FEASIBILITY OF RECYCLING LAUNDRY WASTEWATERS AT MILITARY QUARTERMASTER LAUNDRIES

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Research and Technology Division
Fort Belvoir, VA 22060

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An economic analysis of recycling Army installation laundry wastewater is detailed. Usage, costs, designs, comparisons and assumptions are presented in detail with explanatory narrative. The findings are that the cost for treatment to renovate laundry wastewater to a quality to permit its reuse is not cost effective under present conditions.

Water, water recycle, water reuse, laundry water recovery.
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FEASIBILITY OF RECYCLING LAUNDRY WASTEWATERS
AT MILITARY QUARTERMASTER LAUNDRIES

1.0 INTRODUCTION

1.1 Subject.

The purpose of this study is to determine the economic practicality of reclaiming quartermaster laundry wastes at major installations for recycle.

1.2 Scope.

Using literature data from previous studies in recycling and treating laundry wastewaters, a tentative design for a recycling process will be made. Capital investment, and operating costs of the design will be compared against current water and sewage treatment rates at major installations using a breakeven analysis. The practicality of recycling laundry wastes will be discussed.

1.3 Background and Previous Investigation.

Laundry water waste extraction has been extensively looked at for a number of years. The basic concern in laundry waste treatment has been removal of laundry detergents and phosphates. Prior to 1965 the most common synthetic detergent used in laundry soaps was alkylbenzenesulfonate, or ABS. ABS and its complexes were only biologically oxidated over an extended period of time. Consequently synthetic detergent build-up in certain highly populated areas became a serious problem. Concentrations higher than 12 mg/l imparted to the water disagreeable tastes, odors, and high turbidities. Chemical and physical methods of extracting the synthetic detergents from
the laundry waters were investigated. Chemical treatment investigations included coagulation by aluminum sulfate, activated powdered carbon with a polyelectrolyte and combination of the two. Physical methods of removal were conducted using induced air flotation. A summary of the data obtained and flow diagrams for the processes are shown in Tables 1-1 to 1-5 and Figures 1-1 to 1-3.

![Flow Diagram for Air Flotation](image)

**Figure 1-1.**
Flow Diagram for Air Flotation.

**Table 1-1.**
Operating Results from Flotation Process.

<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>Effluent</th>
<th>Percent Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>8.96*</td>
<td>5.06</td>
<td>--</td>
</tr>
<tr>
<td>ABS (mg/lit)</td>
<td>58.2</td>
<td>35.8</td>
<td>38</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>167</td>
<td>111</td>
<td>33</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>1044</td>
<td>1380</td>
<td>--</td>
</tr>
<tr>
<td>COD (mg/lit)</td>
<td>591</td>
<td>374</td>
<td>37</td>
</tr>
<tr>
<td>Phosphates (mg/lit)</td>
<td>123</td>
<td>39.2</td>
<td>6d</td>
</tr>
</tbody>
</table>

*Eleven (11) samples taken from pilot plant having 8,000 to 10,000 gpd flow rate. Family laundry comprised majority of wash.
Chemical dosages for air flotation were 200 mg/l of sulphuric acid, 400 mg/l of aluminum sulfate, 50 mg/l of soda ash, and 25 mg/l of tallow. The detention period within the flotation chamber was approximately nine minutes. Extraction of laundry wastes by air flotation was unacceptable. As seen in Table 1-1 the percent removal of wastes was generally poor. Other major problems associated with the procedure were erratic waste removal and the high percentage of water retention in the sludge.

![Flow Diagram Using Aluminum Sulfate and Powdered Activated Carbon as the Coagulant](image)

**Figure 1-2.**

Flow Diagram Using Aluminum Sulfate and Powdered Activated Carbon as the Coagulant.

**Table 1-2.**

Operating Results from Using Aluminum Sulfate & Powdered Carbon as Coagulants.

<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>Effluent</th>
<th>Percent Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>7.62</td>
<td>9.0</td>
<td>--</td>
</tr>
<tr>
<td>ABS (mg/l)</td>
<td>31.8</td>
<td>14</td>
<td>56</td>
</tr>
<tr>
<td>Suspended solids (mg/l)</td>
<td>216</td>
<td>12</td>
<td>94</td>
</tr>
<tr>
<td>Dissolved solids (mg/l)</td>
<td>669</td>
<td>1109</td>
<td>--</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>403.2</td>
<td>140</td>
<td>65</td>
</tr>
<tr>
<td>Phosphates (mg/l)</td>
<td>190</td>
<td>4</td>
<td>98</td>
</tr>
</tbody>
</table>
Upflow clarification using aluminum sulfate as a coagulant and powdered activated carbon for adsorption and coagulation provided better results than air flotation. Chemical dosages for aluminum sulfate and powdered carbon varied between 560 mg/lit and 750 mg/lit. Tallow, as a flocculent aid was used in trace amounts. Problems occurred in the upflow clarifier operation due to the temperature fluctuations in the entering laundry wastewaters. Temperature gradients within the clarifier from the cyclic nature of the washers decreased the settleability of the floc, increased the detention time required, and decreased the wastewater flows. Salt build-up would eventually become a problem if the laundry wastewaters were continued to be recycled. Powdered activated carbon gave good results by adsorbing odors and ABS detergents, but created handling and feeding problems due to its low density and special mixing requirements.

