BOD_5	0.106[a]	0.107	0.077	0.109
SS	0.102	—	0.104	0.077
Total N	0.037	0.0362	0.016	0.013
Total P	0.009	0.0086	—	0.009

[a] All results are mean value expressed in pounds per capita per day. The results are for households with typical appliances but omitting the garbage disposal.

Note: 1 pound per capita per day = 454,000 milligrams per capita per day.

apartments and an urban household for analysis. An explanation as to why the values reported by Ligman were found to be substantially higher than the results obtained in this study may be found in the fact that, in this study, the families that had garbage disposal also had large dogs. In each home, the dog received a majority of the meal scraps which otherwise would have been disposed of through the garbage disposal. Bennett and Linstedt (1) actually obtained samples from the garbage disposal wastewaters at several homes and their results compare favorably with the results of this study (Table 13). Since the use of garbage disposals in rural homes served by individual sewage disposal systems has been discouraged recently, and since the results obtained for the garbage disposal in this study were based on a limited number of samples, the garbage disposal results were omitted when calculating the total mass per capita per day loadings from a typical rural household and the percentages contributed by the individual events.

Based on the results obtained in this study, the household operation of washing clothes proved to be a major contributor of pollutants. On a mass per capita per day basis, the automatic clothes washer contributed 29.8% of the unfiltered BOD_5, 31.2% of the suspended solids, 11.9% of the total nitrogen, and 54.1% of the total phosphorus (Table 9). In each case, approx 70% of the pollutants were contained in the wash cycle discharge with the remaining 30% contained in the rinse cycle discharge (Table 7). The results obtained in this study for the automatic clothes washer (wash and rinse cycle discharges combined) were found to be in general agreement with the values reported by earlier investigators when compared on a milligram per event basis (Table 14). However, the milligram per capita per day results of this study are higher. This is due to the difference in the magnitude of the frequency of occurrence used to compute the milligram per capita per day values.

In this study, bath and shower wastewaters were assumed to be equal in terms of their mass per capita per day contribution of pollutants. Thus, the results for this bath/shower event are based on samples of individual bath and shower events grouped together. The results of this study for the bath/shower event proved it to be a minor contributor of pollutants. On a daily basis, this event contributed the lowest percentage of almost all pollutants measured. The percentages were 6.2% of the unfiltered BOD_5, 6.4% of the suspended solids, 5.0% of the total nitrogen, and less than 1.0% of the total phosphorus (Table 9). The BOD_5 and suspended solids contributions from the bath/shower event obtained in this study are compared to the values reported by earlier investigators on a milligram per event basis in Table 15. The mean values reported for the bath/shower by earlier investigators fall within the range of values determined in this study.

The total mass per capita per day, as determined by several investigators for BOD_5, suspended solids, total phosphorus, and total nitrogen, is shown in Table 16. Note how closely the results obtained in this study agree with the results reported by earlier investigators. The only significant discrepancy exists in the total nitrogen production and is most likely due to the lower toilet contribution determined in this study (previously examined).

To develop patterns illustrating the daily fluctuation of various pollutants in the wastewater generated from a home, the mass per capita per day results were combined with the results of the water use (wastewater production) characterization. In determining the hourly distribution of various pollutants, it was assumed that the mass per capita per day generated by an event was, on the average, distributed evenly in the daily flow from the event. For each hour of a typical day (Fig. 1), the percentage of the daily flow generated from

TABLE 17.—Bacteriological Characteristics of Laundry and Bath/Shower Wastewaters

Organism (1)	Data points (2)	Geometric mean number per 100 ml (3)	Range number per 100 ml (4)	Standard deviation of log normalized data (5)	95% confidence interval for geometric mean of log normalized data number per 100 ml (6)
(a) Bath/Shower					
Fecal streptococci	13	44	1-70,000	0.49	4-500
Fecal coliforms	11	220	1-2,500	0.31	46-1,100
Total coliforms	10	1,100	70-8,200	0.21	350-3,200
(b) Clothes Wash					
Fecal streptococci	15	210	1-1,300,000	0.55	14-3,100
Fecal coliforms	13	1,400	9-16,000	0.32	280-6,700
Total coliforms	12	18,000	85-890,000	0.38	2,500-120,000
(c) Clothes Rinse					
Fecal streptococci	16	75	1-230,000	0.55	5-1,100
Fecal coliforms	14	320	35-7,100	0.18	130-790
Total coliforms	12	5,300	190-150,000	0.22	1,700-16,000

