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CHARACTERIZATION OF NONOILY WASTE WATER ON U.S. ARMY LCU 1561

by

Thomas H. Voisinet

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MATERIALS DEPARTMENT

Annapolis

EVALUATION REPORT

December 1973 Report 28-737

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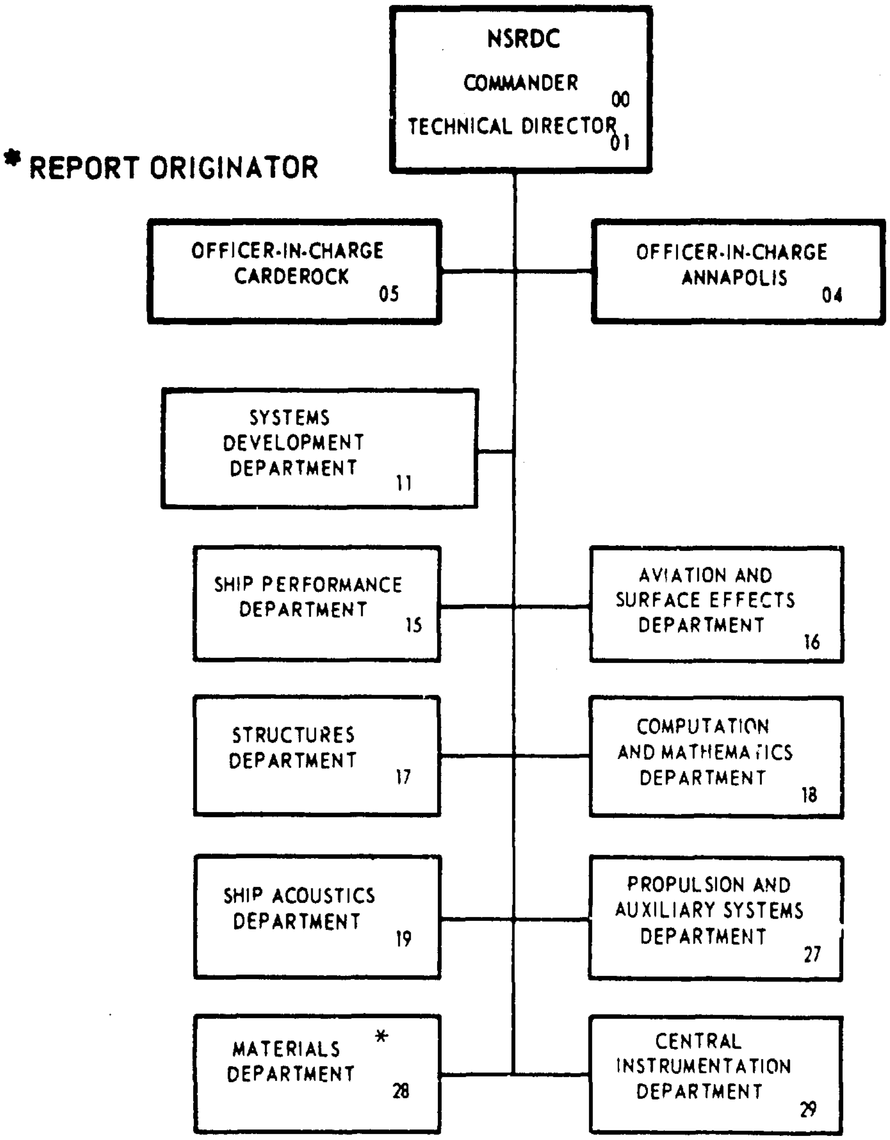

DEPARTMENT OF THE NAVY
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ABSTRACT

The nonoily liquid wastes (other than bilge and ballast waste water) generated aboard U. S. Army LCU 1561, during its normal deployment, were characterized. Waste generation rates, as well as the physical, chemical, and bacteriological nature of the collected waste water, were determined. Twenty-three grab samples, representing the waste water in the port and starboard holding tanks, were collected and analyzed.

ADMINISTRATIVE INFORMATION

This work was accomplished under Work Unit 1-2860-517, and at the request of the U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, under Military Interagency Purchase Request A3184 (reference (a)).

This report fulfills the commitments of reference (b) and is in compliance with Fiscal Year 1973 milestone 4 of reference (c).

ADMINISTRATIVE REFERENCES

(a) U. S. Army MERDC/MIPR A3184 of 1 Feb 1973
(b) NSRDC ltr 4360:AT of 12 Dec 1972
(c) NSRDC Research and Technology Work Unit Summary 1-2860-517 of 1 May 1973

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Appendix A - LCU 1561 Water Usage, Gallons (2 pages)
Appendix B - Waste Water Analysis Data

INITIAL DISTRIBUTION

INTRODUCTION

This is the final report on the study of nonoily liquid waste generation aboard U. S. Army LCU 1561. Waste water generation rates and concentrations of pollutants have been determined by input flow rate measurements and analysis of samples from collecting tanks installed on the craft. This information is related to the craft's normal operation and deployment while assigned to the U. S. Army 7th Transportation Group, Fort Eustis, Virginia.

BACKGROUND

The sanitary waste collection tanks in U. S. Army LCU 1561 are used to meet the requirements of Environmental Protection Agency (EPA) regulations prohibiting the discharge of treated or untreated sewage into navigable waters.[1] Sewage, as well as personal grooming waste water (wash basin, shower), and galley wastes are contained on board until pumped out to a shore receiving facility.

The installation of the collection, holding, and transfer system aboard the craft was accomplished under the responsibility of the Sanitary Sciences Division of the U. S. Army Mobility Equipment Research and Development Center (USA MERDC). A study of that craft was proposed and conducted with the objective of determining the nonoily liquid waste* generation rates during the craft's normal deployment, and of characterizing the physical, chemical, and bacteriological nature of the collected waste water. This data collection effort was made for purposes of future engineering design of watercraft waste treatment and/or systems management, and for development of efficient shore-based handling and processing equipment.

INVESTIGATION

Flowmeters and counters were installed at the initiative of USA MERDC as shown in figure 1. The arrangement of the waste collection system (figure 2) prohibited sampling at any time except when the holding tanks were emptied (averaging every 10 to 14 days). Five samples were collected on 14 February 1973 (samples 1-5), four on 20 February (samples 6-9), four on 22 March (samples 10-13), six on 24 April (samples 14-19), two on 23 May (samples 20-21), and two on 26 June (samples 22-23), for a total of 23 samples.

Laboratory analyses were performed both at Environmental Preventive Medicine Unit (EMPU) 2, Naval Base, Norfolk, Virginia, and at this laboratory as soon as possible after sample collection.

[1] Superscripts refer to similarly numbered entries in the Technical References at the end of the text.

*Defined as liquid wastes other than bilge and ballast waste water.

Problems with the installation and operation of flowmeters in several waterlines were encountered. They are discussed in subsequent sections.

DESCRIPTION OF THE WASTE COLLECTION SYSTEM

Human waste generated on the LCU 1561 is collected in two chemical recirculating commodes (figure 3). The commodes (manufactured by Monogram Industries, Incorporated, Venice, California) are operated with compressed air. When the flush button is depressed, compressed air actuates the toilet pump assembly, which pumps a chemically treated fluid to clean the bowl. The duration of the cycle is approximately 10 seconds. The toilet must eventually be recharged because it recirculates the waste water (averaging approximately 50 flushes between charges). When liquid is visible in the bottom of the bowl, the unit is full and must be serviced.

For recharging, a drain valve below the unit is opened and the bowl is rinsed by flushing with a hose. The drain valve is then closed and the toilet is filled with clean water until the level reaches the bottom of the bowl. The flush button is depressed three times, or until the liquid becomes clear. The toilet is drained again and is ready for charging. The tank is then filled (approximately 8 gallons of fresh water) and toilet chemical is added while flushing. Three different chemicals were employed intermittently and subjectively evaluated by the crew. Once the toilet has been charged, it is ready for use until the liquid again becomes visible in the bottom of the bowl.