Table 1-3.

<table>
<thead>
<tr>
<th>Influent</th>
<th>Effluent</th>
<th>Percent Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>11</td>
<td>5.4</td>
</tr>
<tr>
<td>Volatile suspended solids (mg/lit)</td>
<td>1170</td>
<td>190</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>860</td>
<td>160</td>
</tr>
<tr>
<td>Total solids</td>
<td>1940</td>
<td>1130</td>
</tr>
<tr>
<td>COD</td>
<td>2496</td>
<td>292</td>
</tr>
<tr>
<td>Phosphates</td>
<td>4.42</td>
<td>.3</td>
</tr>
</tbody>
</table>

Similar results seen in Table 1-3 were determined using a high chemical dosage of aluminum sulfate versus aluminum sulfate and powdered carbon. Approximate chemical dosage of aluminum sulfate was 1000 mg/lit followed by a two hour detention period. The major drawbacks to using aluminum sulfate alone were the increased rate of salt build-up within the wastewater recycling.
Process, and h. at gradients affecting the settability of the floc within the clarifier.

Sanitary Sciences Division of MERADCOM used the standard military water purification unit (ERDLATOR) to reclaim laundry wastewater. The process initially used an upflow clarifier followed by filtration through a diatomaceous earth pressure filter. Coagulation was produced by powdered activated carbon and a cationic polyelectrolyte. The powdered carbon dosage was 1000 mg/lit with trace solutions of the polymer.
Table 1-4.
Operating From Coagulation of Wastewater
By Powdered Carbon and a Polyelectrolyte.

<table>
<thead>
<tr>
<th>Characteristics*</th>
<th>Tap Water</th>
<th>Softened Water</th>
<th>Raw Wastewater</th>
<th>Product Water</th>
<th>Percent Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>0.13</td>
<td>0.10</td>
<td>106</td>
<td>2.04</td>
<td>98</td>
</tr>
<tr>
<td>Ph</td>
<td>8.1</td>
<td>8.2</td>
<td>10.3</td>
<td>10.1</td>
<td>--</td>
</tr>
<tr>
<td>BOD (mg/lit)</td>
<td>Not Reported</td>
<td>152</td>
<td>14</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>TOC, Total (mg/lit)</td>
<td>183</td>
<td>20</td>
<td></td>
<td></td>
<td>89</td>
</tr>
<tr>
<td>TOC, Dissolved (mg/lit)</td>
<td>21</td>
<td>21</td>
<td>103</td>
<td>22</td>
<td>79</td>
</tr>
<tr>
<td>Detergents LAS (mg/lit)</td>
<td>0.04</td>
<td>0.02</td>
<td>2.98</td>
<td>0.34</td>
<td>89</td>
</tr>
<tr>
<td>Conductivity (mho/cm)</td>
<td>234</td>
<td>234</td>
<td>1024</td>
<td>1177</td>
<td>--</td>
</tr>
<tr>
<td>Suspended solids (mg/lit)</td>
<td>3</td>
<td>3</td>
<td>116</td>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>Hexane Solubles (mg/lit)</td>
<td>0.0</td>
<td>0.0</td>
<td>52</td>
<td>18</td>
<td>65</td>
</tr>
<tr>
<td>Hardness as CaCO$_3$ (mg/lit)</td>
<td>102</td>
<td>4</td>
<td>Not Reported</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

*Fifty-four (54) samples taken over a 5 month period.

As seen in Table 4 the percent removal from raw wastewater using powdered carbon was similar to previous methods discussed. Use of powdered carbon instead of aluminum sulfate had some advantages. Coagulation by powdered carbon did not form the large flocculant particles alum formed. Consequently powdered carbon was not affected as much by heat fluctuations of the water. Faster flowrates for similar sized equipment could be used with powdered carbon as the coagulant. The detention time for powdered carbon was twenty minutes versus two hours for aluminum sulfate. The use of powdered carbon resulted in handling and feeding problems. Powdered carbon was unable to extract phosphates from the wastewater.
The problem of extracting phosphates and other salts was partially solved by Sanitary Sciences Division using reverse osmosis after filtration by diatomaceous earth. Table 1-5 is a summary of the results.

Table 1-5.