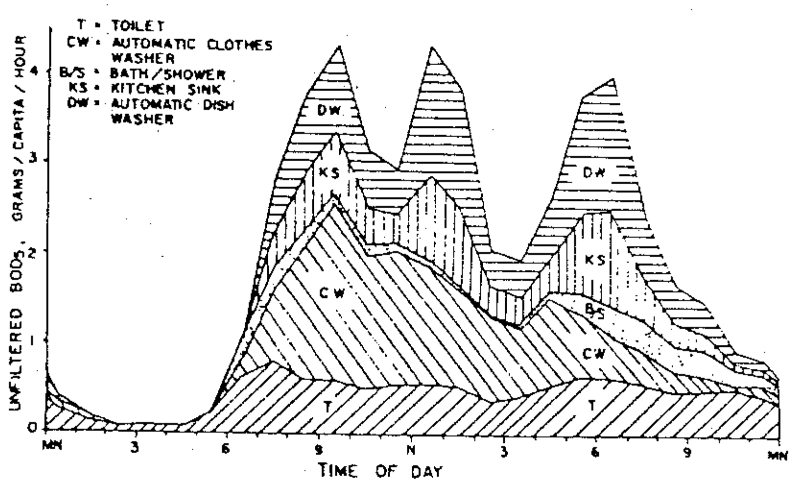

FIG. 3.—Average Hourly Distribution of Unfiltered BOD_5

a given event was multiplied times the mean milligram per capita per day loading of a given pollutant to determine the mass of the pollutant produced during the hour in question. This was performed for the toilet, automatic clothes washer, bath/shower, and dishwashing events to develop hourly distribution curves for BOD_5, suspended solids, total nitrogen, and total phosphorus. The hourly distribution curve developed for unfiltered BOD_5 is shown in Fig. 3. The other curves may be found in Ref. 11.

The bacteriological results, as depicted in Table 17, show that a wide range of indicator organisms can be expected in these wastewaters. The high numbers in wash and rinse wastewaters were primarily associated with the washing of baby clothes. Use of hot water and detergents containing chlorine bleach appeared to reduce those numbers.

In addition to the results shown in Table 17, several isolates were obtained from the three events. Sixty-one fecal isolates were obtained from wash and rinse wastewaters and characterized as 65% *Escherichia* spp. (mainly *E. coli*), 27% *Klebsiella pneumonia* (with the ability to grow at 44.5° C), 5% high temperature *Enterobacter aerogenes* biotypes, and 2% *Citrobacter freundii*. Approximately 90% of the 24 fecal coliform isolates from bath waters were *Escherichia* spp. with the remainder, *Klebsiella pneumonia*. *Enterobacter*, *Klebsiella*, *Citrobacter*, and *Escherichia* spp. were isolated from m-Endo (TC) plates of bath, wash, and rinse wastewater samples.

Forty-eight streptococcal isolates were obtained from bath, wash, and rinse wastewater samples. Enterococci made up 38% of these isolates; the majority of the bath enterococci were *S. faecalis* var. *liquefaciens*, whereas only a few of the enterococcal isolates taken from clothes wash and rinse wastewaters were of this species. Twenty-two percent of streptococcal isolates were characterized as *S. bovis*. Other streptococcal species generally found on and in the body of animals and man, Viridens, and Pyogenic groups were also isolated.

Much of the bacterial contamination in these wastewaters was probably from the natural environment or the natural skin flora of man as indicated by the incidence of *S. faecalis* var. *liquefaciens*, *S. bovis*, and other nonfecal streptococcal isolates found. Many of these organisms, though associated with animal feces, are often considered to exist in nature and probably have less sanitary significance than other enterococcal species. However, the high incidence of *E. coli*, *Klebsiella*, and enterococci especially in wash and rinse wastewaters, indicates that these wastes potentially contain pathogenic organisms, and disinfection prior to reuse is advisable.

Conclusions

1. The water usage in 11 rural homes was monitored for a total of 434 days yielding an average flow of 42.6 gal/capita/day (161.0 l/capita/day) with a 90% confidence interval of 40.8 gal/capita/day-44.4 gal/capita/day (154.2 l/capita/day-167.8 l/capita/day).

2. Monday was found to have the highest average flow with 49.7 gal/capita/day (187.8 l/capita/day), while Friday had the lowest with an average of 37.5 gal/capita/day (141.8 l/capita/day). On a typical day, peak water usage occurred during the morning and evening hours producing flows of 72 gal/capita/day (272.2 l/capita/day) (see Figs. 1 and 2).

3. Of the 42.6 gal/capita/day (161.0 l/capita/day) measured, the individual events contributed the following (see Table 4): (a) Laundry—10.5 gal/capita/day—24.7%; (b) bath/shower—10.0 gal/capita/day—23.5%; (c) toilet flushings—9.2 gal/capita/day—21.5%; (d) dishwashing—4.9 gal/capita/

day—11.4%; (e) water softeners—2.6 gal/capita/day—6.2%; and (f) Others—5.4 gal/capita/day—12.7%.

4. The average size of the events in these households was found to be (see Table 3): (a) Clothes washer—33.5 gal; (b) bath/shower—21.4 gal; (c) toilet—4.(gal; (d) dishwashing—12.5 gal; and (e) water softeners—81.1 gal.

5. The quality of eight major household events was characterized by obtainin individual samples of each over a 35-day period from four rural Wisconsi families.

6. Some of the household events were found to contribute a majority o certain pollutants. Seventy-seven percent of the total daily BOD_5 was produce by three events: (a) The total toilet output (21.7%); (b) the automatic dishwashe (25.5%) and (c) the total clothes washer output (29.8%). Sixty-eight percen of the daily total nitrogen was produced by the toilet (68.1%). Fifty-four percen of the daily total phosphorus was produced by the automatic clothes washe (54.1%) (see Table 9 and note that the garbage disposal results have been omitted)

7. The average daily contributions of BOD_5, suspended solids, total nitrogen and total phosphorus were determined to be 0.109 lb (49,500 mg) BOD_5/capita/day, 0.77 lb (35,000 mg) SS/capita/day, 0.013 lb (5,900 mg) Nitrogen/capita/day and 0.009 lb (4,100 mg) Phosphorus/capita/day (see Table 16 and not that the garbage disposal results have been omitted).

8. The vast majority of pollutant mass produced by an average househol was found to be generated between the hours of 6 a.m. and 9 p.m. with distinc peaks occurring at 9 a.m., 1 p.m., and 7 p.m. (see Figs. 1 and 3).

9. Bacteriological analyses indicated wide variation in indicator organism and the possibility of pathogenic organisms in the bath and laundry wastewaters Therefore, disinfection prior to reuse is recommended (see Table 17).

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Appendix II.—Notation

The following symbols are used in this paper:

BOD_5 F = 5-day biochemical oxygen demand, filtered;
BOD_5 U = 5-day biochemical oxygen demand, unfiltered;
NH_3-N = ammonia nitrogen;
NO_3-N = nitrate nitrogen;
ORTHO-P = ortho-phosphorus;
TOC F = total organic carbon, filtered;
TOC U = total organic carbon, unfiltered;
TOT-N = total nitrogen;
TOT-P = total phosphorus;
TS = total solids;
TSS = total suspended solids;
TVS = total volatile solids; and
TVSS = total volatile suspended solids.