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THE CHEMICAL/PHYSICAL AND MICROBIOLOGICAL CHARACTERISTICS OF TYPICAL BATH AND LAUNDRY WASTE WATERS

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16. Abstract

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SUMMARY

An experimental investigation of the chemical/physical and microbiological characteristics of typical bath and laundry waste waters has been conducted. Data are presented for bath waste water and laundry waste water collected separately and for bath and laundry waste water collected together during a 12-day test in which the untreated waste waters were reused for toilet flush water. When compared to a tap water baseline, the chemical/physical characteristics of combined bath and laundry waste waters showing the most significant changes were ammonia, color, methylene blue active substance (MBAS), phosphates, sodium, sulfates, total organic carbon, total solids, and turbidity. The mean total number of micro-organisms detected from the combined bath and laundry waste waters ranged from 10^6 to 10^7 cells/ml and the mean number of possible coliforms ranged from 10^5 to 10^6 cells/ml. Total micro-organism and coliform counts stabilized at levels of 10^6 and 10^5 cells/ml, respectively. An accumulation of particulates and an objectionable odor were detected in the tankage used during the 12-day reuse of the untreated waste waters. The combined bath and laundry waste waters from a family of four provided 91 percent of the toilet flush water for the same family.

INTRODUCTION

Early studies of proposed extended duration manned spacecraft missions concluded that onboard processing of waste waters and metabolically produced solids would be required (refs. 1 and 2). This conclusion led to a program which included life support system technology developments at the process, subsystem, and integrated system levels (refs. 3 to 5). The recent national emphasis on domestic problems related to water conservation and the treatment of sewage wastes stimulated studies of possible applications of the spacecraft life support system technology to the domestic problems. An experimental program was initiated by the Langley Research Center to explore this possibility. The program was to use existing breadboard hardware originally developed for long duration spacecraft missions. The experimental hardware units were, therefore, not optimum for domestic applications but could be used to obtain needed data on process suitability, power use rates, expendable use rates, and integration problems.

The planned experimental program will investigate several water conservation and reuse concepts. One concept that appears attractive is the reuse of bath and laundry waste water for toilet flushing. Application of this concept can reduce household water requirements up to 40 percent (ref. 6) while possibly requiring minimum treatment of the waste water. In order to determine the level of treatment required, an experimental effort was undertaken to define the chemical/physical and microbiological characteristics of the untreated bath and laundry waters. The results of this effort are presented in this report.

Typical domestic wastes, such as the bath and laundry waters discussed in the report, processed by the experimental hardware units are provided by operating the appliances and fixtures of a simulated single-family household. The single-family household serves as a suitable and convenient focus although the test results and conclusions are equally applicable to multiple-family domestic living units.

TESTS AND RESULTS

Test Setup and Instrumentation

The test setup is shown in figure 1. The setup included a wood platform divided into a kitchen, laundry, and bathroom; an area beneath the platform for collecting and processing waste waters; and a walkway behind the platform for access to the plumbing lines and water meters. The kitchen, laundry, and bathroom contained commercially available household appliances and fixtures. In addition, a commercially available hot water tank was located on the lower level. The lower level simulated a household basement or an apartment furnace and utility room. Domestic water, sewerage, and power services were provided to the setup through connections with the building services. Hot and cold water flow to all appliances and fixtures was measured to the nearest 0.4 liter (0.1 gal) by conventional rotary-disc water meters. Each meter was calibrated in place at the temperature and line pressure encountered during use. Meter errors ranged between 0 and +6.0 percent. All water volumes discussed subsequently in this report have been corrected based on meter calibrations.

Bath Water Tests

Procedure.- Baseline samples were collected prior to bath water samples. The baseline samples provide a reference point for comparison.

Baseline: Baseline water samples for chemical/physical and microbial analyses were taken on the bath fixtures and plumbing prior to conducting the bath water tests. Warm tap water (approximately 311 K (100° F)) was passed through the shower and tub fixtures into the tub. The water drained without restriction through the drain plumbing into a transparent polymer collection tank which, in turn, was drained to the sewer line. Subsequently the tub, drain plumbing, and collection tank were filled with tap water at a temperature of approximately 289 K (60° F). The water was held for 15 minutes. All water was then drained and the fill, water hold, and drain procedure was repeated a second time. During the second drain, the baseline sample for chemical/physical analyses was taken from the collection tank. Immediately thereafter the baseline sample for microbial analyses was obtained. This sample was obtained by the procedure just described except that prior to the initial rinse with warm tap water, the tub and collection tank were hand washed with an antibacterial cleanser.

Bath water: Bath water samples were collected from tub baths and shower baths. A single test subject alternated tub and shower baths over a 4-day period. A single non-biocidal hand soap was used for the four baths. The following week, four similar baths were taken by the same subject using a biocidal hand soap containing hexachlorophene. Samples for chemical/physical analyses of the used bath waters were taken from the collection tank immediately after completion of the baths. The samples were analyzed for the chemical/physical characteristics listed in table I. Table I also lists the techniques used to measure each characteristic and the lowest concentration limit that can be detected by the water analysis laboratory.

Samples for microbial analyses were taken from the collection tank immediately after completion of baths and again after holding bath water 24 hr in the collection tank. The sample port consisted of a 6.35-mm-diameter (1/4 in.) stainless-steel tube. Samples were collected by heat sterlizing the tubing and, after cooling, rejecting the first sample and then collecting the next sample in a sterile container. All samples collected were processed within 30 min after collection. Total counts were performed by making tenfold dilutions of the sample in 0.05-percent peptone water and plating appropriate dilutions on Trypticase soy agar and MacConkey agar. Colonies were counted after a 48-hr incubation at a temperature of 308.15 K (35° C) and the results were expressed as the total number of organisms and possible coliforms per milliliter of sample. Colonies exhibiting a typical brick-red color were identified as possible coliforms. Subsequent studies indicated that these counts were approximately 1 to 2 orders of magnitude greater than results obtained using a standard coliform count procedure.

Discussion of results.- A detailed listing of the chemical/physical characteristics of the bath waters is given in table II. The characteristics having values that were most significantly different from the baseline values are as follows:

Characteristic	Baseline tap water	Bath water and –	
		Nonbiocidal soap	Biocidal soap
Ammonia, ppm	0.2	1.40	0.92
Color, $PtCl_6$ equiv. units.	5	58.0	87.0
Total organic carbon, ppm	20	67	72
Total solids, ppm.	220	310	507
Turbidity (SiO_2 equiv.), ppm	2	144	115

The values in the column "Nonbiocidal soap" are averages of the four bath water samples with nonbiocidal soap. The values in the column "Biocidal soap" are averages of the four bath water samples with biocidal soap.

Other characteristics that exceeded baseline values significantly but to a lesser degree than those just noted were methylene blue active substance (MBAS), manganese, potassium, and sodium. The biocidal soap samples showed a distinct increase in free chlorine. The MBAS values are indicative of the presence of carboxylate ion in soap which reacts with the methylene blue reagent to give a positive test.

The microbial results of the bath water tests are given in detail in table III and are summarized as follows:

	Baseline tap water	Bath water and –			
		Nonbiocidal soap		Biocidal soap	
		Initial	After 24 hr	Initial	After 24 hr
Total number of organisms, cells/ml	9.4×10^1	4.23×10^4	2.15×10^6	3.09×10^5	9.91×10^6
Possible coliforms, cells/ml	0	4.94×10^3	3.77×10^5	1.74×10^4	1.11×10^6

Based on the eight separate baths, the important microbial results were the identification of human subjects as a source of coliforms and the lack of major differences in micro-organism counts between the nonbiocidal and biocidal hand soaps. Also noted was an expected increase in micro-organism count after holding the water for 24 hr in the collection tank.

Laundry Water Tests

Procedure.- Baseline samples were collected prior to laundry water samples. The baseline samples provide a reference point for comparison.

Baseline: Baseline tap water samples for chemical/physical analyses were taken on the laundry appliance and plumbing prior to conducting the laundry water tests. These laundry baseline tap water samples were taken by the same procedure used for the bath water tests except that an antibacterial cleanser was not used during preparation for the microbial baseline sample. Also, during preparation for the microbial baseline sample, the appliances, plumbing, and collection tank were left filled overnight after the second fill. The overnight hold in the filled condition was an attempt to soak the appliances and plumbing clean and thereby provide a clean setup for establishing a chemical and microbial baseline. The next morning, all elements were drained and filled a third time; then the sample was taken from the collection tank.

Laundry water: Laundry water samples were collected from four full loads of mixed domestic laundry. Each load contained at least one item of underclothing, outerclothing, socks, bed clothing, bathroom towels, and kitchen linen. Each load was washed on a separate day with 225 ml of a domestic laundry detergent powder. In order to detect differences in water characteristics that may affect reuse potential, two loads of the four loads of clothes were processed so that the wash cycle discharge could be collected separately. The other two loads were processed so that all discharge water was collected in a single tank. Samples for chemical/physical analyses were taken from the collection tank immediately after completion of the laundry cycle and were analyzed for the characteristics listed in table I. Samples for microbial analyses were taken from the collection tank immediately after completion of the laundry cycle and again after holding 24 hr in the collection tank. Samples were collected and processed by the same procedures used for the bath water tests.