Summary of Wastewater Characteristics Using Reverse Osmosis, Coagulation, and Diatomaceous Earth Filtration

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Equalization Tank</th>
<th>Product Tank</th>
<th>RO Product Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>Turbidity, JTU</td>
<td>25.6</td>
<td>1.5-55</td>
<td>1.5</td>
</tr>
<tr>
<td>pH</td>
<td>8.9</td>
<td>8.2-9.5</td>
<td>8.3</td>
</tr>
<tr>
<td>LAS</td>
<td>39</td>
<td>6-108</td>
<td>1.74</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>71.3</td>
<td>44-120</td>
<td>60.2</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>336</td>
<td>50-520</td>
<td>289</td>
</tr>
<tr>
<td>COD</td>
<td>422</td>
<td>206-1028</td>
<td>173</td>
</tr>
<tr>
<td>TOC</td>
<td>95.8</td>
<td>51-180</td>
<td>54</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>39</td>
<td>1-61</td>
<td>9.6</td>
</tr>
<tr>
<td>Conductivity micromhos/cm</td>
<td>1022</td>
<td>480-2200</td>
<td>940</td>
</tr>
</tbody>
</table>

All units mg/lit except as noted.

Disadvantages to using reverse osmosis were: high cost of equipment, short membrane life, and a high brine to product water ratio.

After 1965 LAS, linear alkylate sulfonate, a biodegradable detergent, replaced the ABS detergent complexes. The majority of investigations into detergent removal were discontinued after LAS gained market acceptance. This was because LAS complexes broke down rapidly enough not to pose a build-up or pollution/source problem. Laundry wastewater investigations continued in the removal and/or replacement of phosphorus compounds in
laundry soap mixes. Phosphorus removal from detergents continued to be considered because phosphorus stimulated algal growths and under some circumstances could produce nuisance conditions. NTA (nirilotriacetic acid) for a while was considered the most promising substitute for phosphorus and its compounds, but was later dropped. NTA, a chelating agent had the property of making many heavy metal ions more soluble in water. This interfered in the formation of insoluble salts used to coagulate heavy metal ions. Replacement of phosphorus by NTA would have caused a more serious problem, that of heavy metal build-up in ground waters. Much of the problems encountered from using phosphorus in detergent mixes have been solved by modern methods of sewage treatment. Current sewage treatment processes are now able to remove up to 99 percent of the phosphorus in the wastewater.

Consequently further study using NTA or other chemicals to substitute for phosphorus have been discontinued. Because the problem of laundry wastewater pollution has effectively been solved it is doubtful that any further study will be made in detergent removal unless the cost of water, and sewage charges become high enough to make recycling of laundry waters profitable.

2.0 ECONOMIC ANALYSIS
2.1 Laundry Water Usage and Costs at Major Army Installations in CONUS

Laundry water usage at military installations depicted in Table 2-1 were estimated by examining the Schedule X's from the installation quartermaster laundries. The Schedule X is used to record the amount of work conducted during the year for use in a manpower survey.
Work levels are recorded by the number of laundry pieces washed each month. Water usage was estimated from pieces of laundry washed by the correlation of three gallons water required for each piece of laundry washed.\textsuperscript{9}

Comparing the installation's total water consumption during the year to the estimated laundry water usage for the six installations in Table 2-1, would indicate that approximately 1.03% of the total water consumed at the installation is used by the installation quartermaster laundry.
Table 2-1.
Estimates for Laundry Water Consumption at Army Installations.\(^9\)

<table>
<thead>
<tr>
<th>Installation*</th>
<th>Year</th>
<th>Number of Laundry Pieces Washed in Year (10^3)</th>
<th>Estimated Yearly Water Consumption at Quartermaster Laundry (kGal)</th>
<th>Total Water Consumption at Installation(kGAL)</th>
<th>Percent Water Used for Laundry Purposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ft. Hood</td>
<td>FY74</td>
<td>7065.7</td>
<td>21.197</td>
<td>2,386,835</td>
<td>.88</td>
</tr>
<tr>
<td>Ft. Bragg</td>
<td>FY74</td>
<td>6406.4</td>
<td>19.219</td>
<td>1,932,887</td>
<td>.99</td>
</tr>
<tr>
<td>Ft. Carson</td>
<td>FY74</td>
<td>5613.2</td>
<td>16.840</td>
<td>1,097,722</td>
<td>1.5</td>
</tr>
<tr>
<td>Ft. Campbell</td>
<td>FY74</td>
<td>5014</td>
<td>15.042</td>
<td>1,640,694</td>
<td>.91</td>
</tr>
<tr>
<td>Ft. Lewis</td>
<td>FY73</td>
<td>5882</td>
<td>17.646</td>
<td>2,725,871</td>
<td>.64</td>
</tr>
<tr>
<td>Ft. Belvoir</td>
<td>FY75</td>
<td>3469.3</td>
<td>10.408</td>
<td>774,057</td>
<td>1.3</td>
</tr>
</tbody>
</table>

*Schedule X data no older than calendar year 1972.
Table 2-2.
Estimated Costs and Consumption Rates for Water Used at Installation Quarter Master Laudnry.