The wastes that accumulate in the tank of the recirculating toilet or urinal are drained into a holding tank (port side) located below the main deck. Top and plan views of the tank are shown in figure 4. The capacity of the tank is approximately 1000 gallons. It will normally hold about 10 days' accumulation of waste. Water from the shower and the sinks (figure 2) is also collected in the port holding tank. As the level in the tank approaches capacity, a high-level switch is activated, indicating that a discharge is necessary.

Another holding tank (with the same specifications as the port tank) is located below deck in the aft section on the starboard side. This tank collects the waste water from the galley sinks and a coffee urn in the crew's mess. The two holding tanks are interconnected by a series of pipes with valves making possible the transfer of waste from one tank to the other. The port tank normally fills before the starboard one, making it desirable to transfer waste from tank to tank while at sea to achieve proper ballast.

The piping system also provides a convenient means of discharging the tanks as they reach their capacity. An overboard discharge pump* (figure 5) is furnished to each tank for simultaneous discharge, as well as providing a reserve pump in the

*Overboard discharge pump: General Electric, d-c explosion-proof motor, model 5BC74AB2257, 1725 r/min, 1/2 hp, 115 volts, and 3.9 amperes.

event of a malfunction. The overboard discharge pumps are activated by a switch in the boiler room. A hose connection (figure 6) is located on either side of the main deck, outside the bulkhead and ahead of the bridge. The waste is pumped through a set of fire hoses into a shore collection unit (septic tank truck in most instances), or directly to sea when out of the contiguous zone.

DESCRIPTION OF THE FRESHWATER SUPPLY SYSTEM

Potable water is collected in a supply tank located below deck in the aft section of the ship prior to leaving port. The tank is generally "topped off" so that no record is kept of the actual number of gallons taken on board. A piping diagram (figure 7) shows the paths of the hot and cold waterlines.

As water is drawn from the supply tank, it travels to any of three locations: (a) the galley sinks, (b) the latrine compartment, and (c) the boiler. System pressure is maintained at approximately 40 lb/in^2.* As the line enters the latrines, it branches off to the drinking fountain, proceeds to the sinks, and continues to the shower, a hose connection, and finally to the commodes. Meters were installed to record the usage of water at the following locations: Shower (No. 5), latrine recharge (No. 1), cold (No. 6) and hot (No. 7) water in head sinks, and cold (No. 8) and hot (No. 9) water in the galley sinks. Electromechanical counters were also installed on the urinal (No. 2) and each commode (Nos. 3 and 4), to obtain an accurate flush-count record.

Readings were taken on all meters and counters, and logged every hour from 0800 to 1600 and every 2 hours from 1800 to 0800. The data appear in appendix A.

EVALUATION CRITERIA

The parameters for which samples were to be tested were: pH, dissolved oxygen, temperature, alkalinity, acidity, salinity, chloride, total solids (TS), total suspended solids (TSS), total volatile solids (TVS), total volatile suspended solids (TVSS), biochemical oxygen demand (BOD_5) (total and soluble), chemical oxygen demand (COD) (total and soluble), total carbon, total organic carbon, total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, phosphate (total and soluble), oil/grease, surfactants (methylene blue absorbing substances (MBAS)), total standard plate count, total coliform, fecal coliform, and formaldehyde.

All of these analyses were performed as soon as possible after the time of collection, and in accordance with the latest edition of Standard Methods.[2] Formaldehyde was determined by the Bricher and Johnson method.[3]

*Abbreviations used in this text are from the GPO Style Manual, 1973, unless otherwise noted.

SAMPLING PROCEDURES

Discharge of the holding tanks took place at the Portsmouth, Virginia, Coast Guard Station on 14 February 1973 (to a shore collection point). Subsequent discharges were made at Fort Eustis into a sewage collection/tank truck.

Before discharging, a suitable length of fire hose was connected to the overboard discharge outlet (figure 5) and fed to the shore collection unit. The discharge cycle was initiated by opening the valve on the tank suction line and starting the overboard discharge pump.

Each holding tank was pumped separately to obtain segregated samples. During a discharge (which required approximately 55 minutes per full tank), the port holding tank (sanitary waste) was usually emptied first. Then the valve on the line connecting the two tanks was opened, and the waste from the starboard tank (galley is source) passed through the port tank and to the collection unit. Therefore, a sample was not taken during the first 15 minutes of the starboard discharge (to allow for a displacement and/or dilution of the waste water remaining in the bottom of the port tank, estimated to be no more than 25 gallons). Samples were generally taken from each tank after approximately one and two thirds of the discharge have been completed (for proper representation). The number of samples obtained from each tank (i.e., two in every case except the first discharge, where three were taken) was considered to be sufficient in defining the wastes, employing the parameters previously mentioned.

All samples were collected in sterile polypropylene bottles (2 liters per sample) and kept on ice (but not frozen) until laboratory analyses were started.

ANALYTICAL PROCEDURES

Temperature and dissolved oxygen were measured immediately after sample collection. The following analyses were performed (or begun) during the initial 24-hour period after collection: pH, salinity, total solids, total volatile solids, total suspended solids, total volatile suspended solids, total and soluble BOD_5, total and soluble COD, total standard plate count, total coliform, and fecal coliform.

For the remainder of the analyses (as stated under Evaluation Criteria), the samples were subdivided, refrigerated, and preserved as follows:

- 200 ml of sample - No preservative (acidity, alkalinity, and formaldehyde).

- 300 ml of sample - 0.24 ml of sulfuric acid (H_2SO_4) added (0.8 ml/liter) (oil/grease, chloride, total carbon, and total organic carbon).

- 500 ml of sample - 0.25 gram of mercuric iodide (H_gI_2) added (0.5 gram/liter) (surfactants (MBAS), total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, and total and soluble phosphate).

The analyses of the preserved samples were performed as soon as possible at this laboratory and were generally completed with 1 week after sampling.

RESULTS

The ship was monitored closely from 17-21 March to obtain flow data that would encompass various peak loadings for "normal operation." Several types of operating conditions were considered: with the ship in port and no crew (only an assigned watch), in port with nominal crew (several men), and at sea with full crew (12-13 men). Figure 8 shows a flow profile of the water usage for the following locations: fresh water to recharge latrines (meter 1), flush counts on commodes (Nos. 3 and 4), cold (No. 6) and hot (No. 7) water usage in the latrines sinks, and hot water (No. 9) usage in galley sinks.

- Sunday, 18 March - The LCU remained in port with a watch assigned (typical weekend routine) and, as expected, the overall water usage was low. (Note: the 38.4 gallons of hot water used between 0900 and 1100 hours was for cleaning purposes, typical of a weekend routine.) There was no usage through meter 1 for recharging the latrines because they had been recharged on the previous day. Flush counts are slightly high between 0900 and 1100 hours (13 total), but are normal for the cleaning procedures involved. Water usage was low in the latrine sinks, as was the hot water usage in the galley sinks.

- Monday, 19 March - The LCU remained in port with a nominal crew assigned (5 men). Peak flows were recorded at all sinks between 0700 and 0900 (8.7 gallons of cold and 7 gallons of hot water at latrine sinks, and 38 gallons of hot water at galley sink). Meter readings fluctuated throughout the day, but held fairly constant through 1600 hours when the crew departed. There were essentially no flows after 1600 until 0800 Tuesday, except for slight hot water usage at latrine sink. Three flushes of commodes were recorded overnight.

- Tuesday, 20 March - The LCU was assigned to an operation on the James River, transporting equipment, with an average crew of 10 men. The overall water usage was again low, with peaks at the latrine sinks occurring at 1800 hours (16.8 gallons of cold and 15.3 gallons of hot water), and two peaks for hot water in the galley sinks (6.9-8.0 gallons) at 0800 and 1300 hours, respectively (which were both following meals). Flush counts remained fairly constant (2 per hour per commode) through 1600 hours, and dropped after that time with only two flushes until 0800 the following morning.