Discussion of results.- A detailed listing of the chemical/physical characteristics of the laundry water is given in table II. The characteristics having values that were most significantly different from the baseline values are as follows:

Characteristic	Baseline tap water	Combined wash cycle/rinse cycle laundry water	Separate wash cycle laundry water
Ammonia, ppm	0.4	1.5	4.3
Chlorine, ppm	0.05	0.35	0.7
Color, $PtCl_6$ equiv. units	10	50	50
Conductivity, μmhos/cm	230	360	775
MBAS, ppm	0.04	52	122
Phosphates, ppm	0.7	250	360
Sodium, ppm	10	92	167
Sulfates, ppm	30	127	237
Total organic carbon, ppm	13	75	162
Total solids, ppm	170	550	1050
Turbidity (SiO_2 equiv.), ppm	6	26	72

The values in the column "Baseline tap water" are the values of the baseline sample. The values in the column "Combined wash cycle/rinse cycle laundry water" are the averages of the two samples in which all discharged water was collected in a single collection tank. The values in the column "Separate wash cycle laundry water" are the averages of the two samples that contained only discharged wash cycle water.

Other characteristics having values that exceeded baseline values significantly but to a lesser degree than those just noted were chloride, chromium, lead, nitrates and nitrites, odor, potassium, and zinc. These data suggest that the detergent is a major contributor to the chemical character of the laundry water. The values of the chemical/physical characteristics approximately doubled when the wash cycle water, which was approximately one-half of the combined wash/rinse cycle waters, was collected and analyzed separately from the rinse cycle water.

A single detergent was used during the laundry water tests. In order to determine which chemical/physical characteristics would change and to what extent if detergents other than the one chosen were used, additional detergent analyses were performed. A distilled water solution of the single detergent used was prepared with a detergent-to-water ratio of 1:250. This ratio corresponds to 1 cup of detergent in 64.3 l (17 gal) of water which duplicates the wash cycle water discharge portion of a complete washing operation. Similar solutions of 1:250 were prepared by using 26 other domestic detergents. All 27 solutions were analyzed for all characteristics listed in table II.

By utilizing the highest level of each characteristic quantified during analyses of the 26 additional detergents, percentage increases over the corresponding characteristic for the detergent used in the laundry water tests were calculated. These percentage increases were then applied to the laundry water sample data of table II. A summary table listing possible highest values for the chemical/physical characteristics appears as follows:

Characteristic	Baseline tap water	Combined wash cycle/rinse cycle laundry water	Separate wash cycle laundry water
Ammonia, ppm	0.4	1.5	4.3
Boron, ppm	<1	<34	34
Chloride, ppm	18	425	660
Chlorine, ppm	0.05	0.35	0.7
Color, $PtCl_6$ equiv. units	10	50	50
Conductivity, μmhos/cm	230	612	1317
Magnesium, ppm	2.4	487	609
MBAS, ppm	0.04	78	183
Phosphates, ppm	0.7	300	432
Potassium, ppm	1.3	168	281
Sodium, ppm	10	92	167
Sulfates, ppm	30	2286	4266
Suspended solids, ppm	<100	<1470	1470
Total organic carbon, ppm	13	172	373
Turbidity (SiO_2 equiv.), ppm	6	36	101

Additional characteristics having values that exceed baseline values significantly but to a lesser degree than those just noted are cadmium, calcium, chromium, nitrates and nitrites, odor, lead, and zinc. No situation is forseen where all possible highest values are encountered at one time; however, any processing system would need to be capable of handling each of the highest values.

An additional observation on physical quality that cannot be seen from inspection of the data is the large amount of fibrous particles present in laundry water. Regardless of the type of clothing washed, a 3.18- to 6.35-mm (1/8 to 1/4 in.) layer of the lint would accumulate on the bottom of the collection tank if the water and tank were left undisturbed after collection. No effort to time the settling was attempted but visual observation disclosed that it continued overnight. In addition, any agitation of the water after settling was completed would resuspend the particles.

On the basis of these visual observations, it appears that any technique used for processing collected laundry water would encounter the particles. Figure 2 shows an accumulation of particles on the bottom of the collection tank after washing one load of clothes and an overnight hold in the tank.

The microbial results of the laundry water tests are given in detail in table IV and are summarized as follows:

	Baseline tap water	Combined wash cycle/rinse cycle laundry water		Separate wash cycle laundry water	
		Initial	After 24 hr	Initial	After 24 hr
Total number of organisms, cells/ml	0	1.27×10^4	9.65×10^6	2.93×10^6	5.88×10^7
Possible coliforms, cells/ml	0	2.55×10^3	1.96×10^6	2.1×10^4	1.95×10^7

Based on the four separate loads of mixed domestic laundry, the important microbial results were the identification of clothing as a carrier of coliforms and the increase in organism counts after holding the laundry waste water for 24 hours in the collection tank.

Combined Bath and Laundry Water Tests

After defining tub/shower bath water and laundry water separately under isolated test conditions, it was advantageous to define combined bath and laundry water under conditions representing those to be encountered in a typical domestic reuse system. A system was set up for collection of the combined bath and laundry waste waters and reuse of the untreated waste waters for flushing the toilet. A portion of the system is shown in figure 3. The drains from the tub/shower and washing machine were connected to a 416.4-l (110 gal) polyethylene tank which served as a collection tank. Water was pumped from the collection tank through a 50.8-mm-diameter (2 in.) copper pipe to a 64.3-l (17 gal) carbon-steel pressure tank by a shallow well jet pump. The pressure tank was maintained between 138 and 276 kN/m^2 (20 and 40 psig) by the jet pump. A 12.7-mm-diameter (1/2 in.) copper pipe carried water from the pressure tank to the commode tank. The commode was a commercial vitreous china household unit using between 17.0 and 22.7 l (4.5 and 6 gal) of water per flush. Upon flushing the commode, water drained through a copper pipe to the building sewer system.

Water transfer through the system was controlled by the jet pump and associated pressure tank. When flushing caused tank pressure to fall below 138 kN/m^2 (20 psig), the jet pump switched on and repressurized the pressure tank with water from the collection tank. Upon reaching a pressure of 276 kN/m^2 (40 psig), the pump cut off.

It was anticipated that waste water supply and flush water demand rates would not always match and, therefore, makeup water may be needed. When the water level in the collection tank fell below the 56.8-l (15 gal) level, a diaphragm-type pressure differential switch activated a solenoid valve to open a makeup water line permitting tap water to fill the tank to the 75.7-l (20 gal) level. At that level, the pressure differential switch closed the solenoid. The pressure differential switch referenced water column pressure in the tank to ambient atmospheric pressure.

It was also anticipated that periods of high waste water supply may overload the collection tank and, therefore, a 50.8-mm-diameter (2 in.) copper pipe overflow was added. The overflow drained directly to the sewer.

Procedure.- The procedure for conducting the combined bath and laundry water characterization test was based on the need to closely simulate an actual domestic system in which waste waters were used for toilet flushing. Only in a close simulation could the effect of the supply-demand cycle on the physical/chemical character and microbial character of the waters be evaluated.

Baseline: The baseline data for the chemical/physical analyses were obtained by averaging the values from the two tap water baselines previously established for the separate bath water tests and laundry water tests. The baseline samples for microbial analyses were obtained after rinsing the tub/shower, washing machine, drain plumbing, and collection tank with warm tap water at a temperature of approximately 311 K (100° F) and then draining and refilling all units twice with tap water at approximately 289 K (60° F). The baseline samples were withdrawn from the collection tank and commode tank after the last refill.

Combined bath and laundry water: The first step in the simulation of a domestic system was to establish an average daily count of toilet flushings. This was accomplished by recording the toilet flush frequency of a family of four, two adults and two children, throughout a continuous 2-week period at their home. The average number of daily flushings was 21. Flushings were recorded by living pattern periods: preschool (6:30 a.m. to 8:30 a.m.), midday (8:30 a.m. to 4:30 p.m.), predinner (4:30 p.m. to 6:30 p.m.), and evening (6:30 p.m. to 10:30 p.m.). Since actual duplication of the living pattern between 6:30 a.m. to 10:30 p.m. was inconvenient to carry out in the laboratory, a concession to realism was made by compressing the 16-hr span into an 11-hr span. However, the number of flushings per time period was maintained. Personal use of the commode was not included in the test procedure since the investigation was conducted to determine only the water quality entering the commode from the waste water storage tank.

Bathing patterns of the same family of four were also observed. The family averaged two baths a day with evening baths slightly preferred over morning baths. This condition was well simulated in the laboratory by arranging one morning bath and one evening bath on day 1 followed by two evening baths on day 2. Subsequent days repeated the cycle of these two days. Each subject alternated tub and shower baths which also simulated home patterns. The same family members observed in the home were used to provide the bath waters in the laboratory.

Laundry waste water was provided by processing the same four-member family's laundry as the normal buildup of soiled laundry occurred. Days requiring none, one, and two loads of laundry were experienced. Each load was processed on normal machine settings with 225 ml of a domestic laundry detergent, the same detergent used during the separate laundry water tests.

A test duration of 12 days was selected. It was known from the separate bath water and laundry water tests that the microbial character of the water would change overnight, and it was anticipated that further changes would occur with additional time. A 12-day period should show this change and should be sufficiently long to show the effects of the family living cycle on the ratio of available waste waters to required toilet flush water.

Combined bath and laundry water samples for chemical/physical analyses were obtained daily from the collection tank immediately after the laundry water dump. On days when there was no laundry, samples were taken immediately after the morning bath. Since the collection tank was never drained, was permitted to overflow, and had makeup water added frequently, water in the collection tank became a composite after 2 or 3 days of operation. Samples would, however, contain concentration gradients since ratios of bath water to laundry water and of combined wash waters to makeup water would be changed without plan. Chemical/physical samples were analyzed for the characteristics listed in table V. Fourteen characteristics proved to be below detectable limits or low to the extent that they were excluded from further analyses, as noted in the table. The baseline data used for comparison were obtained by averaging the valves from the two tap water baselines previously established for the separate bath and laundry water tests.