<table>
<thead>
<tr>
<th>Installation*</th>
<th>Population (10^3)</th>
<th>Estimated Water Usage for QM Laundry Purposes (KGAL)</th>
<th>Estimated Daily Plant Capacity to Process Laundry Wastewater (GAL)</th>
<th>FY75 Price for Purchased Water &amp; Waste Treatment ($/1000 gal)</th>
<th>Total Estimated Cost Per Year For Purchased Water &amp; Sewage treatment By The QM Laundry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ft. Hood</td>
<td>61.9</td>
<td>23,300</td>
<td>89,600</td>
<td>.11</td>
<td>3,560</td>
</tr>
<tr>
<td>Ft. Knox</td>
<td>44</td>
<td>20,500</td>
<td>78,800</td>
<td>1.56</td>
<td>31,980</td>
</tr>
<tr>
<td>Ft. Bragg</td>
<td>41.7</td>
<td>20,000</td>
<td>78,100</td>
<td>1.60</td>
<td>32,480</td>
</tr>
<tr>
<td>Ft. Carson</td>
<td>41.1</td>
<td>16,800*</td>
<td>64,600</td>
<td>.61</td>
<td>10,250</td>
</tr>
<tr>
<td>Ft. Lewis</td>
<td>38</td>
<td>17,600*</td>
<td>67,700</td>
<td>1.05</td>
<td>18,480</td>
</tr>
<tr>
<td>Ft. Benning</td>
<td>37</td>
<td>22,000</td>
<td>84,600</td>
<td>.71</td>
<td>15,620</td>
</tr>
<tr>
<td>Ft. Bliss</td>
<td>36.6</td>
<td>22,800</td>
<td>87,700</td>
<td>.38</td>
<td>8,660</td>
</tr>
<tr>
<td>Ft. Campbell</td>
<td>35.1</td>
<td>17,500</td>
<td>67,300</td>
<td>.76</td>
<td>13,300</td>
</tr>
<tr>
<td>Ft. Ord</td>
<td>34</td>
<td>17,500</td>
<td>67,300</td>
<td>.45</td>
<td>7,900</td>
</tr>
<tr>
<td>Ft. Leonard Wood</td>
<td>31.3</td>
<td>16,900</td>
<td>65,000</td>
<td>.82</td>
<td>14,700</td>
</tr>
<tr>
<td>Ft. Still</td>
<td>29</td>
<td>10,500</td>
<td>40,400</td>
<td>.22</td>
<td>2,310</td>
</tr>
<tr>
<td>Ft. Riley</td>
<td>29</td>
<td>13,000</td>
<td>50,000</td>
<td>.85</td>
<td>11,050</td>
</tr>
<tr>
<td>Ft. Jackson</td>
<td>26</td>
<td>11,900</td>
<td>45,800</td>
<td>.86</td>
<td>10,230</td>
</tr>
<tr>
<td>Ft. Polk</td>
<td>25</td>
<td>8,210</td>
<td>31,600</td>
<td>.17</td>
<td>1,400</td>
</tr>
<tr>
<td>Ft. Amador</td>
<td>22.3</td>
<td>17,900</td>
<td>68,800</td>
<td>.35</td>
<td>6,270</td>
</tr>
<tr>
<td>Ft. Rucker</td>
<td>21</td>
<td>7,900</td>
<td>30,400</td>
<td>1.21</td>
<td>9,560</td>
</tr>
<tr>
<td>Ft. Sam Houston</td>
<td>20</td>
<td>13,200</td>
<td>50,800</td>
<td>.62</td>
<td>8,180</td>
</tr>
</tbody>
</table>

*Values for Ft. Carson and Ft. Lewis were taken from Table 5 instead of the FY75 Facilities Engineering Annual Summary of operations.
Using 1.03" as an indicator of laundry water consumption, Table 2-2 represents the water consumed by the installation quartermaster laundry for the 17 largest installations by population. Water and sewage charges are the FY75 price paid by the installation and supplied by outside utilities. The assumption was made that any decrease in water consumption or sewage treatment for laundry wastewater recycling would be subtracted from the more expensive services supplied by off post utilities. The last column in Table 2-2, the total estimated cost per year for purchased water and sewage treatment used by the quartermaster laundry is the breakeven point for the installation's laundry recycle plant. The total yearly cost of operation and amortization of equipment costs of a laundry wastewater recycling plant must be under those estimated installation costs to be economically feasible.

2.2 Preliminary Design.

Figure 2-1 represents the major process areas that would be involved in laundry waste treatment plant indicated by the literature previously discussed.