- Wednesday, 21 March - The day was spent on the James River with a navigation class aboard (total crew of approximately 12). Flush counts averaged about 2 per hour per commode, with a low water usage at the latrine sinks. Peak cold (2 gallons) and hot water (6.5 gallons) usage at these sinks occurred between 0700 and 0900, while the peak hot water usage (11.4 gallons) for the galley sinks occurred during the same interval.

• Thursday, 22 March - The intensive monitoring was concluded at 0900, after which time the samples were collected and shipped to Annapolis. Note that the 16.7 gallons recorded on meter 1 was used for cleaning and recharging the heads. The commodes received approximately 5 days of usage (and over 125 flushes per 2 units) before they were recharged.

From the data obtained (and estimations for missing flow readings, typically the shower and cold water in the galley sinks), approximate values are obtained on a gallon per capita per day (gal/c/d) basis. Values were calculated for several typical operations as shown in table 1.

TABLE 1
WATER USAGE ABOARD LCU 1561 WITH VARYING CONDITIONS

Condition	In Port with Nominal Crew	At Sea with Nominal Crew	At Sea with Full Crew	At Sea for More than 24 Hours
Usage (gal/c/d)	25	15	10	Add 5 (for showers)

The total waste water generation depends not only on the rates mentioned above, but also on the crew size associated with it. When the ship is in port for a week with a nominal crew assigned (4 men), they may generate as little as 100 gallons per day. However, when the ship is committed to river operations for a week, the average size crew may generate as much as 175 gallons per day. This leads to an interesting observation. Although the generation rate may be high, the small crew size associated with it limits the total volume produced, while lower generation rates are generally associated with larger crews producing a substantially larger volume of waste water.

Appendix B lists the values of the parameters as well as the mean, standard deviation, and the 95% confidence limits for each analysis. Table 2 shows a summary of laboratory data of the samples from both tanks. Differences between the tanks are apparent from the data.

DISCUSSION

A comparison of the results of the bacteriological analyses shows that the port tank contains fewer bacteria by as much as a factor of 10^3 for both total and fecal coliform, and 10^4 for total bacteria (via standard plate count). The anticipated reduction in biological activity is primarily due to the addition of a bactericide (i.e., formaldehyde or a quaternary ammonium compound). It is apparent that the quantity of disinfectant used for maintaining the recirculating fluid of the commodes is not sufficient to prevent bacteriological activity in the holding tank.

TABLE 2
LABORATORY ANALYSIS OF SAMPLES FROM
PORT AND STARBOARD HOLDING TANKS*

Port Tank (Head) Mean Value mg/1	Parameter	Starboard Tank (Galley) Mean Value mg/1
7.5	pH (units)	6.1
3.4	Dissolved oxygen	2.0
2523.0	Total solids	2003.2
1677.3	Total volatile solid	1285.2
1212.9	Total suspended solids	924.0
1016.2	Total volatile suspended solids	823.8
973.5	BOD_5, total	887.2
706.9	BOD_5, soluble	488.6
3042.0	COD, total	2363.4
1505.5	COD, soluble	1275.0
1035.9	Total carbon	783.7
922.2	Total organic carbon	710.0
289.6	Oil and grease	311.6
27.5	MBAS, surfactants	128.6
143.2	Ammonia, as N	20.6
0.33	Nitrate, as N	0.40
0.05	Nitrite, as N	0.03
92.2	Total Kjeldahl, as N	10.1
110.8	Total phosphate, as P	11.0
41.7	Total soluble phosphate, as P	8.2
324.6	Salinity, as NaCl	199.3
691.1	Alkalinity, as $CaCO_3$	334.1
123.4	Acidity	124.3
197.0	Chloride, as Cl^-	121.0
76.9	Formaldehyde	-
17.5	Temperature, °C	16.0
2.5×10^6	Total coliform, #/100 ml	2.58×10^9
2.51×10^4	Fecal coliform, #/100 ml	1.21×10^7
6.02×10^6	Standard plate count, #/100 ml	5.8×10^{10}

*The magnitude of some of the data is, to a degree, influenced by the compositions of flushing fluid additives used. These compositions are commercially confidential.

The system is well buffered, as evidenced by the nearly neutral pH and the neutralization capacity given by the acidity and alkalinity values.

The ratio of suspended solids to BOD_5 is approximately 25% higher for the sanitary waste than for the galley waste: SS/BOD_5 = 1.293 (sanitary), SS/BOD_5 = 1.041 (galley), which shows that the suspended solids in the galley waste exert a relatively greater BOD_5 there.

Of the total solids, 66.4% are voltatile, while 83.7% of the suspended solids are volatile for the sanitary waste. For the galley waste, 64.1% of the total solids and 89.1% of the suspended solids are volatile.

In examining the ratios of carbon to nitrogen to phosphorus (C:N:P) for both wastes, an interesting observation is noted: C:N:P≈11.2:1:1.2 for sanitary waste, and C:N:P≈ 77.6:1:1.1 for galley waste. This shows that the carbon to nitrogen ratio of the galley waste is approximately seven times that of the sanitary waste, while the nitrogen to phosphorus ratios are similar.

The actual number of pounds of BOD_5 and solids produced per day for the total craft has been established by using mean values for both BOD_5 and total solids, and a typical generation rate of 900 gallons per 10 days for the port tank (sanitary waste), and 600 gallons per 10 days for the starboard tank (galley waste) (i.e., approximately 150 gallons per day total). BOD_5 mean values of 973.5 mg/liter (sanitary) and 887.2 mg/liter (galley) result in 0.735 lb/day and 0.447 lb/day being produced in each tank, respectively. Total suspended solids mean values of 1213 mg/liter (sanitary) and 924 mg/liter (galley) result in 0.92 and 0.47 lb/day produced in each tank, respectively. Summing the values for both tanks gives the following total production rates: 1.18 pounds of BOD_5 per day and 1.39 pounds of suspended solids per day.

The sanitary waste has approximately ten times more total Kjeldahl nitrogen and total phosphate then the galley waste.

The galley waste is slightly higher in oil and grease content and shows approximately five times more MBAS surfactants than the sanitary waste.

Initially (February 1973), the dissolved oxygen of the sanitary waste was higher than that of the galley waste, but after several months, the dissolved oxygen dropped to below 0.5 mg/liter in each tank, indicating the onset of anaerobiosis. (Note the corresponding drop in bacterial counts over the same time frame.)

The waste water characteristics are of the same order of magnitude as measured aboard Navy Fleet ships in port* and, as such, are significantly more concentrated than normal domestic sewage. This must be taken into consideration in the design of shore-based receiving and/or treatment facilities.

CONCLUSIONS

- The nonoily liquid waste generation rates, as well as the concentrations of pollutants, have been characterized aboard U. S. Army LCU 1561 during its normal deployment.

*Unpublished data from survey conducted by this laboratory under the Navy Environmental Protection Data Base (NEPDB) Program.

• Wastes accumulate at approximately 150 gallons per day (all sources) and have a concentration that is approximately five times that of ordinary domestic sewage.

RECOMMENDATIONS

• Efficient shore-based management of the waste generated on LCU 1561 should pose no problems; however, dilution and/or correction factors should be considered before discharging to a shore receiving station.

• The onset of anaerobic conditions in the installed holding tanks and the attendant nuisance problems require corrective action (either as engineering changes or via appropriate operating schedules).

• The data generated by this program are applicable to the NEPDB, and will be accordingly incorporated into the data bank.