Water samples for microbial analyses were taken five times daily from the collection tank and the commode tank. The first set of samples was taken simultaneous with the chemical/physical sample. The other four sets of samples were taken at approximately 2-hr intervals over the 8-hr workday. Samples were drawn with a sterile 5.0-ml pipette and were placed in a small sterile container. Dilution, plating, and incubation were as previously described.

During the 12-day test in which the simulated flushing cycle was inserted into the test procedure, the air around the base of the toilet was sampled to detect organisms aerosolized during the flushing operation of the toilet. The air samples were obtained by placing two Reynier air samplers, one containing Trypticase soy agar and the other containing MacConkey agar, on the floor beside the toilet bowl. The samplers were operated at a rate of 1 l/min during five 2-hr periods per day with 15-min intervals between periods. Each Trypticase agar plate was incubated for 48 hr and counted for total colonies. Each MacConkey agar plate was incubated for 24 hr and counted for total colonies and possible coliform colonies.

After completion of the 12-day test, a 3-day test was performed using a daily load of soiled baby diapers, a known source of concentrated coliform organisms. Microbial samples were taken using the same procedure as for the 12-day test, but samples for chemical/physical analyses were not taken.

Discussion of results.- In addition to chemical/physical and microbiological analyses, subjective observations and supply-use rate relationships are important in a domestic water reuse loop. Significant results related to these two considerations are also presented.

Chemical/physical analyses: A detailed listing of the chemical/physical characteristics of the combined bath and laundry waters is given in table V. The characteristics that were most significantly different from the baseline values are as follows:

Characteristic	Baseline tap water	Combined bath and laundry waters	
		Average of days 1 to 12	Average of days 1, 2, 8, 10 (a)
Ammonia, ppm	0.3	2.4	2.6
Color, $PtCl_6$ equiv. units	7.5	43.0	70.0
MBAS, ppm	0.3	17.9	37.7
Phosphates, ppm	0.42	49.4	112.2
Sodium, ppm	9	34	61
Sulfates, ppm	33.0	67.1	102.5
Total organic carbon, ppm	17.0	47.7	65.5
Total solids, ppm	195	274	382
Turbidity (SiO_2 equiv.), ppm	4.0	22.9	44.0

[a]Days 1, 2, 8, and 10 were days in which two loads of laundry were washed.

These characteristics showing the greatest rise in concentration above the tap water baseline are the same as those observed to increase above baseline during the separate bath water and laundry water tests. Also, the characteristics previously showing an increase during the separate laundry water tests were significantly higher on double laundry days. Concentrations of potassium and chlorides showed some increase above baseline as they did in the separate bath and laundry water tests. Free chlorine showed a rise during the separate laundry water tests but did not show an increase during the 12-day combined bath and laundry water test. Inspection of the data shows that although free chlorine increased during the laundry water test relative to the tap water baseline, the concentration of 0.7 ppm is low. A free chlorine concentration as low as 0.7 ppm would be consumed during oxidation of organics. It is assumed that free chlorine would not be a factor in subsequent processing of the combined bath and laundry waters. Zinc and lead showed a small concentration increase during the separate laundry water test but were not present in significant concentrations in the combined bath and laundry waters. It is assumed that the dilutions due to bath waters and tap water makeup during the 12-day test reduced the concentrations of zinc and lead to a level of insignificance.

Microbial analyses: The microbial results of the combined bath and laundry water test are given in detail in table VI. The daily total counts of microbes are summarized in the following table, each number in the columns being an average of the five samples taken during that day:

Test day	Water sample counts in cells/ml from –				Air sample counts, colonies/plate	
	Commode tank		Collection tank			
	Total	Possible coliform	Total	Possible coliform	Total	Possible coliform
1	2.36×10^6	1.44×10^3	3.41×10^6	1.04×10^4	42	0 to 1
2	1.27×10^7	3.68×10^5	6.17×10^6	3.16×10^5	53	1 to 2
3	1.97×10^7	1.08×10^7	3.88×10^6	1.25×10^5	21	0
4	1.08×10^7	7.66×10^6	3.96×10^5	2.24×10^5	58	0 to 2
5	1.23×10^7	2.54×10^6	6.01×10^6	2.37×10^6	40	0 to 3
6	1.69×10^7	9.68×10^6	2.48×10^7	1.15×10^7	17	0 to 2
7	8.94×10^6	2.64×10^6	2.01×10^7	6.10×10^6	6	0 to 1
8	8.04×10^6	2.32×10^5	2.73×10^6	3.36×10^5	23	0 to 2
9	1.23×10^7	2.24×10^5	1.01×10^7	1.27×10^6	18	0
10	1.67×10^7	7.48×10^5	5.62×10^6	1.51×10^6	25	1 to 4
11	8.32×10^6	4.40×10^5	3.37×10^6	4.16×10^5	14	0 to 2
12	8.86×10^6	---------	3.59×10^6	---------	51	0 to 2
Baseline	2.14×10^2	0	0	0	24	0

The important microbiological results from the 12-day combined bath water and laundry water test were the stabilization after 3 days of total counts and possible coliform counts from the commode tank and collection tank at 10^6 to 10^7 and 10^5 to 10^6 cells/ml, respectively, and no significant increase in air sample counts over baseline values. Also, a plot of the commode tank data from the foregoing table shows that the addition of makeup water to the waste water in the collection tank had the effect of reducing the total count and the number of possible coliforms. The plot is shown in figure 4.

The detailed results of the microbial analyses of the 3-day soiled baby diaper laundry test are presented in table VII. The daily counts of microbes are summarized in the following table, each number in the columns being an average of the five samples taken during that day:

Test day	Water sample counts in cells/ml from –				Air sample counts, colonies/plate	
	Commode tank		Collection tank			
	Total	Possible coliform	Total	Possible coliform	Total	Possible coliform
1	3.43×10^6	1.04×10^4	3.37×10^6	1.0×10^4	80	0
2	1.28×10^7	1.40×10^4	5.63×10^6	1.2×10^4	62	0 to 1
3	1.03×10^7	6.70×10^5	7.92×10^6	1.64×10^5	43	0 to 2

The important microbial results of the 3-day diaper laundry test were that the upper levels of possible coliform counts from the collection tank and commode tank and the counts of airborne possible coliforms were not significantly higher than those obtained during the 12-day test. It was anticipated that washing an obvious source of fecal contamination, such as diapers, would markedly raise the upper levels of coliform counts. However, in some samples, the upper level was lower than those of the 12-day test (fig. 4). There is no apparent explanation of this result.

Subjective observations: During the combined bath and laundry water test, several subjective observations of the wash waters and reuse system were made. A daily observation of the collection tank noted a change from an initial laundry odor to a putrid odor from day 6 until the end of the test. The intensity of the putrid odor was greatest during the days when little or no makeup water was added to the collection tank. Along with the putrid odor, a scum accumulated on the upper walls of the collection tank. The putrid odor did not carry over to the commode tank and bowl. Only the laundry odor remained at the commode, and it was not noticeable unless the commode tank lid was removed. The results do indicate that an offensive odor can occur in the collection tank unless positive steps are taken to prevent it. It is assumed that the odor could ultimately carry over to the commode. Other subjective observations indicate that wash waters are suitable for reuse as toilet flush water. Expected foaming and color changes were not experienced. The increased turbidity measured during the test was not considered to be objectionable.

Water balance and use rates: Although water balance and use rates were not a primary objective of the tests documented in this report, data were obtained on the quantity relationships between available waste wash waters, required toilet flush waters, and collection tank overflow and makeup water. These data are summarized in the following table:

Test day	Flush water required		Combined bath and laundry water available		Collection tank overflow		Makeup added	
	Liters	Gallons	Liters	Gallons	Liters	Gallons	Liters	Gallons
1	291.1	76.9	461.0	121.8	117.0	30.9	0	0
2	329.7	87.1	391.4	103.4	28.0	7.4	0	0
3	333.1	88.0	158.6	41.9	16.3	4.3	224.1	59.2
4	334.2	88.3	179.8	47.5	12.1	3.2	112.4	29.7
5	335.4	88.6	328.5	86.8	37.5	9.9	87.4	23.1
6	328.2	86.7	263.1	69.5	24.6	6.5	100.3	26.5
7	330.4	87.3	185.1	48.9	27.6	7.3	173.0	45.7
8	328.2	86.7	446.3	117.9	132.1	34.9	0	0
9	311.9	82.4	315.7	83.4	60.2	15.9	72.7	19.2
10	345.6	91.3	367.5	97.1	24.2	6.4	0	0
11	333.1	88.0	193.0	51.0	26.5	7.0	246.8	65.2
12	333.8	88.2	278.6	73.6	30.3	8.0	74.9	19.8
Total:	3934.7	1039.5	3568.6	942.8	536.4	141.7	1091.6	288.4

These data can be used to establish a water balance. The balance can be stated as

$$V_f = V_a + V_m - V_o - V_s - V_{te}$$

where

V_f flush water used

V_a wash waters available

V_m makeup water added

V_o water lost in collection tank overflow

V_s water withdrawn for samples

V_{te} water remaining in the collection tank at test end in excess of water in the tank at test initiation

In units of liters:

$$3934.7 \approx 3568.6 + 1091.6 - 536.4 - 68.1 - 104.1$$

$$3934.7 \approx 3951.6$$

In units of gallons:

$$1039.5 \approx 942.8 + 288.4 - 141.7 - 18.0 - 27.5$$

$$1039.5 \approx 1044.0$$

The difference of 17.0 l (4.5 gal) between the theoretical equalities is due to experimental error and is insignificant to the results.