![Flow Diagram of Possible Process Equipment Used in Recycling Laundry Wastes](image)

Figure 2-1.
Estimated equipment costs were made using Figure 2-1 as a guide for the possible process equipment that would be used in recycling wastewater. A plant capacity of 70,000 gpd of wastewater was chosen as being representative of the laundry water consumption at installations where reuse of laundry water was feasible. Equipment sizing and cost estimation was completed for coagulation by alum, and powdered carbon with a polyelectrolyte to determine if coagulation by either process amounted to any savings. The lowest value between the two was used to determine the total cost of equipment. Installation costs for the equipment were determined by using a cost proposal by a private contractor for a laundry waste treatment plant to have been located at Ft. Jackson. Operating costs include the cost of chemicals using literature dosages and the cost of an operator maintaining the equipment two to four hours daily or $5,000 per year. Electrical charges & other maintenance expenses were not added into the operating charge.

2.2.1 Mass Balance.

The basis for the treatment facility is 70,000 gallons of wastewater per operating day. Table 2-3 is representative of the typical quality of laundry water wastes found in literature.

Table 2-3.

Average Quality of Laundry Wastes.\textsuperscript{11}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average (mg/lit)</th>
<th>Range (mg/lit)</th>
<th>Process Flow (Average lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>7.13</td>
<td>5.0-7.6</td>
<td>--</td>
</tr>
<tr>
<td>BOD</td>
<td>120</td>
<td>50-185</td>
<td>8.75</td>
</tr>
<tr>
<td>COD</td>
<td>315</td>
<td>136-455</td>
<td>22.98</td>
</tr>
<tr>
<td>ABS</td>
<td>33</td>
<td>15-144</td>
<td>2.4</td>
</tr>
<tr>
<td>TDS</td>
<td>700</td>
<td>290-1450</td>
<td>51.07</td>
</tr>
<tr>
<td>Phosphate (PO\textsubscript{3}\textsuperscript{-4})</td>
<td>146</td>
<td>84-199</td>
<td>10.67</td>
</tr>
<tr>
<td>Acidity as CaCO\textsubscript{3}</td>
<td>91</td>
<td>73-124</td>
<td>6.6</td>
</tr>
<tr>
<td>Alkalinity as CaCO\textsubscript{3}</td>
<td>368</td>
<td>340-420</td>
<td>26.8</td>
</tr>
</tbody>
</table>
Process flows are determined from the basis. The system is expected to be operated 8 hours per day.

2.2.2 Mixing/Setting.

Air flotation because of the poor reliability i.e., the large amount of liquid entrapment within the foam overflow and poor separation, will not be considered as a suitable method of wastewater recovery.

Assumptions used in the preliminary design of the upflow clarifier and sedimentation chamber are listed below.

2.2.2.1 Assumptions for design of upflow clarifier and sedimentation chamber.

2.2.2.1.1 Approximate loadings for aluminum floc are shown in Table 2-4.

Table 2-4.

<table>
<thead>
<tr>
<th>Nature of Solids</th>
<th>Specific Gravity</th>
<th>Settling Velocity (cps)</th>
<th>Surface Loading* (gpd per ft²)</th>
<th>Detention Period (for 10 ft tank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, slit &amp; clay</td>
<td>2.65</td>
<td>7 x 10⁻³</td>
<td>146</td>
<td>12.3</td>
</tr>
<tr>
<td>Aluminum floc</td>
<td>1.002</td>
<td>8.2 x 10⁻²</td>
<td>1800</td>
<td>1</td>
</tr>
</tbody>
</table>

* gpd is for 24 hour period.

2.2.2.1.2 Powdered activated carbon absorbs within 15 to 20 minutes approximately 95% of the removable COD. Inordinate times are required to remove the other 5%.

2.2.2.1.3 Powdered carbon has a rise rate of 1.1 gal/min/ft² and a detention time of 20 minutes.

2.2.2.1.4 Average depth of upflow clarifier is from 8 to 12 feet.
2.2.2.1.5 Sedimentation tanks are designed with length to width ratios of 3:1 to 5:1, are almost twice as long as the estimated settling velocity would require and have a depth of approximately 8 feet.\textsuperscript{16}

2.2.2.1.6 Average clarifier diameters range from 35 to 200 feet, 100 feet being the average. Cost of clarifiers range from $28,000 to $470,000. Cost estimates are from 1972.\textsuperscript{17}

2.2.2.1.7 Aluminum floc will remove by clarification 75% ABS and 94% phosphates at a pH between 4 and 5. Concentration of $\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$ used is 1000 mg/l.