TECHNICAL REFERENCES

1 - Environmental Protection Agency, "Performance Standards for Marine Sanitation Devices," Federal Register 40CFR 140:37 FR 12391 (20 June 1972)

2 - Taras, M. J., et al, ed., Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., New York, 13th Ed. (1971)

3 - Bricker, C. E., and H. R. Johnson, "Spectrophotometric Method for Determining Formaldehyde," Industrial and Engineering Chemistry, Analytical Ed., Vol. 17, p. 400 (1945)

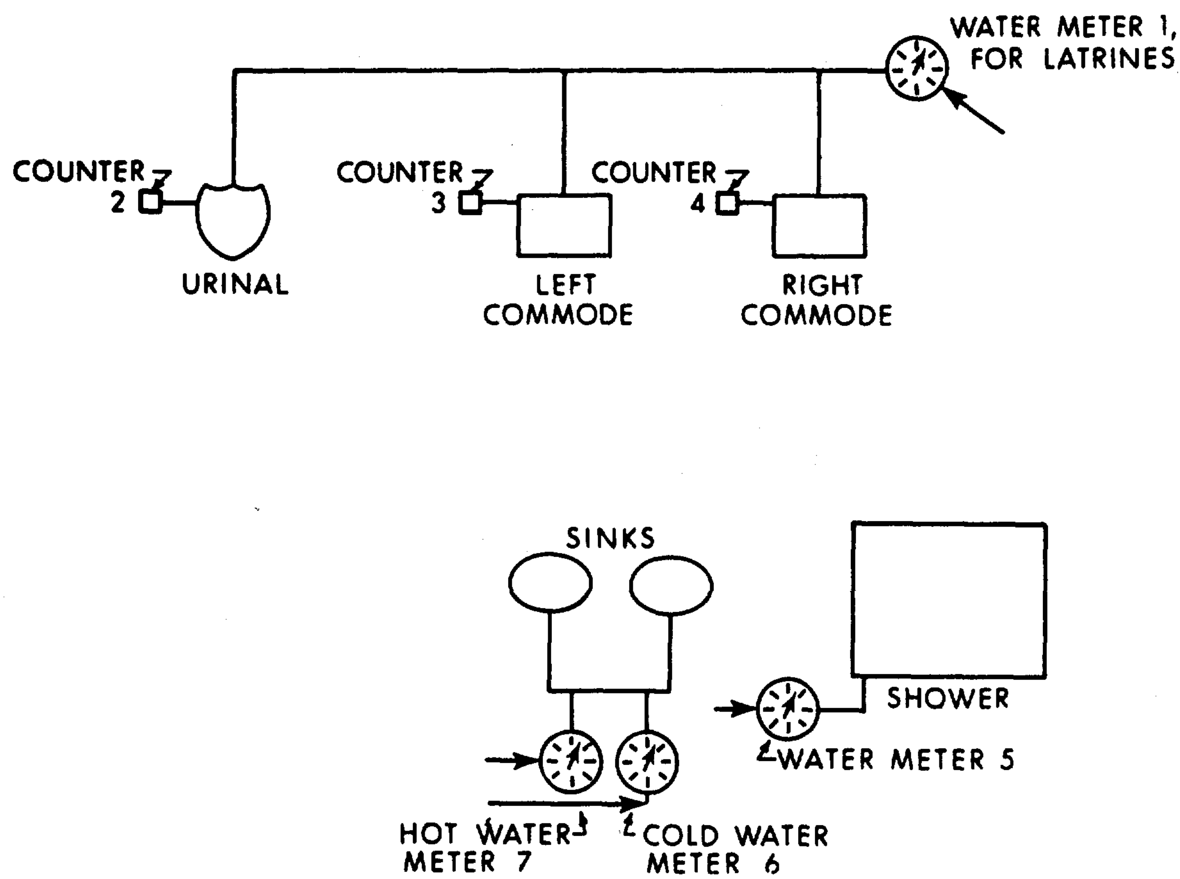

Figure 1
Configuration of Latrines Aboard LCU 1561

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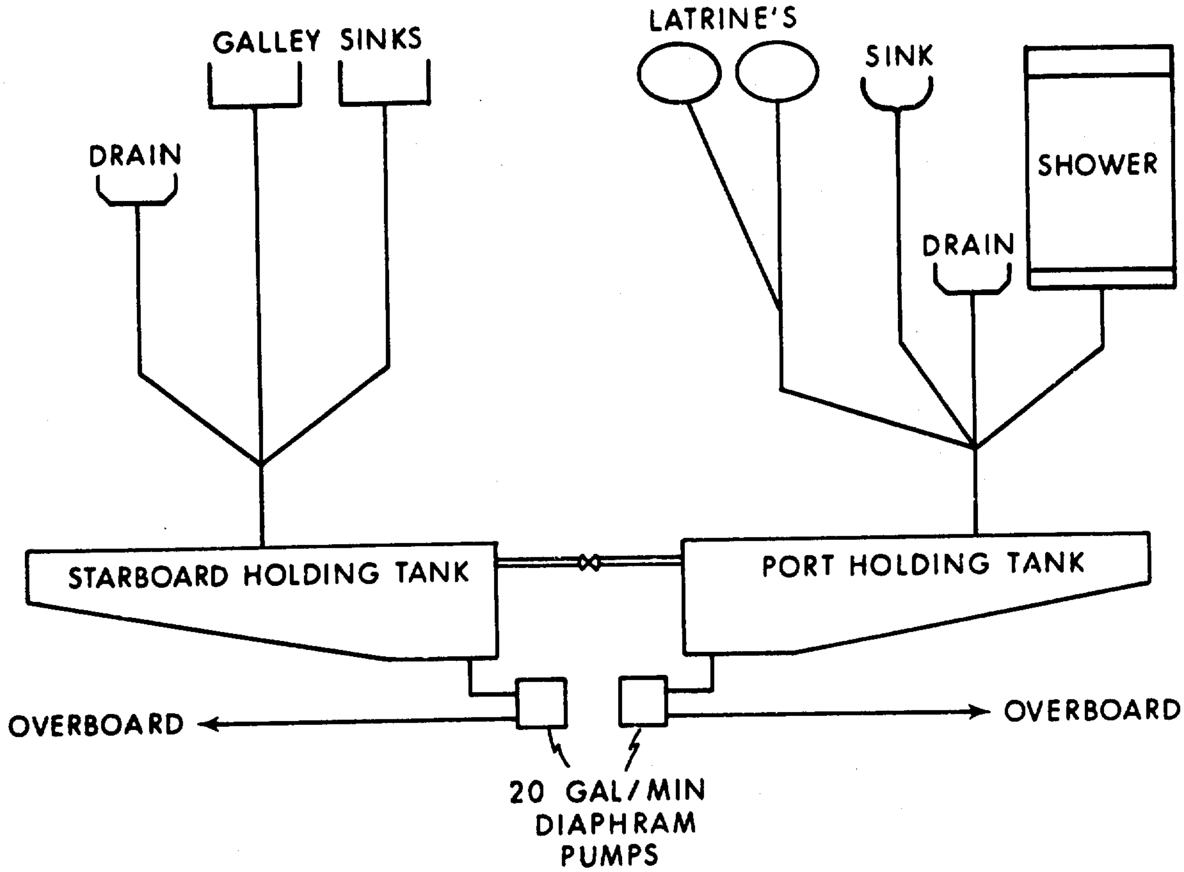