Inspection of these data shows that the flush water used exceeded wash waters available by 366.0 l (96.7 gal). Thus, 91 percent of the required flush water could be available as combined wash waters. However, 1091.6 l (288.4 gal) of makeup water were added. The additional makeup water was required because of the collection tank overflow. Overflow occurred frequently because the combined wash waters were collected in large batches with little time intervals between. Typical of this situation would be a day in which a morning bath and two loads of laundry were discharged in an approximate 2-hr period. The 416.4-l (110 gal) tank could not contain the total volume discharged in the 2-hr period. A larger tank could prevent the loss due to overflow. In an actual domestic reuse application, however, the upper limit of tank size may be limited by practical considerations of tank cost and available space for installation. It is speculated that some overflow would always occur in a domestic application of a water reuse system.

Other water volume data were obtained and are presented in table VIII. The data of table VIII (a) indicate that tub baths average 75.7 l (20.0 gal) per bath of which 39 percent is hot water and shower baths average 60.2 l (15.9 gal) of which 16 percent is hot water. Collectively, tub and shower baths average 67.4 l (17.8 gal) per bath of which 29 percent is hot water. The data of table VIII (b) indicate that laundry water will vary between 18 and 42 percent hot water except when all cold water is used; these values correspond to washing machine settings of warm wash/cold rinse and hot wash/warm rinse, respectively. The third machine setting, cold wash/cold rinse, uses no hot water. These data are not absolute values because variations in bathing habits of larger populations and variations in washing machine settings among available machines may alter the values. The averages, however, are believed to be useful indicators and can be used as experimental backup data for water reuse system studies.

SUMMARY OF RESULTS

Results of an experimental investigation of the chemical/physical and microbiological characteristics of typical bath and laundry waste waters are summarized as follows:

1. The chemical/physical characteristics of bath waters showing the most significant changes from a tap water baseline were ammonia, total organic carbon, color, turbidity, and total solids. The total microbial counts in bath waters were high and, on the basis of limited testing, were independent of the type of soap. Mean initial counts ranged from 4.23×10^4 to 3.09×10^5 cells/ml. After 24 hr in the collection tank, average counts ranged from 2.15×10^6 to 9.91×10^6 cells/ml. Average possible coliform counts were also high with initial counts ranging from 4.94×10^3 to 1.74×10^4 cells/ml. After 24 hr in a collection tank, average counts ranged from 3.77×10^5 to 1.11×10^6 cells/ml.

2. The chemical/physical characteristics of laundry waters showing the most significant changes from a tap water baseline while using a single detergent were ammonia, chlorine, methylene blue active substance (MBAS), phosphates, sulfates, sodium, total organic carbon, color, turbidity, total solids, and conductivity. If other detergents were used, significant increases in boron, chloride, magnesium, potassium, and suspended solids could have occurred. The total microbial counts in laundry waters were high. Average initial counts ranged from 1.27×10^4 to 2.93×10^6 cells/ml. After 24 hr in a collection tank, average total counts ranged from 9.65×10^6 to 5.88×10^7 cells/ml. Average possible coliform counts were also high with initial counts ranging from 2.55×10^3 to 2.1×10^4 cells/ml. After 24 hr in a collection tank, average counts ranged from 1.96×10^6 to 1.95×10^7 cells/ml.

3. In a covered (not sealed) tank where bath and laundry waters were collected daily and in which no positive steps were taken to clean it, the microbial buildup increased for 3 days after which the count stabilized.

Some additional observations supported by the tests are as follows:

Laundry water contains a significant amount of particulates which may present a problem to processing systems. Collection tanks supplied daily with bath and laundry waters develop an objectionable odor unless positive steps are taken to prevent it. Data on water quantities suggest that an average family of four may produce a quantity of combined bath and laundry waste waters sufficient to supply 91 percent of the required toilet flush waters for the same family.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., February 6, 1974.

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TABLE I.- CHARACTERISTICS OF BATH AND LAUNDRY WATERS DETERMINED BY CHEMICAL/PHYSICAL ANALYSES

Characteristic	Unit	Lower detection limit	Technique and/or instrument
Metals			
Arsenic	ppm	0.1	Atomic absorption
Barium	ppm	1	Atomic absorption
Boron	ppm	1	Atomic absorption
Cadmium	ppm	0.005	Atomic absorption
Chromium	ppm	0.01	Atomic absorption
Copper	ppm	0.1	Atomic absorption
Iron	ppm	0.2	Atomic absorption
Lead	ppm	0.05	Atomic absorption
Magnesium	ppm	0.001	Atomic absorption
Manganese	ppm	0.01	Atomic absorption
Mercury	ppm	0.001	Atomic absorption
Nickel	ppm	0.2	Atomic absorption
Potassium	ppm	0.05	Atomic absorption
Selenium	ppm	0.05	Atomic absorption
Silver	ppm	0.01	Atomic absorption
Sodium	ppm	0.1	Atomic absorption
Zinc	ppm	0.05	Atomic absorption
Ions			
Ammonia	ppm	0.2	Specific ion electrode
Calcium	ppm	0.1	Atomic absorption
Chloride	ppm	5	Specific ion electrode
Chlorine	ppm	0.05	Colorimetric
Cyanide	ppm	0.02	Specific ion electrode
Fluoride	ppm	0.10	Specific ion electrode
Nitrates and nitrites	ppm	0.05	Colorimetric
Phosphates	ppm	0.05	Colorimetric
Sulfates	ppm	5	Colorimetric
Organics			
MBAS[a]	ppm	0.01	Colorimetric
Phenols	ppm	0.01	Colorimetric
Total organic carbon	ppm	5	Total carbon analyzer
Urea	ppm	50	Colorimetric
Physical properties			
Color	$PtCl_6$ equiv. units	5	Colorimetric
Conductivity	µmhos/cm	0.4	Conductivity meter
Odor	Subjective	-------	Dilution/subjective
pH	pH units	1	pH meter
Suspended solids	ppm	100	Filtration-gravimetric
Total solids	ppm	100	Gravimetric
Turbidity (SiO_2 equiv.)	ppm	0.1	Turbidimeter

[a]Methylene blue active substance; the test for determining the presence of a substance that reacts with methylene blue is used to indicate the presence of surfactants from soaps and detergents.

TABLE II.- CHEMICAL/PHYSICAL CHARACTERISTICS OBTAINED FROM BATH AND LAUNDRY WATER TESTS

Characteristic	Unit	Bath water test									Laundry water test				
		Baseline tap water	Bath water and nonbiocidal soap				Bath water and biocidal soap				Baseline tap water	Combined wash cycle/rinse cycle		Separate wash cycle	
			Sample 1 (a)	Sample 2 (a)	Sample 3 (b)	Sample 4 (b)	Sample 1 (a)	Sample 2 (a)	Sample 3 (b)	Sample 4 (b)		Sample 1	Sample 2	Sample 1	Sample 2
Metals															
Arsenic	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Boron	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	ppm	<0.005	0.01	0.005	0.005	0.01	0.01	0.005	0.007	0.009	<0.04	<0.04	0.005	0.01	0.005
Chromium	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.01	0.05	0.05
Copper	ppm	0.1	0.1	0.1	0.1	0.1	<0.1	0.1	0.1	0.1	<0.1	0.1	0.1	0.1	0.1
Iron	ppm	0.2	0.5	0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.2	0.4	0.4	0.4	<0.2
Lead	ppm	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.5	0.2	0.1	0.2
Magnesium	ppm	2.4	2.4	2.3	2.2	2.1	2.3	2.2	3.8	2.9	2.4	2.9	2.7	3.5	3.5
Manganese	ppm	0.01	0.03	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.02
Mercury	ppm	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.002	<0.002	<0.2	<0.2	0.3	0.2	<0.2
Nickel	ppm	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5
Potassium	ppm	1.6	6.6	5.2	4.0	3.5	3.7	4.5	4.4	3.1	1.3	4.1	4.5	7.9	6.6
Selenium	ppm	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.04	<0.04	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sodium	ppm	8	23	19	10	10	24	18	17	12	10	100	84	191	144
Zinc	ppm	0.6	0.7	0.6	0.7	0.7	0.7	0.5	0.4	0.4	0.5	0.5	1.2	1.9	1.0
Ions															
Ammonia	ppm	<0.2	0.9	1.6	0.7	2.1	0.8	0.7	1.2	1.0	0.4	1.2	1.9	5.8	2.9
Calcium	ppm	31	28	29	28	28	28	30	32	37	27	27	25	40	32
Chloride	ppm	25	30	30	23	22	22	18	18	17	18	41	44	68	64
Chlorine	ppm	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	0.1	0.1	0.1	<0.05	0.4	0.3	0.8	0.5
Cyanide	ppm	<0.02	0.03	0.02	<0.02	<0.02	0.04	0.02	0.02	0.02	<0.02	<0.02	<0.03	0.06	0.05
Fluoride	ppm	1.0	1.0	0.8	0.8	0.7	0.6	0.6	0.6	0.7	1.0	1.1	1.2	1.3	1.3
Nitrates and nitrites	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.5	1.9	1.5	1.8
Phosphates	ppm	0.1	0.1	0.2	<0.05	<0.05	0.5	<0.05	<0.05	0.06	0.7	350	150	420	300
Sulfates	ppm	35	70	60	35	30	25	30	10	35	30	144	110	175	300
Organics															
MBAS	ppm	0.02	0.02	0.1	0.1	0.1	0.2	0.03	0.29	0.25	0.04	66	38	137	108
Phenols	ppm	<0.05	0.06	0.06	<0.05	<0.05	0.1	0.1	0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05
Total organic carbon	ppm	20	134	89	25	20	106	39	-------	-------	13	75	75	225	100
Urea	ppm	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Physical properties															
Color	$PtCl_6$ equiv. units	<5	>100	>100	20	10	>100	>100	>100	50	10	60	40	(c)	50
Conductivity	µmhos/cm	290	300	310	240	220	260	230	235	235	230	450	270	850	700
Odor	Subjective	No	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
pH	pH units	7.2	7.2	7.5	7.2	7.3	7.3	7.2	7.4	7.3	7.2	7.9	7.7	7.8	7.5
Suspended solids	ppm	<100	113	124	<100	<100	164	114	<100	<100	<100	500	100	100	<100
Total solids	ppm	220	460	341	203	236	804	722	280	221	170	600	500	1100	1000
Turbidity (SiO_2 equiv.)	ppm	2	250	290	20	15	175	125	115	45	6	14	38	85	60

[a]From shower baths.

[b]From tub baths.

[c]Unable to quantify because of extensive blue color interference.

TABLE III.- TOTAL NUMBER OF MICRO-ORGANISMS AND OF POSSIBLE COLIFORMS RECOVERED FROM BATH WATER SAMPLES

Type of count	Baseline tap water	Bath water and nonbiocidal soap				Bath water and biocidal soap			
		Sample 1 (a)	Sample 2 (a)	Sample 3 (b)	Sample 4 (b)	Sample 1 (a)	Sample 2 (a)	Sample 3 (b)	Sample 4 (b)
Total number of micro-organisms at collection, cells/ml	9.4×10^{1}	1.26×10^{4}	1.82×10^{4}	2.35×10^{4}	1.15×10^{5}	7.6×10^{3}	5.9×10^{5}	5.4×10^{5}	9.9×10^{4}
Total number of micro-organisms after 24-hr hold, cells/ml	--------	2.49×10^{6}	2.10×10^{6}	2.63×10^{6}	1.39×10^{6}	4.1×10^{6}	4.43×10^{6}	4.2×10^{6}	2.69×10^{7}
Possible coliforms at collection, cells/ml	14	59	3.6×10^{3}	3.1×10^{4}	1.3×10^{4}	5.4×10^{2}	1.2×10^{4}	2.5×10^{4}	3.2×10^{4}
Possible coliforms after 24-hr hold, cells/ml	--------	8.8×10^{5}	2.6×10^{5}	2.8×10^{5}	9.0×10^{4}	1.22×10^{6}	1.67×10^{6}	1.25×10^{6}	3.0×10^{6}

[a]From shower baths.

[b]From tub baths.

TABLE IV.- TOTAL NUMBER OF MICRO-ORGANISMS AND OF POSSIBLE COLIFORMS RECOVERED FROM LAUNDRY WATER SAMPLES

Type of count	Baseline tap water	Combined wash cycle/rinse cycle laundry water		Separate wash cycle laundry water	
		Sample 1	Sample 2	Sample 1	Sample 2
Total number of micro-organisms at collection, cells/ml	0	8.5×10^3	1.69×10^4	5.7×10^6	1.55×10^5
Total number of micro-organisms after 24-hr hold, cells/ml	--	1.35×10^7	5.8×10^6	1.87×10^7	9.9×10^7
Possible coliforms at collection, cells/ml	0	1.3×10^3	3.8×10^3	No sample	2.1×10^4
Possible coliforms after 24-hr hold, cells/ml	--	No sample	1.9×10^6	8.0×10^6	3.1×10^7

TABLE V.- CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND LAUNDRY WATERS

Characteristic	Unit	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
		Number of laundry loads											
		2	2	0	1	1	1	0	2	1	2	0	1
		Number of baths											
		1	2	2	2	2	2	2	2	2	2	2	2
Metals													
Arsenic	ppm	<0.01	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Barium	ppm	<1	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Boron	ppm	<1	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Cadmium	ppm	<0.00	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Chromium	ppm	<0.01	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Copper	ppm	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	<0.1	0.2	0.1
Iron	ppm	0.2	0.3	<0.2	0.2	<0.2	0.2	0.2	0.5	0.2	<0.2	0.2	0.2
Lead	ppm	<0.05	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Magnesium	ppm	2.8	4.7	3.4	4.5	3.1	3.3	4.2	3.7	3.9	3.7	3.2	3.1
Manganese	ppm	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	<0.01	0.01	0.02	<0.01
Mercury	ppm	0.002	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Nickel	ppm	<0.2	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Potassium	ppm	4.5	3.8	2.4	3.1	3.3	3.3	2.3	4.0	3.5	3.8	2.1	3.3
Selenium	ppm	<0.04	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Silver	ppm	<0.01	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Sodium	ppm	100	82	11	23	21	28	5	26	26	35	25	25
Zinc	ppm	0.5	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Ions													
Ammonia	ppm	2.0	3.1	2.0	1.6	5.7	1.6	0.6	3.4	3.6	1.8	0.8	2.6
Calcium	ppm	38	34	34	35	34	35	36	37	27	33	37	-------
Chloride	ppm	31	30	25	30	31	32	24	38	30	29	34	29
Chlorine	ppm	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cyanide	ppm	<0.02	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Fluoride	ppm	0.5	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Nitrates and nitrites	ppm	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phosphates	ppm	146	131	5	28	20	40	1	120	10	57	4	31
Sulfates	ppm	120	90	40	55	55	65	30	115	50	85	40	60
Organics													
MBAS	ppm	42	42	1.7	12	8.0	15	0.3	48	14	19	1.5	11
Total organic carbon	ppm	80	64	33	45	42	45	29	79	47	39	24	45
Urea	ppm	<50	(a)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Physical properties													
Color	$PtCl_6$ equiv. units	>100	>100	>100	10	10	20	30	50	20	30	10	40
Conductivity	µmhos/cm	400	330	240	240	180	270	205	400	280	290	210	270
Odor	Subjective	No	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
pH	pH units	7.5	7.3	7.3	7.3	7.7	7.3	7.2	7.3	7.7	7.3	7.2	7.3
Suspended solids	ppm	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total solids	ppm	451	447	213	229	240	294	171	361	252	271	186	177
Turbidity (SiO_2 equiv.)	ppm	100	30	3.2	7	5	10	19	27	15	19	15	25

[a]Analyses discontinued because of very low concentrations.

TABLE VI.- MICROBIAL ANALYSES OF COMBINED BATH AND LAUNDRY WATERS

(a) Total number of micro-organisms

Test day	Sample	Total micro-organism count, cells/ml, in water from – Commode tank	Collection tank	Total micro-organism count in air, colonies per plate
1	1	9.30×10^4	1.15×10^5	60
	2	1.47×10^5	1.97×10^5	27
	3	5.80×10^4	8.10×10^4	12
	4	5.60×10^6	1.49×10^7	20
	5	5.90×10^6	1.78×10^6	92
2	1	9.50×10^6	2.96×10^6	98
	2	7.20×10^6	1.74×10^6	21
	3	1.75×10^7	4.14×10^6	11
	4	1.23×10^7	1.34×10^7	70
	5	1.68×10^7	8.70×10^6	65
3	1	1.76×10^7	2.38×10^6	4
	2	3.08×10^7	4.70×10^6	5
	3	1.54×10^7	5.35×10^6	40
	4	3.22×10^7	6.90×10^6	28
	5	2.57×10^6	3.90×10^4	28
4	1	2.02×10^7	8.90×10^5	24
	2	1.26×10^7	2.00×10^5	26
	3	1.66×10^7	4.10×10^5	20
	4	2.79×10^6	3.20×10^5	38
	5	1.79×10^6	1.60×10^5	183
5	1	1.79×10^7	1.41×10^7	90
	2	1.20×10^7	6.90×10^6	13
	3	1.13×10^7	3.48×10^6	29
	4	5.93×10^6	1.84×10^6	23
	5	1.46×10^7	3.74×10^6	43
6	1	1.98×10^7	3.04×10^7	25
	2	9.90×10^6	2.59×10^7	14
	3	9.00×10^6	2.80×10^7	10
	4	2.25×10^7	2.66×10^7	27
	5	2.31×10^7	1.32×10^7	8
7	1	4.59×10^6	2.69×10^7	16
	2	9.60×10^6	2.01×10^7	2
	3	1.04×10^7	2.28×10^7	2
	4	5.80×10^6	1.92×10^7	9
	5	1.43×10^7	1.16×10^7	3
8	1	1.03×10^7	3.96×10^6	41
	2	8.50×10^6	3.06×10^6	26
	3	1.25×10^7	6.00×10^5	21
	4	5.13×10^6	4.62×10^6	9
	5	3.78×10^6	1.40×10^6	16
9	1	8.80×10^6	7.40×10^6	35
	2	1.73×10^7	1.74×10^7	9
	3	1.17×10^7	9.00×10^6	16
	4	1.19×10^7	5.70×10^6	14
	5	1.17×10^7	1.06×10^7	18
10	1	2.60×10^7	1.62×10^7	23
	2	1.29×10^7	3.70×10^6	16
	3	2.14×10^7	1.18×10^6	18
	4	1.35×10^7	2.96×10^6	51
	5	9.60×10^6	4.07×10^6	17
11	1	4.50×10^6	2.85×10^6	11
	2	7.10×10^6	4.47×10^6	22
	3	7.20×10^6	1.60×10^6	4
	4	5.90×10^6	5.61×10^6	15
	5	1.69×10^7	2.34×10^6	20
12	1	7.70×10^6	5.93×10^6	21
	2	1.05×10^7	3.08×10^6	67
	3	1.45×10^7	2.45×10^6	46
	4	5.01×10^6	3.17×10^6	61
	5	6.58×10^6	3.34×10^6	59