2.2.2.1.8 Nomenclature.

- $Q$: Volumetric flow rate
- $C$: Volumetric capacity of the settling zone
- $t_0$: Detention period
- $V_0$: Settling velocity or surface loading
- $h$: Height of settling zone
- $W$: Width of settling zone
- $L$: Length of settling zone
- $A$: Surface Area

2.2.2.2 Calculation for Upflow Clarifier.

2.2.2.2.1 Using Alum as the coagulant.

Surface loading: 1800 gpd/ft\textsuperscript{2}

Tank height: 10 feet

Surface loading 1800 gpd/ft\textsuperscript{2} = 10.025 ft\textsuperscript{3}/hr/ft\textsuperscript{2}

\[
(a) \quad A = \frac{Q}{V_0} = \left( \frac{1170}{10.025} \right) = 117 \text{ ft}^2
\]
(b) Detention time = \( \frac{V}{Q} = \frac{(117 \text{ ft}^3)}{(10 \text{ ft})} = 1 \text{ hour} \)

(c) Doubling size to account for entrance and rapid mixing effects gives a tank whose surface area is 234 ft\(^2\), diameter is 18 ft, and height is 10 ft.

2.2.2.2 Using powdered carbon as the coagulant.

Surface loading: \( 1.1 \text{ gal/min/ft}^2 \)

Tank height: 10 feet

Surface loading \( 1.1 \text{ gal/min/ft}^2 = 8.8 \text{ ft}^3/\text{hr/ft}^2 \):

(a) \( A = \frac{Q}{V} \left( \frac{1170}{8.8} \right) = 132.9 = 133 \text{ ft} \)

(b) Detention time = \( \frac{V}{Q} = \frac{133 (10)}{1170} = 1.1 \text{ hour} \)

(c) Doubling size to account for entrance and rapid mixing effects, gives a tank whose surface is 266 ft\(^2\), diameter is 18 ft, and height is 10 feet.

2.2.2.3 Cost of clarifiers.

Clarifiers range in price from \$28,000 to \$470,000 for clarifiers with diameters from 35 to 200 ft. Chemical feed systems for clarifiers having diameters below 35 ft are the major cost. Consequently clarifiers with diameters of 18 to 19 feet would cost approximately the same or \$28,000. Using economic indicators from Chemical Engineering, cost of clarifiers bought in Dec 1975 would be as follows:

\[
(\$28,000) \left( \frac{186.6}{137.2} \right) \text{ Dec 1975} = \$38,100
\]

2.2.2.4 Calculations for Sedimentation Chamber using Aluminum Sulfate as Flocculate Aid.
Let \( h = 8 \text{ ft} \) and \( L = 4W \).

(a) Settling velocity \( = \left(8.3 \times 10^{-5} \frac{\text{cm}}{\text{sec}} \cdot \frac{3600}{30.48} \right) = 9.8 \text{ ft/hr} \).

(b) \( V_0 = \frac{h}{t_0}; \ t_0 = \frac{8 \text{ ft}}{9.8 \text{ ft/hr}} = .81 \text{ hr detention time} \ 4W^2/h/Q \)

(c) \( t_0 = \frac{C}{Q} \)

\[
W = \left[ \frac{Q}{4V_0} \right]^\frac{1}{2} = \left[ \frac{1170}{4 \cdot 9.8} \right]^\frac{1}{2} = 5.5 \text{ ft} \\
L = 22 \text{ ft.}
\]

(d) Doubling sedimentation volume to account for freeboard, and entrance and exit effects gives a tank width 6 ft, length 40 ft, and height of 8 ft.

(e) Cost of sedimentation tank

Current prices for sedimentation tanks could not be found in literature at this writing. Chemical feed and mixing systems for clarifiers would be similar to sedimentation units. Construction of the settling basin of a sedimentation tank should be similar but less expensive than an upflow clarifier because of its shape. The price should then be somewhere less than a clarifier of similar capacity or \$38,000. Without knowing the degree difference for estimation purposes the cost of the sedimentation basin is \$38,000.

2.2.5 Filtration.

2.2.5.1 Sand or Mixed Media Filter.

2.2.5.1.1 Assumptions.

(a) Hydraulic loading on surface of sand bed is \( 24.07 \text{ ft}^3/\text{hr}/\text{ft}^2 \).\(^{19}\)

(b) Backwash when loss of head is 5 psi. Backwash at rates between 12-15 gal/ft\(^2/min for sand filtration. Continue backwashing for 5-10 minutes.\(^{20}\)

(c) Bed depth is between 2 to 3 feet deep.\(^{21}\)

(d) Bed can contain between \( \frac{1}{4} \) to \( \frac{1}{2} \) cubic feet of suspended solids prior to backwashing.\(^{22}\)
2.2.5.1.2 Calculations.

(a) Surface area of filter.

\[
\text{Surface area} = \frac{(\text{Volumetric flow rate})}{(\text{Hydraulic loading})} = \frac{1170 \text{ ft}^3/\text{hr}}{20.07 \text{ ft}^3/\text{hr}/\text{ft}^2} = 58.6 \text{ ft}^2
\]

(b) Cost is then; \((50 \text{ ft}^2) \times (\$80/\text{ft}^2) = \$4000\) for 1970 without pump.