Figure 2
Waste Collection System

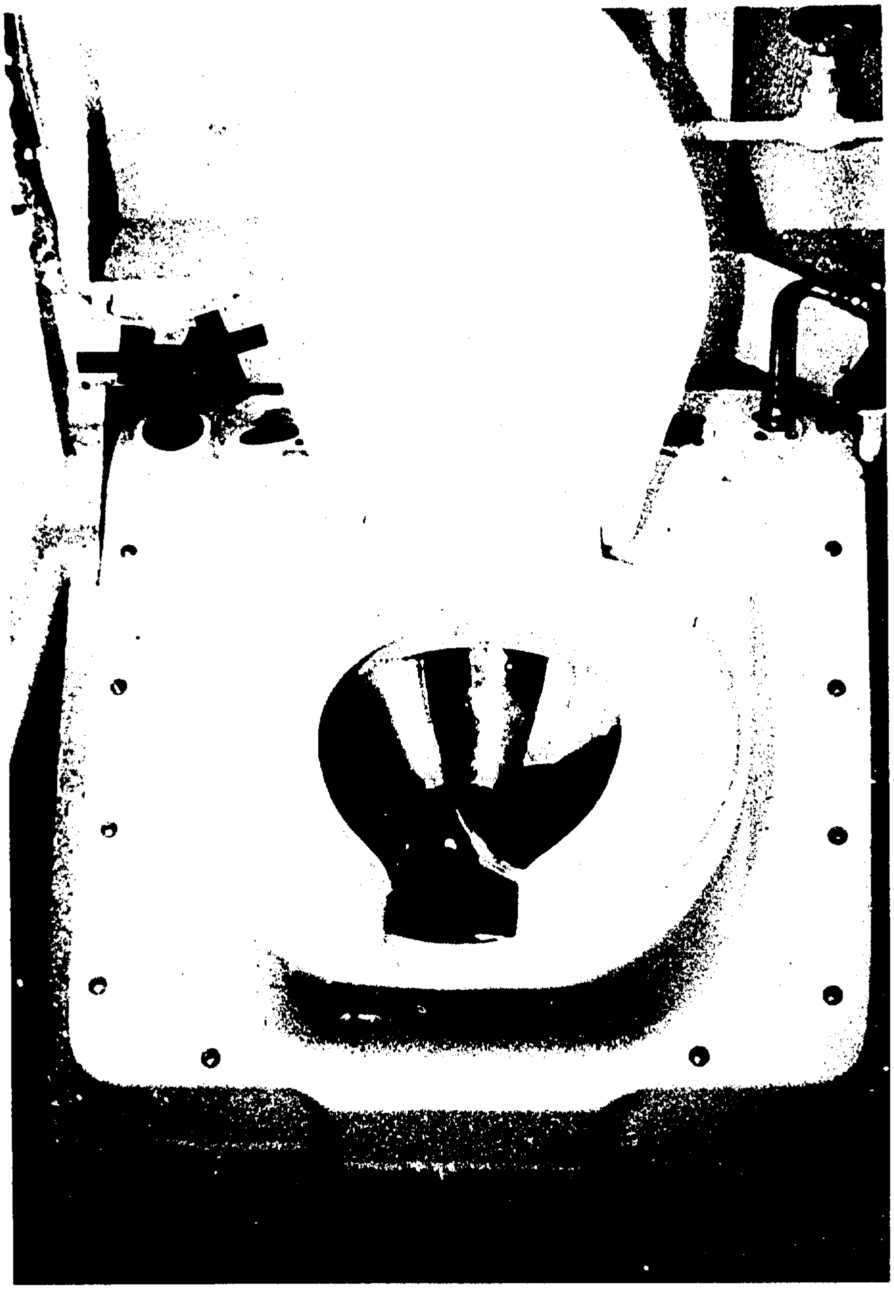

Figure 3
Recirculating Commode

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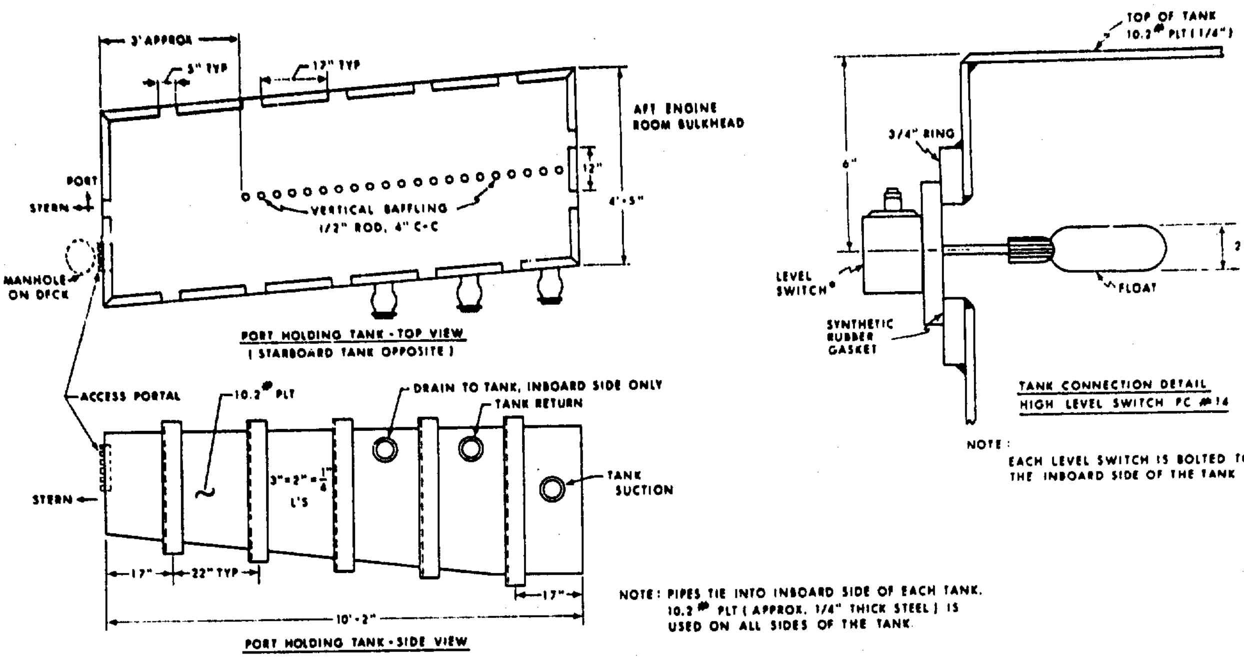

Figure 4
Holding Tank Details

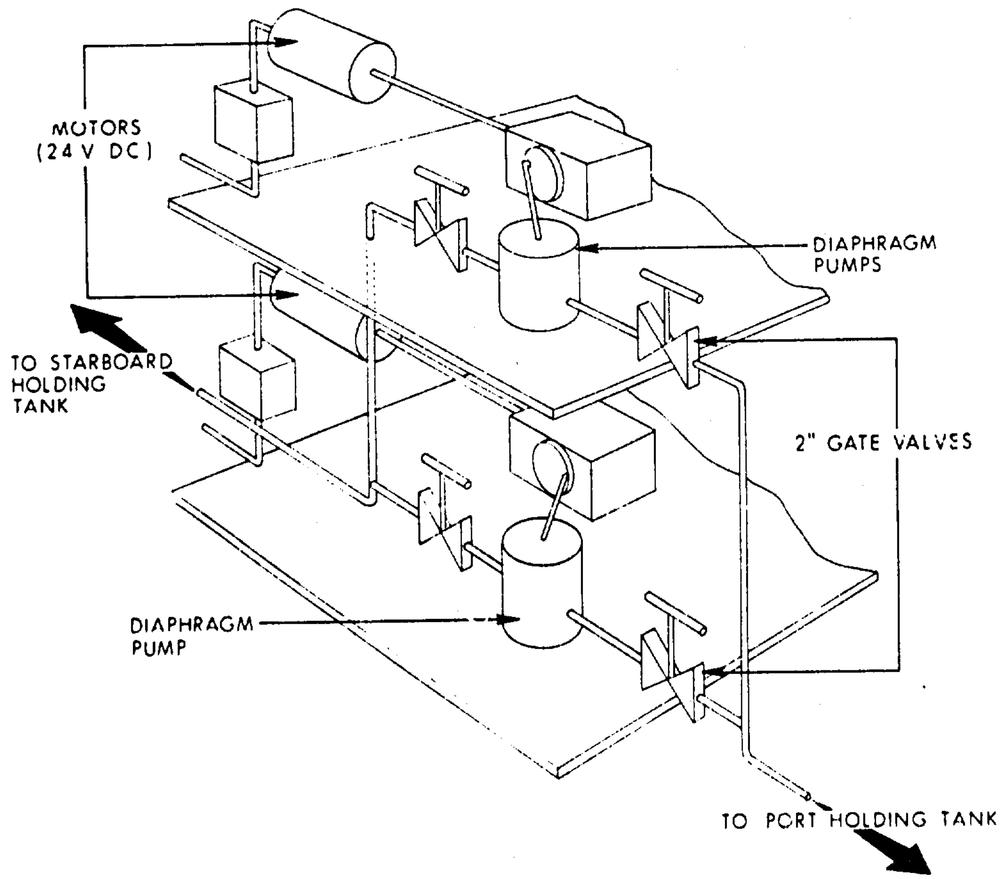

Figure 5
Pump Assembly

Figure 6
Hose Connection for Overboard Discharge

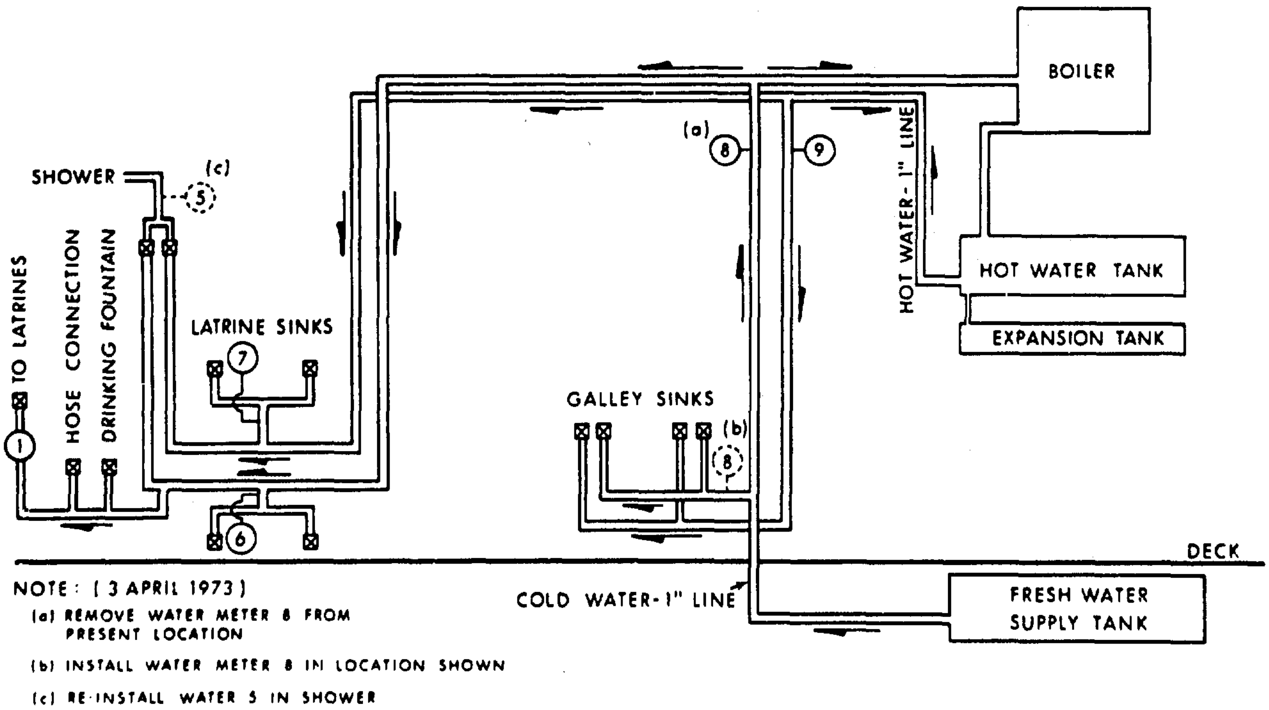

Figure 7
Piping Diagram for U. S. Army LCU 1561

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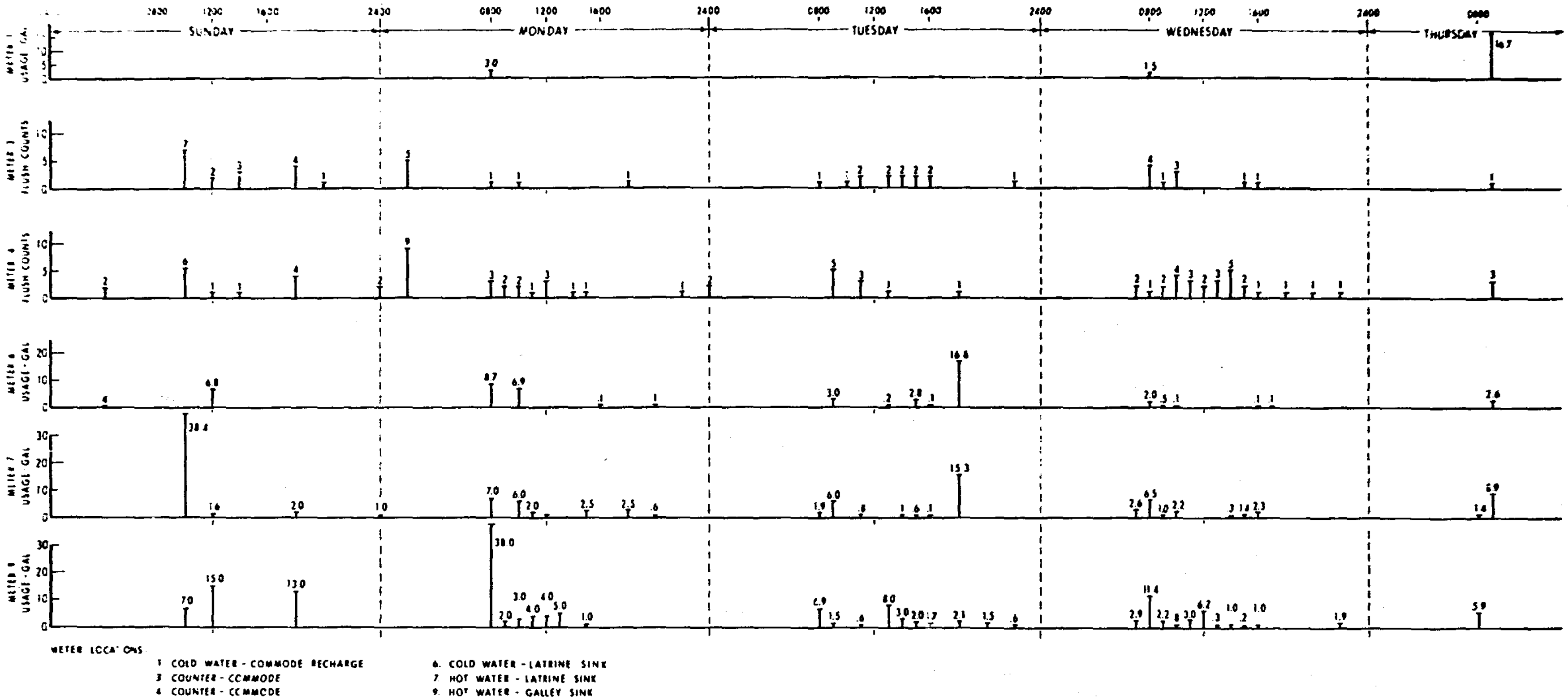

Figure 8
Flow Profile for Liquid Waste Generation, LCU 1561

APPENDIX A
LCU 1561 WATER USAGE, GALLONS

Time	Meter 1	2*	3*	4*	5	6	7	8	9
17 March									
2200	0	Out of Service	0	0	Out of Service	0	0	0	0
2400	0		0	0		0	0	0.2	0
18 March									
0200	0		0	0		0.4	0	0	0
0400	0		0	2		0	0	0.2	0
0600	0		0	0		0	0	0	0
0800	0		0	0		0	0	0	0
1000	0		7	6		6.8	38.4	35.5	7
1200	0	Out of Service	2	1	Out of Service	0	1.6	18.0	15
1400	0		3	1		0	0	0	0
1600	0		0	0		0.	0	0	0
1800	0		4	4		0	2	14	13
2000	0		1	0		0	0	3	0
2200	0		0	0		0	0	0	0
2400	0		0	2		0	1	3	0
19 March									
0200	0		5	9		0	0	0	0
0400	0		0	0		0	0	0	0
0600	0		0	0		0	0	0	0
0800	3		1	3		8.7	7	47	38
0900	0		0	2		0	0	4	2
1000	0		1	2		6.9	6	15.1	3
1100	0	Out of Service	0	1	Out of Service	0	2	6	4
1200	0		0	3		0	1	5	4
1300	0		0	0		0	0	3	5
1400	0		0	1		0	0	0	0
1500	0		0	1		0	2.5	2	1
1600	0		0	0		0.1	0	0	0
1800	0		1	0		0	2.5	1	0
2000	0		0	0		0.1	.6	1	0
2200	0		0	1		0	0	0	0
2400	0		0	2		0	0	0	0

*Meters 2, 3, and 4 are electromagnetic counters which record the number of flushes.

Note: See figure 7 in the text for the location of any meter. The values for meters 2, 3, and 4 are actual flushes (i.e., on 22 March, there was 1 flush (No. 3) and 3 flushes (No. 4) from 0800 to 0900). All other values represent the number of gallons used during the specified time interval.

Time	Motor 1	2	3	4	5	6	7	8	9
					20 March				
0200	0	↑	0	0	↑	0	0	0	0
0400	0		0	0		0	0	0	0
0600	0		0	0		0	0	0	0
0800	0		1	0		0	1.9	4.6	6.9
0900	0		0	5		3.0	6.0	9.0	1.5
1000	0	Out of Service	1	0	Out of Service	0	0	0.1	0
1100	0		2	3		0	0.8	0.9	0.6
1200									
1300	0		2	1		0.2	0	8.8	8.0
1400	0		2	0		0	0.1	0.2	3.0
1500	0		2	0		2.8	0.6	0.6	2.0
1600	0		2	0		0.1	0.1	2.9	1.7
1800	0		0	1		16.8	15.3	0.6	2.1
2000	0		0	0		0	0	0.6	1.5
2200	0		1	0		0	0	50.3	.6
2400	0	↓	0	0	↓	0	0	0	0
					21 March				
0200	0	↑	0	0	↑	0	0	0	0
0400	0		0	0		0	0	1	0
0600	0		0	0		0	0	0	0
0700	0		0	2		0	2.6	5.6	2.9
0800	0		4	1		2.0	6.5	17.0	11.4
0900	0		1	2		0.5	1.0	3.3	2.2
1000	1.5	Out of Service	3	4	Out of Service	0.1	2.2	2.3	0.8
1100	0		0	3		0	0	3.4	3.0
1200	0		0	2		0	0	3.0	6.2
1300	0		0	3		0	0	3.4	0.3
1400	0		0	5		0	0.3	.4	1.0
1500	0		1	2		0	1.4	1.2	0.2
1600	0		1	1		0.1	2.3	1.3	1.0
1800	0		0	1		0.1	0	0	0
2000	0		0	1		0	0	0	0
2200	0		0	1		0	0	1.7	1.9
2400	0	↓	0	0	↓	0	0	0	0
					22 March				
0200	0	↑	0	0	↑	0	0	.4	0
0400	0		0	0		0	0	0	0
0600	0	Out of Service	0	0	Out of Service	0	0	0	0
0800	0		C	0		0	1.4	11.9	5.9
0900	16.7	↓	1	3	↓	2.6	8.9	29.7	0

Measurement	Detectable Limit*	Method	001	002	003	004	005	006	007	008	009	0
pH	0.02 Unit	pH meter	7.2	7.1	7.2	5.7	5.7	7.0	7.3	5.9	5.6	
Dissolved oxygen	0.1	Dissolved oxygen meter	5.5	4.8	4.5	2.0	2.3	5.9	5.1	2.3	2.4	
TSS	1.0	As per	421	343	444	180	454	412	480	486	268	22
TVSS	1.0	Standard	370	320	407	157	409	345	323	404	218	21
TS	1.0	Methods	1888	2146	1486	1156	1368	1698	1608	1654	1402	232
TVS	1.0		1138	1480	958	646	734	992	848	922	652	14
BOD_5, total	1.0	5 day/probe	670	680	590	435	420	710	675	780	600	121
BOD_5, soluble	1.0	5 day/probe	600	585	495	400	310	450	440	500	460	8
COD, total	1.0	Dichromate reflux	2269	2288	2066	1415	1660	1530	1406	1965	1406	27
COD, soluble	1.0	Dichromate reflux	1383	1387	1051	1058	1148	960	961	1199	1059	23
Total carbon	1.0	Infrared combustion	1000	1078	940	710	750	825	735	940	580	17
Total organic carbon	1.0	Infrared combustion	919	977	851	679	721	758	673	922	570	16
Oil & grease	0.5	Gravimetric/ extraction	240.5	102.0	144.0	86.0	64.0	146.5	144.5	90.5	66.0	2
MBAS	0.05	Methylene blue	6.60	8.45	5.15	121.00	122.50	22.65	19.50	130.00	157.00	[illegible]
N-Ammonia	0.05	Distillation/ nesslerization	146.0	97	49	-2[1]	-2	51	79	-2	-2	1
N-Nitrate	0.03	Brucine	0.03	0.06	0.03	0.06	0.10	0.06	0.04	-2	-2	
N-Nitrite	0.02	Diazo	0.07	0.04	0.06	0.02	0.04	0.07	0.07	-2	-2	
Total Kjeldahl nitrogen	0.05	Distillation/ nesslerization	146	97	49	0.13	0.20	83	98	1.1	1.4	1
Total soluble phosphate	0.05	Persulfate digestion	59	59	47	3.5	5.5	43.4	27.0	8.25	5.75	[illegible]
To the soluble phosphate	0.05	Stannous chloride & persulfate	23.8	24.3	18.7	1.5	2.3	17.0	17.0	4.3	3.8	[illegible]
Salinity	1.0	Cl^-/-607	336	339	269	178	178	206	214	135	125	3
Alkalinity	0.1	Methyl orange	312	306	254	69	73	272	266	69	62	2
Acidity	0.1	Phenolphthalien	235	243	219	89	97	151	135	113	86	[illegible]
Chloride	1.0	Titration	204	206	163	108	108	125	130	82	76	1
Temperature	1° C	Thermometer	13	13	13	13	13	15	15	15	15	[illegible]
Formaldehyde	4.0	Chromotropic acid	40	48	28	-2	-2	38.8	34.4	-2	-2	2
Total coliform	<1/100 ml	Membrane Filter/MF	7E10+5	1.7E10+5	2E10+6	9.8E10+9	4.9E10+9	1.3E10+7	7E10+6	2E10+8	2.8E10+9	
Fecal Coliform	<1/100 ml		1E10+4	2E10+4	2E10+4	1E10+6	1E10+8	1E10+4	2E10+4	4E10+4	5E10+6	4.5
Standard plate count	<1/100 ml	As per standard methods	1E10+6	1E10+6	1.5E10+7	8E10+10	1E10+10	2E10+7	2.5E10+7	1E10+11	3E10+10	1.5
Source ◄——► of ◄——► Sample			Port	Port	Port	Starboard	Starboard	Port	Port	Starboard	Starboard	[illegible]

[1] A dash through the space indicates no analysis was performed; -2 in the space indicates that the result was below the detectable limit; scientific notation is used for expre
Note: The statistical treatment does not intend to show uniformness of the samples, but implies the randomness and wide range involved.
*All units in mg/l except as noted.

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APPENDIX B
WASTE-WATER ANALYSIS DATA
(Units are in MG/Liter Unless Specified Otherwise)

	Sample																
	008	009	010	011	012	013	014	015	016	017	018	019	020	021	022	023	M
	5.9	5.6	7.1	7.2	5.5	5.4	6.6	6.4	6.2	8.2	8.3	8.3	7.7	7.8	7.4	8.0	
	2.3	2.4	-	-	-	-	-	-	-	-	-	-	<0.5	1.0	<0.5	<0.5	
	486	268	224	144	654	258	460	290	260	476	372	152	9,480	5930	1407	1413	121
	404	218	212	132	584	242	388	234	222	380	294	110	8,050	5380	947	1320	101
	1654	1402	2328	2486	1538	1312	1196	1066	1196	1752	1628	1738	9,857	8144	2416	1768	252
	922	652	1442	1666	930	764	766	656	770	954	840	990	8,201	6012	1348	946	167
	780	600	1215	1005	772	585	1050	870	930	1260	1110	1080	1,830	2430	960	870	97
	500	460	855	915	457	352	645	540	705	1140	990	900	330	517	780	710	70
	1965	1406	2793	2983	1862	1505	1726	1749	1686	2729	2604	2541	11,496	8660	2717	2124	304
	1199	1059	2337	2451	1577	1382	1176	1122	1106	1741	1718	1639	1,405	1923	1200	1338	150
	940	580	1700	1725	800	790	574	555	540	784	740	738	1,462	1598	860	880	103
	922	570	1644	1669	780	773	555	534	521	735	687	682	1,162	1045	677	554	92
5	90.5	66.0	218.0	244.0	276.0	211.0	279.5	65	198.5	205	189.5	98.0	1,793.5	1779.0	126.0	113.0	28
50	130.00	157.00	27.00	26.00	120.00	244.00	-	-	-	2.7	2.35	3.20	1.1	6.0	23.2	9.6	2
	-2	-2	136	135	1.90	0.55	12	25	27	382.5	325	345	73	57	13	30	14
04	-2	-2	0.07	0.04	-2	-2	0.57	0.63	0.62	1.54	0.84	0.32	0.33	0.80	0.53	0.67	
07	-2	-2	0.03	0.04	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	
	1.1	1.4	160	158	6.1	2.7	-	-	-	-	-	-	78.9	59.2	16.4	35.2	9
0	8.25	5.75	40	37	6.75	5.50	13.25	13.25	12.25	46.60	51.00	46.60	184	36	280	520	11
0	4.3	3.8	25	22.6	3.4	2.8	9.25	9.00	8.00	24.60	24.60	22.00	52	38	95	175	4
	135	125	321	318	92	92	158.2	143.3	166.4	425.0	411.9	395.4	323	725	254	407	324
	69	62	275.65	277.50	61.00	59.20	318.7	292.0	279.1	1269.1	1227.6	1247.0	1,283	2038	752.4	1242.5	69
	113	86	78	72	102	74.4	139.3	131.6	136.7	31.0	25.8	38.7	196	274.4	80.4	99.2	123
	82	76	103	193	56	56	96	87	101	258	250	240	195	440	154	247	197
	15	15	14	14	14	14	18	18	18	19	19	19	23	22	25	25	17
4	-2	-2	281.2	288.0	-2	-2	-2	-2	-2	4	3.2	3.0	-	-	-	-	76
0+6	2E10+8	2.8E10+9	-	-	-	-	9E10+8	2E10+9	1.1E10+7	7.1E10+5	1.35E10+6	1.8E10+5	2.2E10+6	4.5E10+7	1.5E10+5	1.1E10+5	2.50E
0+4	4E10+4	5E10+6	4.5E10+3	2.1E10+5	2.9E10+6	8E10+6	1E10+4	1E10+3	5E10+4	1E10+4	1E10+4	1E10+4	5E10+2	4.6E10+5	9E10+2	1E10+2	2.51E
0+7	1E10+11	3E10+10	1.5E10+6	1.1E10+6	3.0E10+9	4.4E10+9	3.5E10+11	5E10+9	2E10+7	1E10+6	2E10+6	1E10+6	6.7E10+5	2.5E10+7	7E10+6	2E10+6	6.02E
	Starboard	Starboard	Port	Port	Starboard	Starboard	Starboard	Starboard	Starboard	Port	Port	Port	Port	Starboard	Port	Port	

tific notation is used for expression of bacteriological data.

			Port Samples			Starboard Samples		
021	022	023	Mean	Standard Deviation	95% Confidence of Mean	Mean	Standard Deviation	95% Confidence of Mean
7.8	7.4	8.0	7.538	0.494	7.538 ±.269	6.080	0.722	6.080 ±0.448
1.0	<0.5	<0.5	3.413	2.448	3.413 ±1.696	2.000	0.579	2.000 ±0.507
5930	1407	1413	1212.9	2517.8	1212.9 ±1338.7	924.0	1764.8	924.0 ±1093.8
5380	947	1320	1016.2	2139.9	1016.2 ±1163.3	823.8	1606.1	823.8 ±995.4
8144	2416	1768	2523.0	2227.8	2523.0 ±1211.1	2003.2	2165.1	2003.2 ±1341.9
6012	1348	948	1677.3	1978.1	1677.3 ±1075.3	1285.2	1663.9	1285.2 ±1031.3
2430	960	870	973.5	341.5	973.5 ±185.7	887.2	580.2	887.2 ±359.6
517	780	710	706.9	245.9	706.9 ±133.7	488.0	122.5	488.0 ±75.9
8660	2717	2124	3042.0	2583.7	3042.0 ±1404.5	2363.4	2219.8	2363.4 ±1375.8
1923	1200	1338	1505.5	471.3	1505.5 ±256.2	1275.0	278.9	1275.0 ±172.9
1598	860	860	1035.9	358.2	1035.9 ±194.7	783.7	314.7	783.7 ±195.1
1045	677	554	922.2	362.5	922.2 ±197.1	710.0	175.6	710.0 ±108.8
1779.0	120.0	113.0	289.6	454.7	289.6 ±247.2	311.6	522.9	311.6 ±324.1
6.0	23.2	9.6	27.5	59.5	27.5 ±32.4	128.6	69.9	128.6 ±51.8
57	13	30	143.2	125.6	143.2 ±68.3	20.6	21.0	20.6 ±16.8
0.80	0.53	0.67	0.33	0.40	0.33 ±0.22	0.40	0.31	0.40 ±0.23
-2	-2	-2	0.05	0.02	0.05 ±0.01	0.03	0.01	0.03 ±0.02
59.2	16.4	35.2	92.2	50.6	92.2 ±31.3	10.1	21.7	10.1 ±16.1
36	280	520	110.8	142.8	110.8 ±77.6	11.00	9.47	11.00 ±5.87
38	95	175	41.7	45.4	41.7 ±24.7	8.2	10.8	8.2 ±6.7
725	254	407	324.6	73.2	324.6 ±39.8	199.3	187.3	199.3 ±116.1
2058	752.4	1242.5	691.1	480.6	691.1 ±261.3	384.1	615.5	334.1 ±381.5
271.4	80.4	99.2	123.4	78.8	123.4 ±42.8	124.3	57.3	124.3 ±35.5
440	154	247	197.0	44.4	197.0 ±24.2	121.0	113.7	121.0 ±70.4
22	25	25	17.5	4.5	17.5 ±2.5	16.0	2.9	16.0 ±1.8
-	-	-	76.9	110.7	76 9 ±68.6	-	-	-
4.5E10 + 7	1.3E10 + 5	1.1E10 + 5	2.50E10 + 6	4.00E10 + 6	2.50E10 + 6 ±2.37E10 + 6	2.58E10 + 9	3.37E10 + 9	2.58E10 + 9 ±2.33E10 + 9
4.6E10 + 5	9E10 + 2	1E10 + 2	2.81E10 + 4	5.60E10 + 4	2.81E10 + 4 ±3.04E10 + 4	1.21E10 + 7	3.09E10 + 7	1.21E10 + 7 ±1.92E10 + 7
2.5E10 + 7	7E10 + 6	2E10 + 6	6.02E10 + 6	8.38E10 + 6	6.02E10 + 6 ±4.56E10 + 6	5.82E10 + 10	1.09E10 + 11	5.82E10 + 10 ±6.73E10 + 10
Starboard	Port	Port						

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13. ABSTRACT

The nonoily liquid wastes (other than bilge and ballast waste water) generated aboard U. S. Army LCU 1561, during its normal deployment, were characterized. Waste generation rates, as well as the physical, chemical, and bacteriological nature of the collected waste water, were determined. Twenty-three grab samples, representing the waste water in the port and starboard holding tanks, were collected and analyzed.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Shipboard waste characterization						
Utility landing craft waste						
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Shore collection unit						