(b) Number of possible coliforms

Test day	Sample	Total micro-organism count, cells/ml, in water from – Commode tank	Collection tank	Total micro-organism count in air, colonies per plate
1	1	4.0×10^2	1.8×10^3	0
	2	1.0×10^3	1.0×10^4	0
	3	1.4×10^3	4.0×10^3	0
	4	3.2×10^3	3.0×10^4	0
	5	1.2×10^3	6.0×10^3	1
2	1	1.4×10^5	4.0×10^5	1
	2	1.0×10^5	4.0×10^4	0
	3	4.0×10^5	1.4×10^5	1
	4	6.0×10^5	4.0×10^5	2
	5	6.0×10^5	6.0×10^5	1
3	1	8.8×10^6	1.6×10^5	0
	2	3.4×10^7	6.0×10^4	0
	3	8.4×10^5	1.2×10^5	0
	4	6.0×10^5	2.8×10^5	0
	5	1.0×10^7	6.0×10^3	0
4	1	1.0×10^6	8.0×10^4	0
	2	6.8×10^7	1.2×10^5	0
	3	3.6×10^7	3.8×10^5	1
	4	8.0×10^4	4.6×10^5	1
	5	5.4×10^5	8.0×10^4	2
5	1	6.4×10^6	6.6×10^6	3
	2	6.0×10^5	1.0×10^6	0
	3	2.4×10^5	2.6×10^5	0
	4	6.0×10^4	1.0×10^6	0
	5	5.4×10^6	3.0×10^6	0
6	1	1.7×10^7	1.22×10^7	2
	2	6.0×10^6	8.4×10^6	0
	3	4.0×10^5	1.4×10^7	0
	4	1.1×10^7	1.2×10^7	2
	5	1.4×10^7	1.1×10^7	0
7	1	4.0×10^6	8.8×10^6	1
	2	2.0×10^6	5.4×10^6	1
	3	2.2×10^6	1.03×10^7	0
	4	6.0×10^5	3.4×10^6	0
	5	4.4×10^6	2.6×10^6	1
8	1	2.8×10^5	5.0×10^5	2
	2	2.6×10^5	4.2×10^5	0
	3	4.0×10^4	2.0×10^5	2
	4	2.2×10^5	1.6×10^5	0
	5	3.6×10^5	4.0×10^5	0
9	1	1.4×10^5	3.0×10^5	0
	2	2.4×10^5	5.2×10^6	0
	3	1.4×10^5	2.4×10^5	0
	4	1.6×10^5	2.4×10^5	0
	5	4.4×10^5	3.6×10^5	0
10	1	8.0×10^5	6.0×10^6	1
	2	2.0×10^6	6.0×10^5	1
	3	1.4×10^5	8.0×10^5	1
	4	4.0×10^5	8.0×10^4	4
	5	4.0×10^5	8.0×10^4	1
11	1	1.0×10^6	$<1.0 \times 10^6$	0
	2	--------	----------	1
	3	--------	----------	0
	4	4.0×10^5	$<1.0 \times 10^6$	0
	5	8.0×10^5	8.0×10^4	2
12	1	--------	----------	1
	2	--------	----------	2
	3	--------	----------	0
	4	--------	----------	0
	5	--------	----------	0

TABLE VII.- MICROBIAL ANALYSES OF COMBINED BATH AND SOILED DIAPER LAUNDRY WATERS

Test day	Sample	Total micro-organism count, cells/ml, in water from –		Total micro-organism count in air, colonies per plate
		Commode tank	Collection tank	
(a) Total number of micro-organisms				
1	1	6.6×10^6	7.9×10^6	154
	2	3.09×10^6	1.65×10^6	79
	3	1.76×10^6	2.39×10^6	18
	4	1.19×10^6	2.78×10^6	86
	5	4.53×10^6	2.12×10^6	62
2	1	1.27×10^7	6.1×10^6	57
	2	1.33×10^7	1.19×10^7	31
	3	1.31×10^7	5.0×10^6	32
	4	1.40×10^7	4.70×10^6	29
	5	1.11×10^7	4.50×10^5	160
3	1	1.50×10^7	1.14×10^7	13
	2	1.26×10^7	8.10×10^6	11
	3	4.72×10^6	1.70×10^6	24
	4	1.29×10^7	2.90×10^6	7
	5	6.5×10^6	1.55×10^7	158
(b) Number of possible coliforms				
1	1	$<1 \times 10^4$	$<1 \times 10^4$	0
	2	$<1 \times 10^4$	$<1 \times 10^4$	0
	3	$<1 \times 10^4$	$<1 \times 10^4$	0
	4	$<1 \times 10^4$	$<1 \times 10^4$	0
	5	$<1 \times 10^4$	$<1 \times 10^4$	0
2	1	2×10^4	2×10^4	0
	2	$<1 \times 10^4$	$<1 \times 10^4$	0
	3	$<1 \times 10^4$	$<1 \times 10^4$	0
	4	$<1 \times 10^4$	$<1 \times 10^4$	1
	5	2×10^4	$<1 \times 10^4$	0
3	1	7.6×10^5	4.2×10^5	0
	2	6.8×10^5	4.0×10^4	1
	3	4.6×10^5	1.2×10^5	2
	4	1.2×10^6	4.0×10^4	0
	5	2.48×10^5	1.98×10^5	0