(c) Updating the cost to December 1975 is \((\$4000) \times \left(\frac{186.6}{125.7}\right) = \$5600\)

for sand filter.

(d) Pump sizing.

Backwash rate is 13.5 gal/ft²/min or \((13.5) \text{ gal/ft}^2/\text{min} (50 \text{ ft}^2)\) = 675 gal/min. Total water requirement for backwashing is \((675 \text{ gal/min}) (7.5 \text{ min}) = 5100 \text{ gal}\). Backwashing requires pump with suction pressure of 15 psi \((34 \text{ ft of water})\). Using chart in Reference 1, cost of a cast iron centrifugal in line pump with motor is \$650 for 1971 costing. Updating cost to Dec 1975; \$650 \times \left(\frac{186.6}{132.2}\right) = \$900\)

(e) Total cost of sand filter is then; \$6000 + \$900 = \$6,900.

2.2.5.2 Diatomaceous Earth Filtration.

2.2.5.2.1 Assumptions.

(a) Body feed at constant rate of 29 mg/lit.²⁵

(b) Precoat filter at rate of .1 lb/ft².²⁵

(c) Hydraulic loading of filter area is 4.16 gal/ft²/min.²⁶

(d) Head loss at end of run between 35-100 psi. Backwash at 50 psi.²⁷

2.2.5.2.2 Calculations.

(a) Filter area

\[
Q = 1170 \text{ ft}^3/\text{hr} = 8753 \text{ gal/hr}
\]
\[ L_0 = 4.16 \text{ gal/ft}^2/\text{min (60 min/hr)} = 249.6 \text{ gal/ft}^2/\text{hr} \]
\[ Q/L_0 = A: \frac{8753}{249.6} = 35 \text{ ft}^2 \text{ of filter area.} \]

(b) Cost using Figure 19-108 in Perry's Handbook for a continous vacuum precoat filter is $9,000 for 1968. Cost includes pumping charges.

(c) Updating cost to Dec 1'75 total cost of uninstalled diatomaceous earth filter is $9000 \frac{(186.5)}{113.7} \text{ Dec 1975} = 14,800\text{ 1968}

2.2.6 Polishing.
2.2.6.1 Reverse Osmosis.
2.2.6.1.1 Assumptions.

(a) Membrane life is 6 to 9 months. This membrane life is currently longer than the actual life expectancy of the current model but membrane life can be expected to increase as technology improves. Membrane life will also vary due to the following: construction of membrane, percent influent recovered to brine exhausted, and initial clarity of influent waste.\text{28}

(b) Using a spiral wound RO unit and 90% recovery of pretreated wastewater, the power requirement is 9.8 kw-hr/1000 gal and the flux is 12 gpd/ft² of membrane at 530 psi and 70°F.\text{29}

(c) Membrane cost is between $3 and $8 per sq ft. Cost of equipment is $30/ft² of installed membrane.\text{30}

2.2.6.1.2 Calculations.

(a) Membrane size.

\[ Q/L_0 = A \quad 70,000 \text{ gpd/ft}^2 = 5,833 \text{ ft}^2 \]
(b) Membrane Cost.

\((5.5/\text{ft}^2) \times (5,833 \text{ ft}^2) = \$32,081\) each 6 to 9 months depending on length of membrane life.

(c) Cost of equipment: \((\$30/\text{ft}^2) \times (5,833 \text{ ft}^2) - \$32,081 = \$142,909\).

(d) Total cost: Fixed costs for a reverse osmosis unit is \$143,000 plus an operating cost of \$32,000 each 6 to 9 months for membrane replacement. Economic indicators were not used to update the unit cost since reverse osmosis units are expected to drop in price eventually.

2.2.6.2 Ion Exchange

2.2.6.2.1 Assumptions.

(a) Use two bed system for demineralization with sodium hydroxide and sulfuric acid as regenerates.

(b) Exhaustion and regeneration reactions are as follows*:

\[ H_2R + MgCl_2 \rightarrow \text{Cation Exchange} \rightarrow RMg + 2HCl \]

\[ AOH + HCl \rightarrow \text{Anion Exchange} \rightarrow ACi + H_2O \]

\[ RMg + H_2SO_4 \rightarrow \text{Cation Regeneration} \rightarrow H_2R + MgSO_4 \]

\[ ACi + NaOH \rightarrow \text{Anion Regeneration} \rightarrow AOH + NaCl \]

*R&A are cation and anion exchange resins respectively.

(c) Hydraulic loading per square foot of bed area is between 8 and 12 gallons per minute.
(d) Average bed depth is between 2 to 8 feet.\textsuperscript{32}

(e) Cation has a resin life expectancy of 10 years. Anion resins have a life expectancy between 2 and 8 years.\textsuperscript{33}

(f) Resins are regenerated every 4 hours.\textsuperscript{34}

(g) Cation resin can adsorb 1 to 3 pounds of ions per cubic foot of bed. Anion resin can adsorb 1.5 to 2.5 pounds of ion per cubic foot of bed.\textsuperscript{35}

(h) Between 2 and 5 lbs of \( \text{H}_2\text{SO}_4 \) are required to regenerate each cubic foot of cation resin. Approximately 4 lbs of \( \text{NaOH} \) are required to regenerate each cubic foot of anion resin.\textsuperscript{36}

(i) Rinsing and backwashing of resin beds requires 40 to 60 gallons per cubic foot of bed.\textsuperscript{37}

(j) Chemical regenerate consumption (percent of stoichiometric) is between 120 and 200 percent.\textsuperscript{38}

(k) Resin costs are $20 per cubic foot for cation resin and $60 to $100 per cubic foot for anion resin at 1970 cost.\textsuperscript{39}

(l) The solubility of \( \text{Al(OH)}_3 \) in solution is very low (2.62 \( \times \) 10\textsuperscript{-9} mole/lit at 25\textdegree C). For design purposes \( \text{Al(OH)}_3 \) does not add to salt build-up.

2.2.6.2.2 Calculations.

2.2.6.2.2.1 Surface area of resin bed (tanks are cylindrical).

\[
\frac{Q}{L_0} = A
\]

\[
Q = 70,000 \text{ gpd} = 146 \text{ gal/min}
\]

\[
L_0 = 10 \text{ gal/ft}^2/\text{min}
\]

\[
A = 146/10 = 14.6 \text{ ft}^2 \text{ bed}
\]
2.2.6.2.2.2 Resin Volume.

(a) Cation resin.

1) Cation resin adsorbs 2 lbs ion/ft$^3$ resin/4 hr.

2) From Table 2-3, 26.8 lbs alkalinity as CaCO$_3$/hr is 107.2 lbs of alkalinity as CaCO$_3$ added each four hour period to the wastewater system.

3) Required cation resin is then; (107.2 lbs as CaCO$_3$)/(2 lbs as CaCO$_3$/ft$^3$/resin).

(b) Anion Resin.

1) Anion resin adsorbs 2 lbs ion/ft$^3$ resin.

2) From Table 2-3, 6.6 lbs acidity as CaCO$_3$/hr/4 hr is 26.4 lbs of acidity as CaCO$_3$ added each four hour period to the wastewater system.

3) Powdered activated carbon if added to the system will not increase the ion content. Aluminum sulfate will add the sulfate ion to the wastewater mix. If 1000 mg/lit of aluminum sulfate (Al$_2$(SO$_4$)$_3$ 18 H$_2$O) is used, 250 lbs of SO$_4$ ion will be added each day.

4) Required anion resin when using aluminum sulfate as coagulant is then (151.4 lbs acidity as CaCO$_3$) (2 lbs as CaCO$_3$/ft$^3$ resin) = 76 ft$^3$ of anion resin.

5) Required anion resin using powdered carbon is (26.4/2) = 13 ft$^3$ anion resin.

2.2.6.2.2.3 Tank Volume.

Freeboard is 70% of bed volume.
(a) Cation resin.
1) 1.7 (54 ft³ resin) = 92 ft³ volume.
2) Dimension of tank.
   Height = Volume/Surface area = 92/14.6 = 6.3 (height of tank is then 6.3 ft and diameter is 4.3 ft).
(b) Anion resin.
1) Aluminum sulfate as coagulant.
   Volume = (1.7) (76 ft³) = 129 ft³
   Dimension of tank. ht = 129/14.6 = 8.8 ft and diameter is 4.3 ft
2) Powdered carbon as coagulant.
   Volume = (1.7) (13 ft³) = 22.1 ft³
   Dimension of tank. Let diameter be 3 ft due to small volume.
Height is then 22 ft³/7 ft³ = 3 ft.
2.2.6.2.2.4 Chemical dosage for regeneration.
(a) Cation resin.
1) 3.5 lbs H₂SO₄/ft³ resin are required for regeneration.
2) The pounds of H₂SO₄ required to regenerate cation bed is;
   (3.5) (54) = 189 lbs of H₂SO₄ required for regeneration every four hours.
3) Sulfuric acid is transported at 66% strength in 55 gallon drums.
The amount used in one regeneration cycle is;
(1.842 sp.g.) (62.4 lb/ft³ H₂O) \(\frac{35.31 \text{ ft}^2}{264.2 \text{ gal}}\) = 15.36 lb/gal (189 lbs) (1/15.36 lbs/gal) (1/0.66) = 18.6 gal of stock solution.
(b) