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Rural Household Wastewater Characterization

by

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The characteristics of waste flows from individual households can have a profound effect on the performance of individual household treatment and final disposal methods. In order to study and improve these methods effectively, qualitative and quantitative characterization of wastewater is necessary. To enhance the existing wastewater characterization data base, field studies were conducted at The University of Wisconsin. Water use was monitored at eleven homes for a total of 434 days. To investigate seasonal variation, data was collected from three of the homes for both the summer and winter seasons. The daily water use of various individual household events was determined on a per capita basis and daily and weekly flow patterns were developed. Wastewater quality characterization was accomplished on eight individual household events by sampling at four residences for a total of 35 days. The mg/capita/day contribution from each of the eight events was determined for various quality parameters. The bacteriological quality of three of the eight events was also investigated.

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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 create an intermittent flow pattern of wastes that vary widely in strength and volume. In order to study and improve treatment and disposal alternatives effectively, qualitative and quantitative characterization of wastewater is necessary. A review of the current literature (Ligman et al., 1974) indicated the need for a better data base in order to characterize waste contributions from selected events within the home. This report provides a summary of field studies conducted at the University of Wisconsin to enhance this data base.

PROCEDURES

The field analyses on wastewater characteristics were accomplished in two phases: (1) water use monitoring, and (2) wastewater quality characterization.

Water Use Monitoring. Eleven sites were selected for the water use monitoring phase. These sites offered a wide variety of family types and sizes as indicated in Table 1. In monitoring water use within these homes, every effort was made to avoid interruption of the normal activity within the home. A chart recorder linked mechanically to a water meter was employed at all sites. The charts collected from the surveys were interpreted with the use of a preliminary questionnaire survey at each home tested. Details of the procedures used are found in Witt (12). Data was collected for a total of 434 days from these eleven sites. To investigate seasonal variation, data was collected from three of the sites for both the summer and winter seasons.

Wastewater Quality Characterization. Wastewater quality studies were conducted at residences C, G and I as shown in Table 1. Residence C was occupied by a second family (two adults, one-year old child) during the course of the wastewater quality study and was therefore treated as two residences. Of these residences, C had a garbage disposal and no dishwasher, while G and I had no garbage disposals, but did have dishwashers. From the many water use events which occur in the home, eight were selected for qualitative characterization: (1) fecal toilet flush, (2) nonfecal toilet flush, (3) garbage disposal, (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 and to minimize the involvement of the homeowner, a unique portable automatic wastewater sampler was designed, constructed and tested. It was used over a period of 35 days during the spring and summer of 1974 to monitor wastewater flow and obtain individual samples of the wastewaters produced by each of the eight selected

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events. Details of the procedures used are outlined by Siegrist (9). The samples obtained in the field were preserved on ice, pending transportation back to the Sanitary Engineering Laboratory. The following analyses were then run according to procedures outlined in Standard Methods (10): unfiltered BOD_5, filtered BOD_5, unfiltered TOC, filtered TOC, total solids, volatile solids, suspended solids, volatile suspended solids, total nitrogen, ammonia nitrogen, nitrate nitrogen, total phosphorus, ortho phosphorus, and grease.

Bacteriological characterization was also conducted on three of the eight events: bath/shower, clothes washer-wash cycle, and 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 which would have been present. Samples of the three events were taken by the individual homeowners and refrigerated until analyses were made. Each sample taken was analyzed for fecal streptococci, fecal coliforms and total coliforms according to procedures outlined in Standard Methods (10).

RESULTS

Water Use Monitoring. A summary of the results of the water use survey for all eleven sites are tabulated in Tables 2 and 3. Table 2 provides a summary of frequency and size of water uses for each of the five events that were monitored. Table 3 presents the total daily per capita water usage for each event. In order to illustrate water use patterns in a home, daily and weekly event plots were constructed for each of the sites as well as summary plots for all eleven sites combined. The summary plots are given in Figures 1 and 2. As would be expected, the patterns for any given household were more extreme than the attenuated, eleven site average patterns presented in these figures. Detailed data for each site can be found in Witt (12).