TABLE VIII.- QUANTITY OF BATH AND LAUNDRY WATERS USED IN 12-DAY TEST

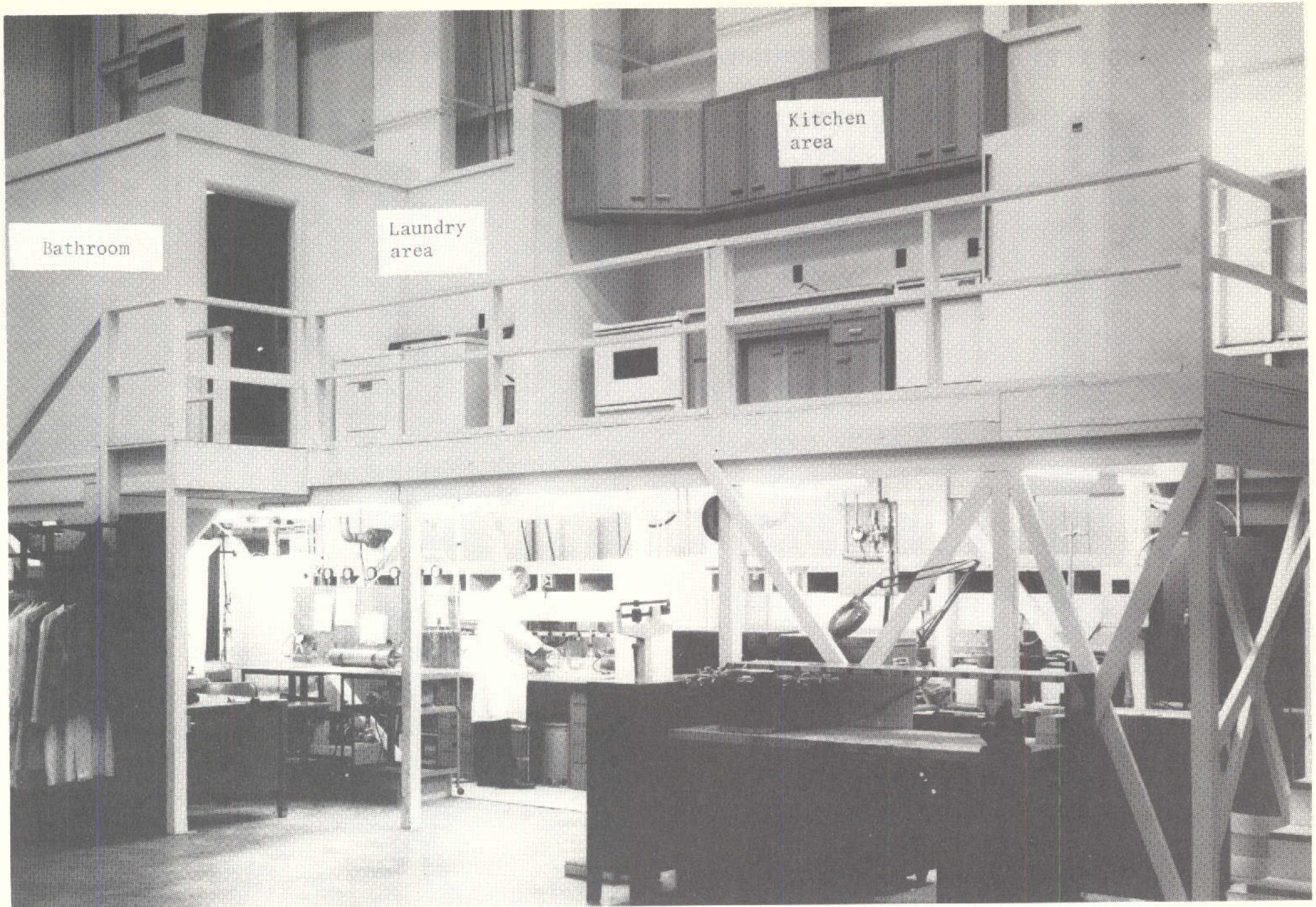
(a) Bath water

Test day	Baths per day	Tub bath				Shower bath				Total quantity of water		Percent hot water	Percent cold water
		Hot water (336 K; 145° F)		Cold water (291 K; 65° F)		Hot water (336 K; 145° F)		Cold water (291 K; 65° F)					
		Liters	Gallons	Liters	Gallons	Liters	Gallons	Liters	Gallons	Liters	Gallons		
1	1	------	----	------	-----	34.06	9.0	104.47	27.6	138.53	36.6	25	75
2	2	17.79	4.7	15.90	4.2	8.71	2.3	31.42	8.3	73.81	19.5	36	64
3	2	37.85	10.0	68.89	18.2	9.46	2.5	42.39	11.2	158.59	41.9	30	70
4	2	13.25	3.5	19.30	5.1	4.92	1.3	24.98	6.6	62.45	16.5	29	71
5	2	42.01	11.1	54.50	14.4	10.60	2.8	63.97	16.9	171.08	45.2	31	69
6	2	16.28	4.3	27.63	7.3	9.08	2.4	43.91	11.6	96.90	25.6	26	74
7	2	40.50	10.7	48.45	12.8	12.11	3.2	84.03	22.2	185.09	48.9	28	72
8	2	46.93	12.4	52.99	14.0	1.89	0.5	20.44	5.4	122.26	32.3	40	60
9	2	30.66	8.1	46.56	12.3	6.06	1.6	73.43	19.4	156.70	41.4	23	77
10	2	11.73	3.1	31.79	8.4	7.95	2.1	19.30	5.1	70.78	18.7	28	72
11	2	45.80	12.1	85.92	22.7	7.57	2.0	53.75	14.2	193.04	51.0	28	72
12	2	21.95	5.8	54.50	14.4	4.54	1.2	42.77	11.3	123.77	32.7	21	79
Total:	23	324.75	85.8	506.43	133.8	116.95	30.9	604.86	159.8	1553.00	410.3	--	--
Average:	--	29.52	7.8	46.04	12.2	9.75	2.6	50.40	13.3	67.52	17.8	29	71

(b) Laundry water

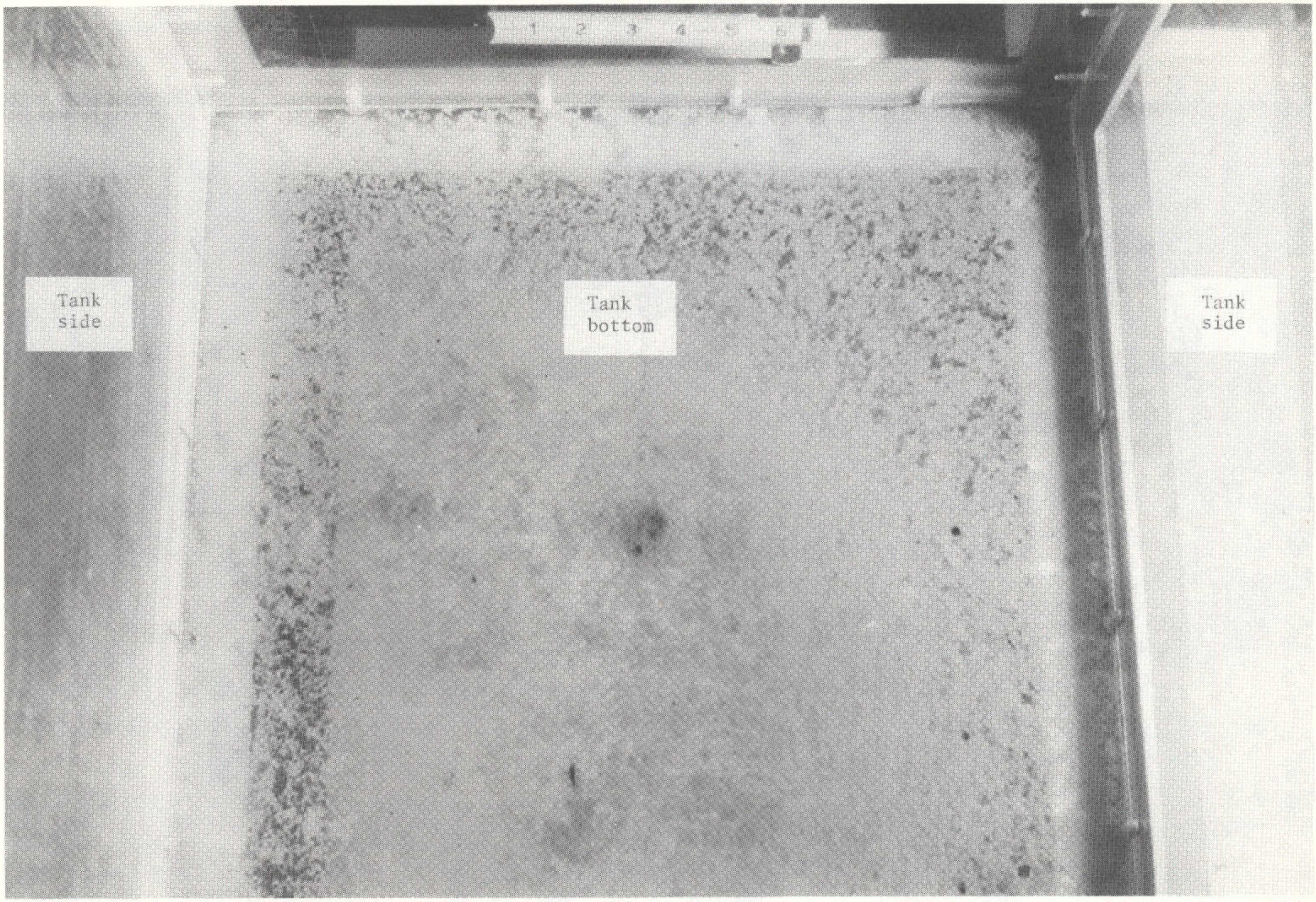
Test day	Loads of clothes per day	Hot water (336 K; 145° F)		Cold water (291 K; 65° F)		Total quantity of water		Percent hot water	Percent cold water
		Liters	Gallons	Liters	Gallons	Liters	Gallons		
1	2	57.91	15.3	264.57	69.9	322.48	85.2	18	82
2	2	58.29	15.4	259.27	68.5	317.56	83.9	18	82
3	0	------	-----	-------	-----	-------	-----	---	---
4	1	23.84	6.3	110.52	29.2	134.37	35.5	18	82
5	1	28.39	7.5	129.07	34.1	157.46	41.6	18	82
6	1	30.66	8.1	135.50	35.8	166.16	43.9	18	82
7	0	------	-----	-------	-----	-------	-----	---	---
8	2	59.05	15.6	263.44	69.6	322.48	85.2	18	82
9	1	28.01	7.4	129.07	34.1	157.08	41.5	18	82
10	2	123.39	32.6	173.35	45.8	296.74	78.4	[a]42	[a]58
11	0	------	-----	-------	-----	-------	-----	---	---
12	1	27.63	7.3	127.18	33.6	154.81	40.9	18	82
Total:	13	437.17	115.5	1591.97	420.6	2029.14	536.1	---	---

[a]On all days except day 10, the water temperature setting on the washing machine was warm wash/cold rinse; on day 10, the setting was hot wash/warm rinse.



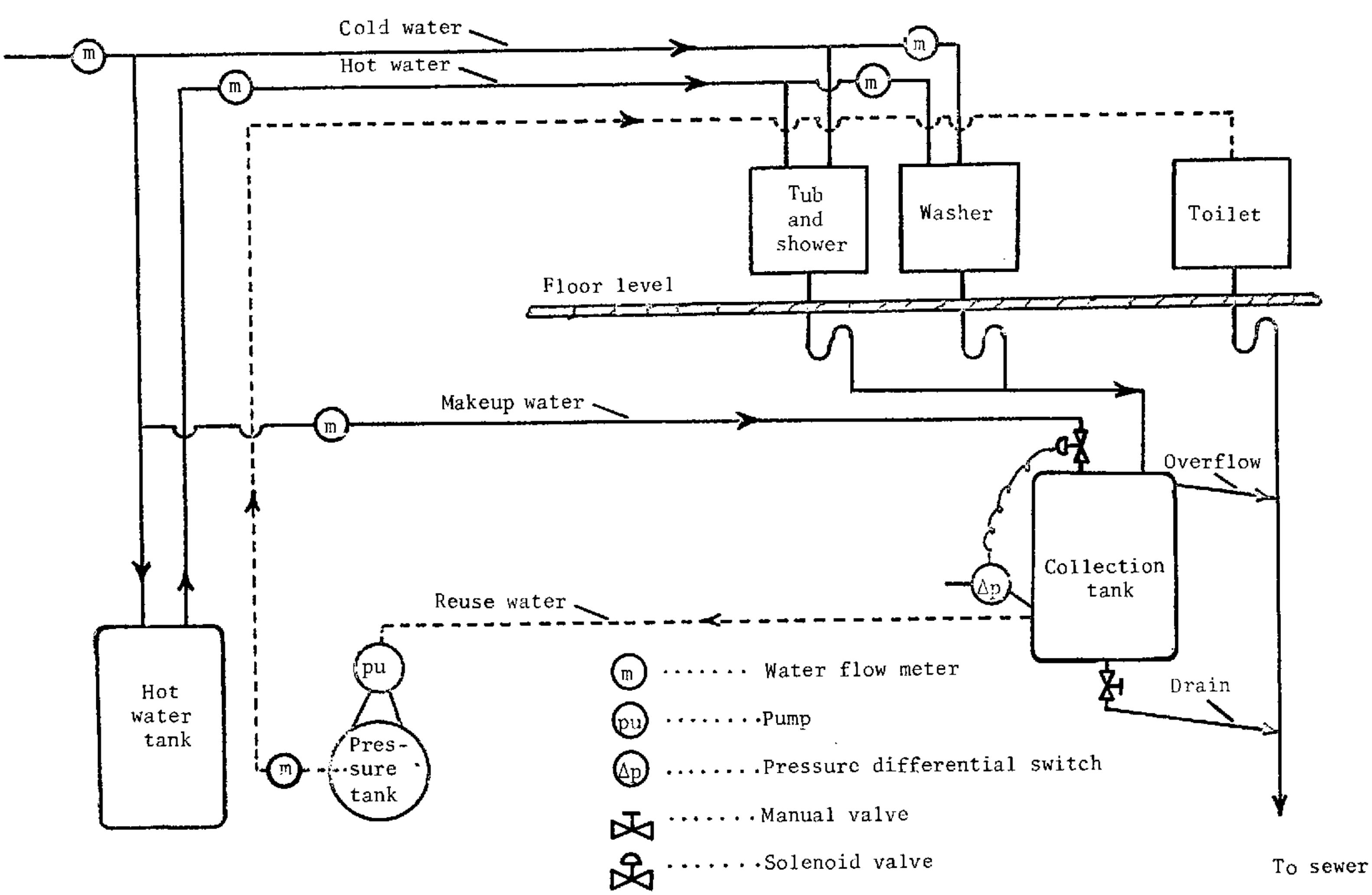
L-73-1656.1

Figure 1.- Domestic water reuse and waste treatment test facility.



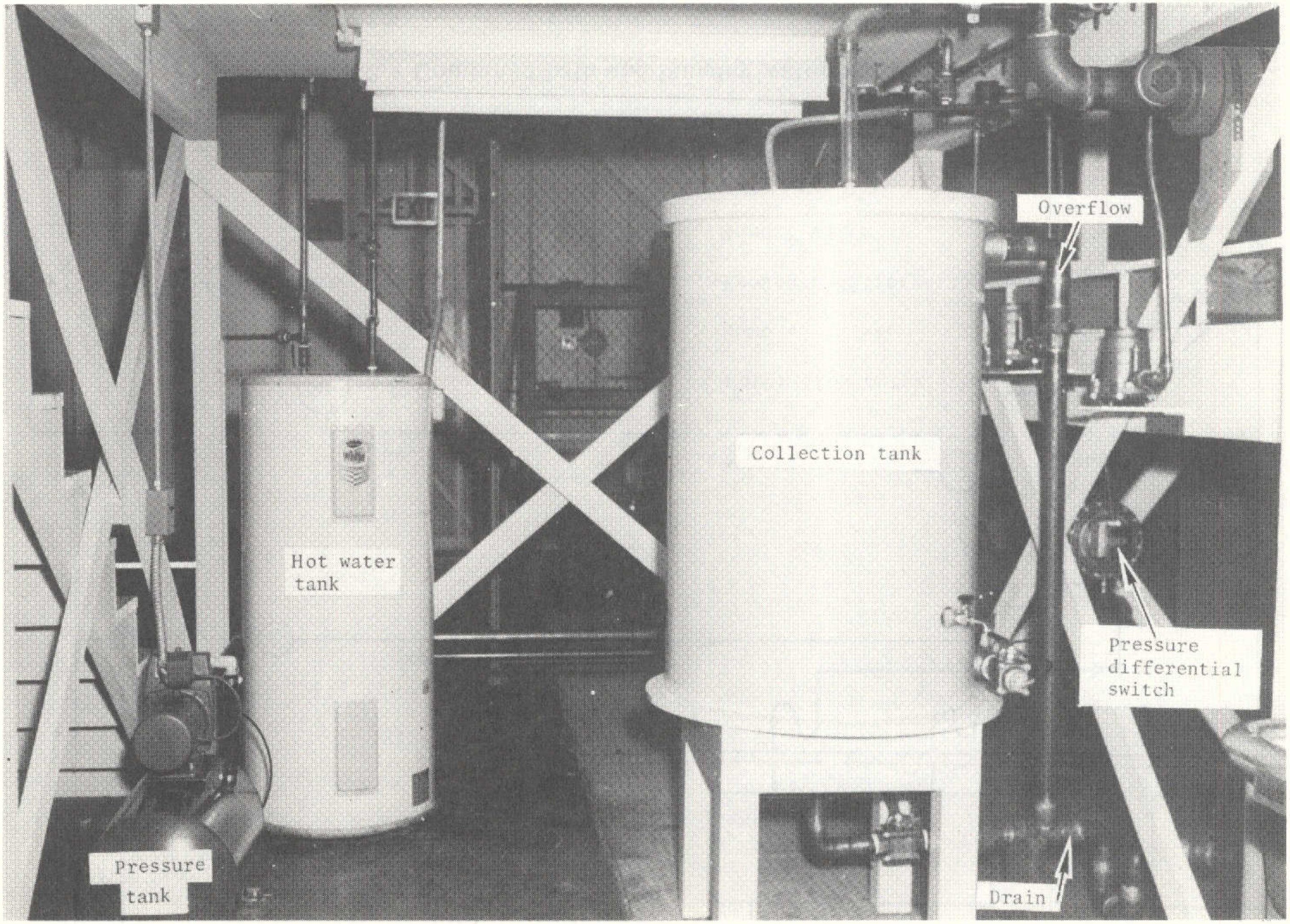
L-72-2788.1

Figure 2.- Accumulation of particles in laundry water after washing one load of clothes.



(a) Schematic of system.

Figure 3.- Combined bath and laundry water reuse system.



L-72-4057.1

(b) Units below floor level.

Figure 3.- Concluded.

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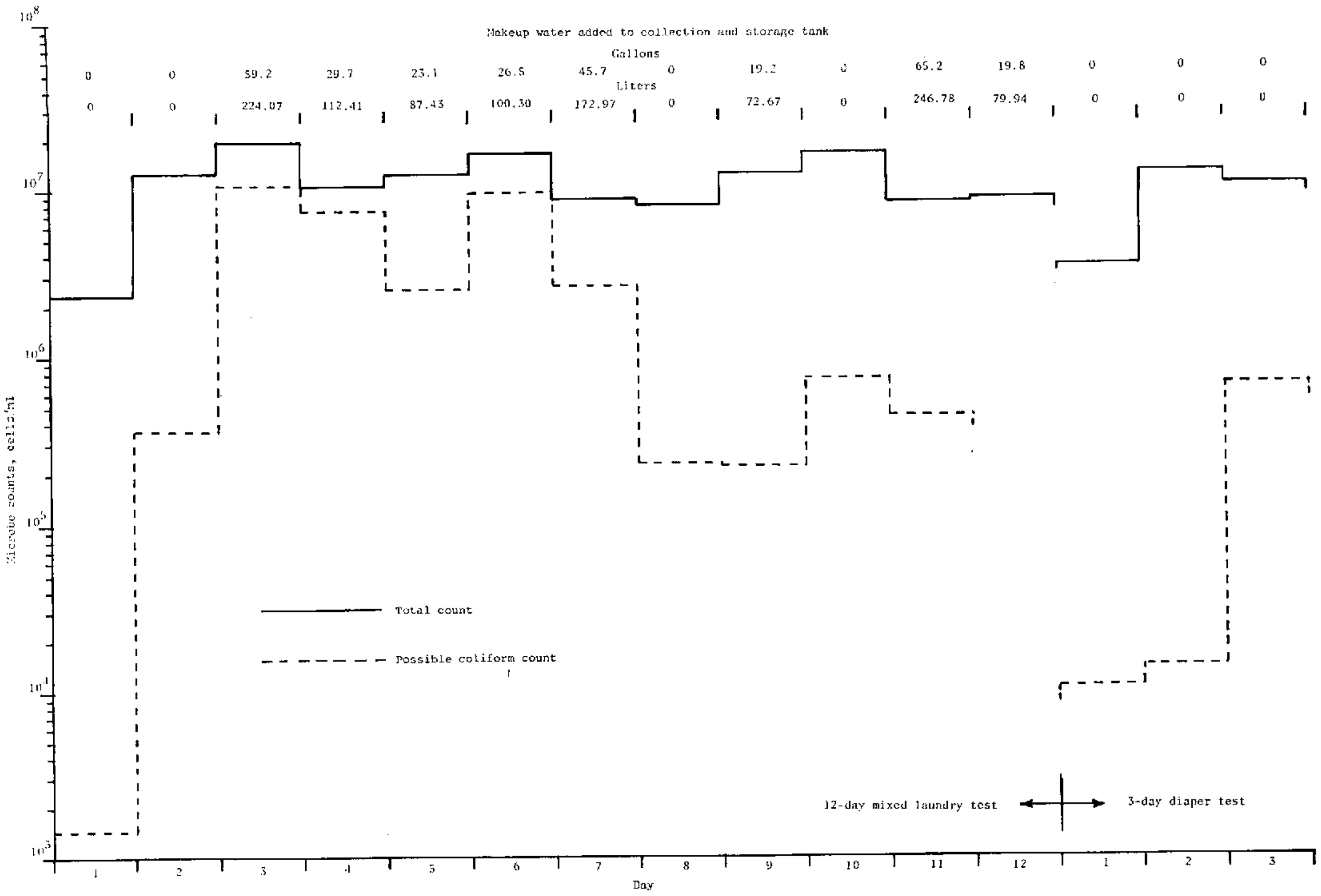

Figure 4.- Daily average total count and possible coliform count of microbes in the commode tank.