Wastewater Quality Characterization. The carriage water characteristics were subtracted from each sample analyzed for wastewater quality. The resulting mg/l value was converted to mg/event by multiplying by the measured wastewater volume of the event which produced the sample being analyzed. Using these mg/event values and the respective event frequencies determined by Witt (12), Ligman (5) and Perry (7), mg/capita/day values were calculated for the parameters of each sample. The mean, standard deviation and range were then determined for the various parameters of each event. The mean values determined are summarized in Table 4.

The average event frequencies of Witt (12), Ligman (5) and Perry (7), in combination with the results of the wastewater quality study were used to develop daily and weekly loading patterns. Examples of daily and weekly patterns for unfiltered BOD_5 are shown in Figures 3 and 4. More detailed data can be found in Siegrist (9).

The results of the bacteriological investigation are shown in Table 5.

DISCUSSION

Water Use Monitoring. An average flow of 42.6 gpcd was calculated for all data collected over the 434 day sampling period with a 90% confidence interval of 40.8 to 44.4 gpcd. This average flow is comparable to that found by others (Table 6).

Little daily variations in flow existed for any of the events studied, except for bath and laundry (Figure 1). No single day, however, exhibited significantly higher total flows than another (Figure 2). The daily flow pattern indicated two peak flow periods, the morning and evening hours. Water softening contributed very significant use patterns in a number of homes although the summary plots attenuate its influence.

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. The results of this study (Table 4) illustrate how the mg/capita/day contributions from each of the eight events vary from event to event. In general, the results for each of the events compare favorably with those of earlier investigators. Discrepancies are present, however, especially in regard to the toilet and garbage disposal events. In this study, the sum of fecal and nonfecal toilet flush events produced a substantially lower contribution of pollutants than had been reported earlier by Laak (4) and Ligman (6). For this study, samples were actually taken from the toilet flushes whereas Ligman and Laak did not sample, but estimated toilet waste output from the literature. This difference in obtaining results no doubt caused the discrepancies. The results of garbage disposal analyses in this study were significantly lower than earlier results. This was probably due to the fact that each of the two families studied who had garbage disposals also had large dogs. These dogs received the majority of meal scraps which otherwise would have been put down the disposal.

The daily per capita contribution of various parameters were calculated as the sum of the daily contributions from each of the events except the garbage disposal. The garbage disposal values were omitted since the use of this appliance in homes served by individual household treatment systems is discouraged. The contributions of unfiltered BOD_5, suspended solids, total nitrogen and total phosphorus were found to be .109 lb. BOD_5/capita/day, .078 lb. SS/capita/day, .013 lb. N/capita/day and .009 lb. P/capita/day. Ligman (6) reported values of .174 lb. BOD_5/capita/day, .198 lb. SS/capita/day and .009 lb. P/capita/day. Laak's (4) data yielded .108 lb. BOD_5/capita/day. The BOD_5 and suspended solids values reported by Ligman are substantially higher than values found in this study due to the addition of .068 lb. BOD_5/capita/day and .096 lb. SS/capita/day as daily contributions from the garbage disposal.

The bacteriological results as depicted in Table 5, 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 5, several isolates were obtained from the three events. Sixty-one fecal coliform 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.

CONCLUSION

1. The water usage in eleven homes was monitored for a total of 434 days yielding an average flow of 42.6 gpcd with a 90% confidence interval of 40.8 to 44.4 gpcd.
2. The frequency, size and per capita contributions of five major water use events are summarized in Tables 2 and 3.
3. The quality of eight major household events was characterized by obtaining individual samples of each over a 35 day period from four rural Wisconsin families. These results are summarized in Table 4.
4. Seventy-seven percent of the total daily BOD_5 was produced by the total toilet output (21.7%), the dishwasher (25.5%), and the total clothes washer output (29.8%). Sixty-eight percent of the total daily nitrogen was produced by the total toilet output (68.1%). Fifty-four percent of the total daily phosphorus was produced by the total clothes washer output (54.1%).
5. Average contributions were calculated for BOD_5, suspended solids, total nitrogen and total phosphorus: .109 lb. BOD_5/cap/day, .078 lb. SS/cap/day, .013 lb. N/cap/day and .009 lb. P/cap/day. (Garbage disposal results omitted)
6. Bacteriological analyses indicated wide variation in indicator organisms and the possibility of pathogenic organisms in the bath and laundry wastewaters. Therefore disinfection prior to reuse is recommended.

TABLES AND FIGURES

TABLE 1. FAMILY INFORMATION

LOCATION	ADULTS	CHILDREN (AGE)	BATHROOMS	AUTOMATIC CLOTHES WASHER	AUTOMATIC DISH WASHER	WATER SOFTENER	OCCUPATION OF HEAD OF HOUSEHOLD
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 mo.)	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. FREQUENCY AND SIZE OF EVENTS

	TOILET		LAUNDRY		BATH OR SHOWER		DISH WASH		WATER SOFTENER	
LOCATION	FREQ. NO/CAP/ DAY	AVERAGE SIZE GALLONS	FREQ. NO/CAP/ DAY	AVERAGE SIZE GALLONS	FREQ. NO/CAP/ DAY	AVERAGE SIZE GALLONS	FREQ. NO/CAP/ DAY	AVERAGE SIZE GALLONS	FREQ. NO/CAP/ DAY	AVERAGE SIZE GALLONS
A	2.07	4.40	0.36	35.42	0.43	31.54	0.29	17.00	0.08	75.67
B	2.29	3.80	0.19	11.37	0.38	20.87	0.26	10.18	-	-
C	1.70	3.31	0.36	36.32	0.31	23.61	0.31	11.16	0.06	71.65
D	2.79	3.00	0.23	33.17	0.66	20.13	0.41	12.17	0.02	95.17
E	1.71	4.80	0.33	41.86	0.45	19.03	0.24	11.60	-	-
F	1.39	4.51	0.46	27.28	0.26	22.28	0.39	12.78	-	-
G	1.49	4.34	0.15	28.61	0.47	18.48	0.36	10.48	0.05	69.83
H	2.29	4.00	0.32	34.91	0.36	16.27	0.36	7.92	0.24	66.41
I	1.68	4.72	0.59	27.68	0.34	21.28	0.49	12.46	-	-
J	3.10	4.44	0.27	34.92	0.57	21.51	0.40	13.75	-	-
K	2.93	3.73	0.34	38.37	0.55	21.23	0.54	13.27	0.03	144.62
AVERAGE (Weighted)	2.29	3.99	0.31	33.49	0.47	21.35	0.39	12.50	0.03	81.07

TABLE 3. WATER USAGE - GPCD

LOCATION	TOILET	LAUNDRY	BATH OR SHOWER	DISH WASH	WATER SOFTENER	OTHER	TOTAL	90% CONFIDENCE INTERVAL	DAYS
A	9.10	12.63	13.50	5.00	6.07	10.42	56.73	48.67-64.79	28
B	8.69	2.17	7.95	2.67	0.0	3.95	25.43	19.97-30.88	14
C	5.63	13.08	7.28	3.48	3.95	5.43	38.85	34.46-43.24	77
D	8.37	7.63	13.26	4.98	2.27	4.54	41.05	37.88-44.21	42
E	8.23	13.95	8.61	2.76	0.0	7.92	41.46	32.15-50.78	28
F	6.24	12.66	5.73	5.02	0.0	4.08	33.74	27.87-39.60	28
G	6.49	4.20	8.67	3.72	3.42	3.27	29.78	26.43-33.14	35
H	9.17	11.15	5.88	2.86	15.68	4.94	49.68	44.78-54.59	24
I	7.92	16.21	7.14	6.14	0.0	4.39	41.81	36.79-46.82	28
J	13.75	9.54	12.16	5.52	0.0	4.16	45.11	42.82-47.41	68
K	10.91	13.00	11.73	7.12	4.67	9.51	56.93	50.70-63.16	62
AVERAGE (Weighted)	9.16	10.51	10.00	4.86	2.64	5.43	42.59	40.84-44.35	434

FIGURE 1. DAILY FLOW PATTERN

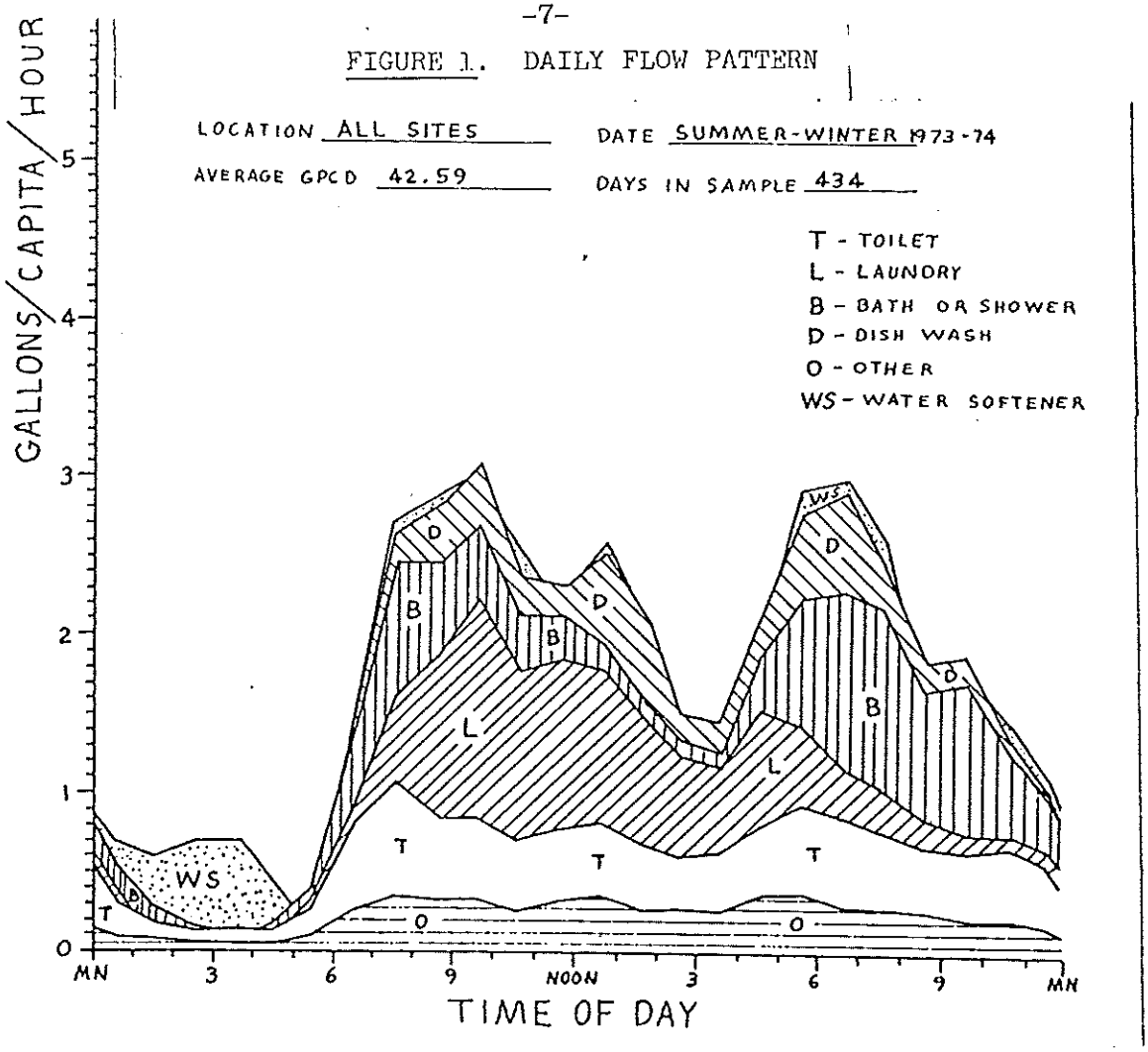

FIGURE 2. WEEKLY FLOW PATTERN

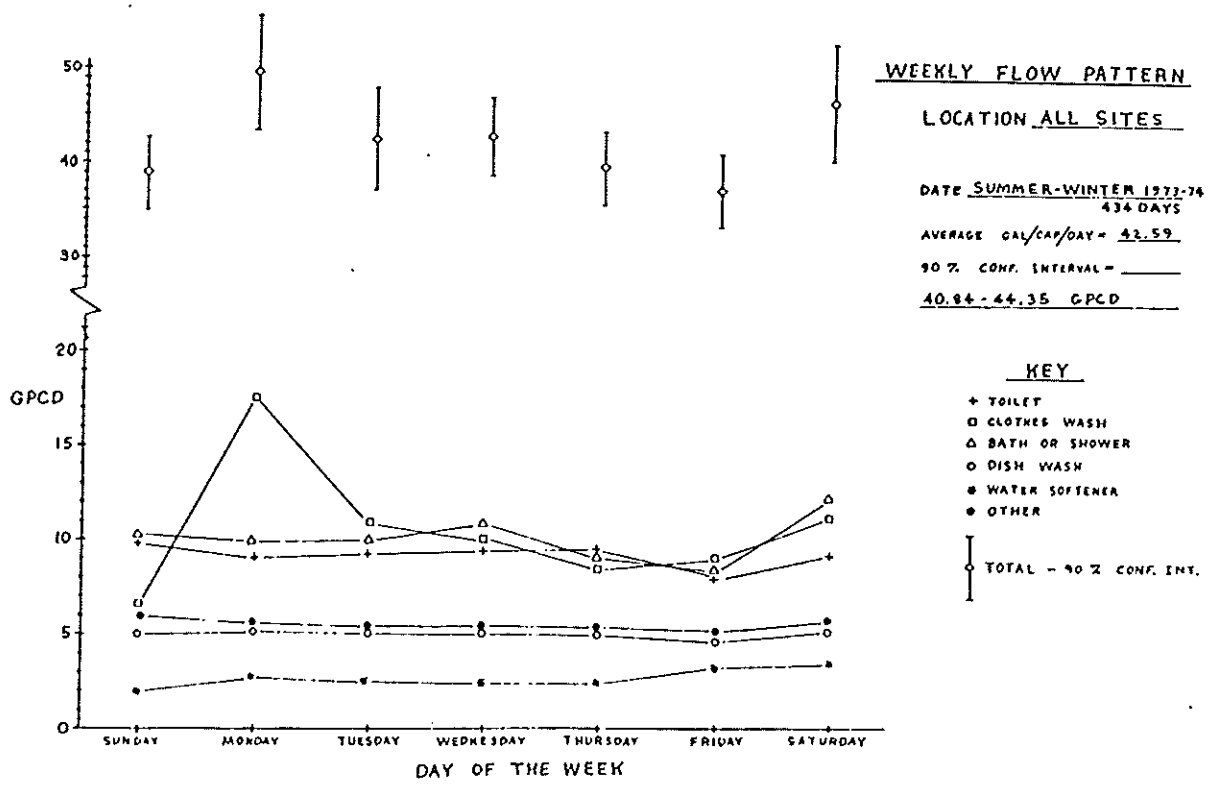

TABLE 4. MEAN WASTEWATER CONTRIBUTIONS FROM INDIVIDUAL HOUSEHOLD EVENTS, MG/CAP/DAY

PARAMETER \ EVENT	FECAL TOILET FLUSH	NONFECAL TOILET FLUSH	GARBAGE DISPOSAL	KITCHEN SINK USAGE	AUTOMATIC DISH-WASHER	CLOTHES WASH	CLOTHES RINSE	BATH/ SHOWER	Σ (MEANS) LESS DISPOSAL
FLOW[1]	7.1	19.5	10.6	5.7	12.1	30	26.5	18.5	119.4
BOD_5 UNFILTERED	4337	6379	10923	8344	12625	10763	4011	3086	49545
BOD_5 FILTERED	2339	3979	2568	4576	7835	6965	2842	1872	30408
TOC UNFILTERED	3533	4246	7317	5000	7276	7698	2605	1749	32107
TOC FILTERED	1574	3165	3911	4111	4686	5381	1907	1128	21952
TOTAL SOLIDS	10671	17799	25755	13761	18157	37489	10941	4590	113408
VOLATILE SOLIDS	7757	11972	24018	9731	10544	14657	4794	3596	63051
SUSPENDED SOLIDS	6473	6276	15823	4111	5267	7927	3043	2261	35358
VOLATILE SUSPENDED SOLIDS	5087	5122	13486	3841	4457	4699	1817	1571	26594
TOTAL NITROGEN	1497	2644	632	424	487	579	146	306	6083
AMMONIA NITROGEN	593	521	9.6	32.3	54	19.4	11.4	40	1271
NITRATE NITROGEN	6.3	21.1	.2	1.8	4.1	17	10.3	7.4	68
TOTAL PHOSPHORUS	268	280	128	419	819	1602	548	36	3972
ORTHO PHOSPHORUS	115	188	88	177	382	411	112	21	1406
NUMBER OF SAMPLES	35	34	6	10	14	25	26	21	
GREASE[2]	928	2423	2100	2329	2476	1844	1406	3219	14625

[1] Flow values were determined in the wastewater quality study and are in liters/capita/day.
[2] Number of samples used for grease analysis varies from 2-8 depending on event.
All Values do not include carriage water contributions.

FIGURE 3. DAILY BOD_5 PATTERN

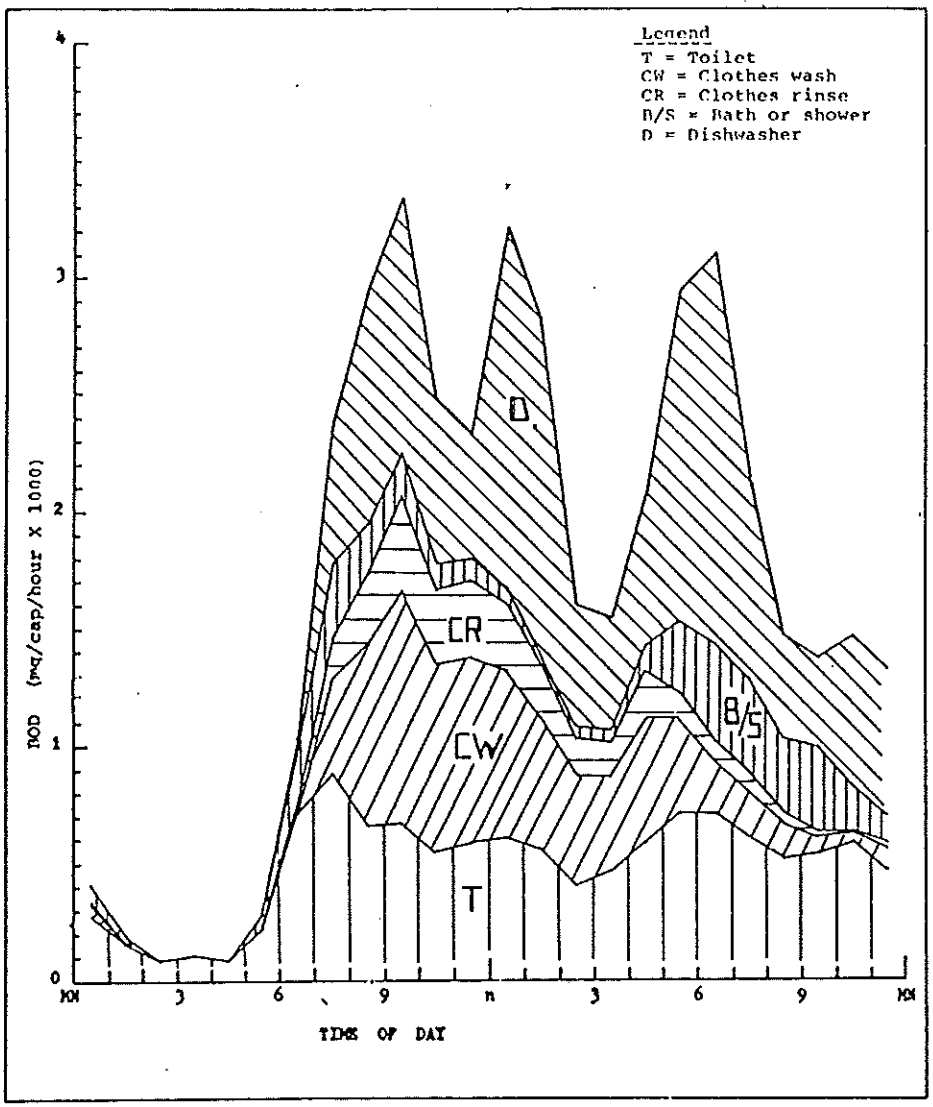

FIGURE 4. WEEKLY BOD_5 PATTERN

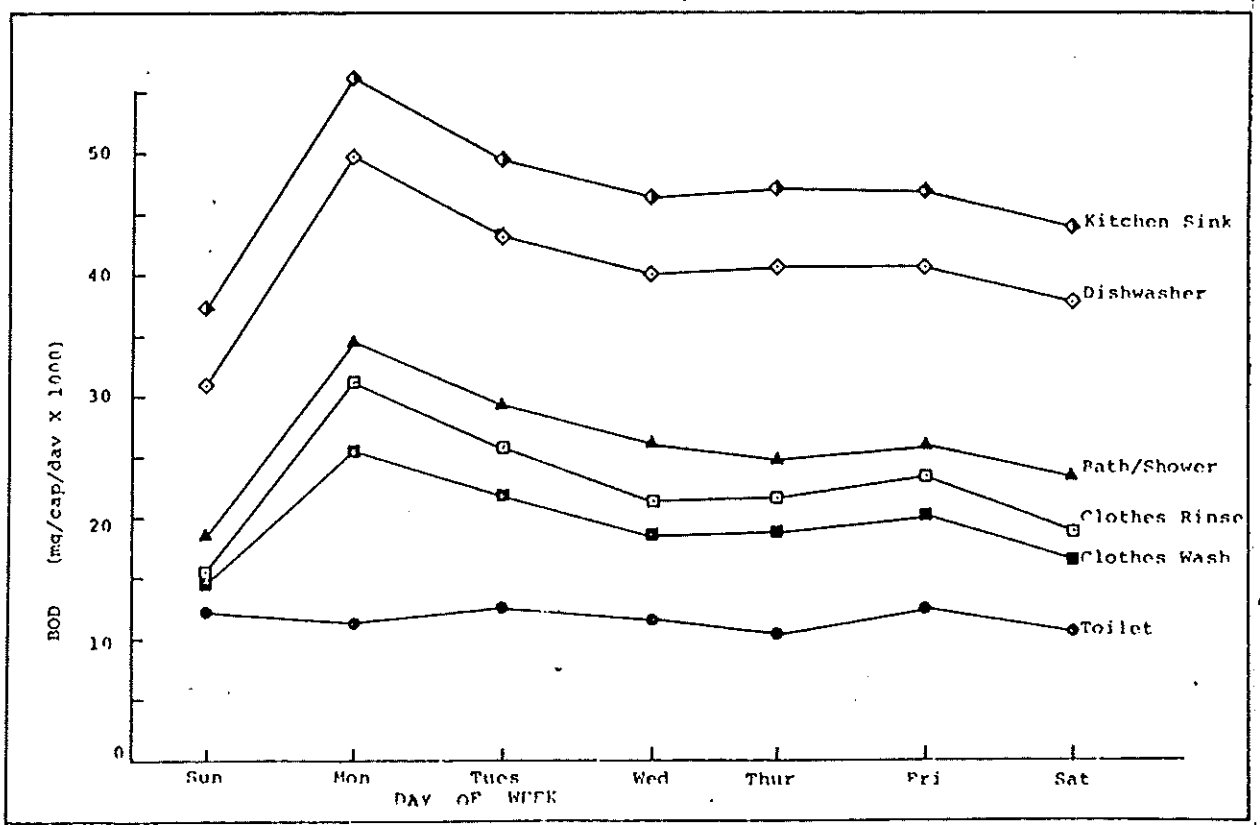

TABLE 5. BACTERIOLOGICAL CHARACTERISTICS OF THE LAUNDRY AND BATH/SHOWER EVENTS

EVENT	ORGANISM	DATA PTS.	GEOMETRIC MEAN #/100 mls	RANGE #/100 mls		STANDARD DEVIATION of LOG NORMALIZED DATA	95% CONFIDENCE INTERVAL FOR GEOMETRIC MEAN of LOG NORMALIZED DATA #/100 mls	
BATH / SHOWER	FECAL STREPTOCOCCI	13	44	1	70,000	.49	4	500
	FECAL COLIFORMS	11	220	1	2,500	.31	46	1100
	TOTAL COLIFORMS	10	1,100	70	8,200	.21	350	3200
CLOTHES WASH	FECAL STREPTOCOCCI	15	210	1	1300,000	.55	14	3100
	FECAL COLIFORMS	13	1,400	9	16,000	.32	280	6700
	TOTAL COLIFORMS	12	18,000	85	890,000	.38	2,500	120000
CLOTHES RINSE	FECAL STREPTOCOCCI	16	75	1	230,000	.55	5	1100
	FECAL COLIFORMS	14	320	35	7,100	.18	130	780
	TOTAL COLIFORMS	12	5,300	190	150,000	.22	1,700	16000

TABLE 6. WATER USAGE COMPARISON - PERCENTAGE

	USGS[8] 1962	HANEY & HAMANN[5] 1967	LAAK[6] 1971	LIGMAN[7] 1972	WALLMAN[9] 1972	ONTARIO RESEARCH[3] 1973	BENNETT[2] 1973	THIS STUDY 1974
TOILET	41	45	43	41	27-45	38	33	22
LAUNDRY	4	5	16	19	18	12	26	25
BATH	37	30	19	26	18-36	34	20	23
KITCHEN	6	6	8	10	13	10	12	11
CLEANING	3	4	5	1	-	3	3	-
DRINKING	5	3	3	3	-	3	3	-
MISC.	4	7	6	0	6	0	3	13 OTHER 6 WATER SOFTENER
FLOW (gpcd)	-	-	41	45	30-50	-	44	43

ACKNOWLEDGEMENTS

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REFERENCES

1. Bennett, Linstedt and Felton, "Comparison of Septic Tank and Aerobic Treatment Units: The Impact of Wastewater Variation of These Systems," Presented at the Rural Environmental Engineering Conference, Warren, Vermont, September, 1973.

2. Besik, F. K., "Remarks," Ontario Research Foundation, Ontario, Canada, May, 1973.

3. Haney, P. D. and Hamann, C. L., "Dual Water Systems," Journal of American Water Works Association, 57, September, 1965.

4. Laak, R., "Home Plumbing Fixture Waste Flows and Pollutants," Unpublished report, University of Connecticut, Storrs, Connecticut, 1972.

5. Ligman, K., "Rural Wastewater Simulation," M.S. Independent Study Report, University of Wisconsin, Madison, Wisconsin, 1972.

6. Ligman, Hutzler and Boyle, "Household Wastewater Characterization," Journal of the Environmental Engineering Division, ASCE, February, 1974.

7. Perry, R., "Adaptation of an Aerobic Sewage Treatment Process for Individual Homes," M.S. Thesis, 1952, as presented in "Summary of Studies on Aerobic Sewage Treatment for Individual Homes," by Perry, Rigby, et al., Unpublished report, Purdue University, 1954.

8. "Public Water Supplies of the 100 Largest Cities in the United States," U. S. Geological Survey Water Supply Paper No. 1812; 1962.

9. Siegrist, R., "Characterization of Rural Household Wastewaters," M.S. Thesis, University of Wisconsin, Madison, Wisconsin, 1975.

10. Standard Methods for the Examination of Water and Wastewater, 13th Edition, APHA, 1971.

11. Wallman, H., "Should We Recycle/Conserve Household Water?" 6th International Water Quality Symposium, Washington, D.C., April 18-19, 1972.

12. Witt, M., "Water Use in Rural Homes," M.S. Independent Study Report, University of Wisconsin, Madison, Wisconsin, 1974.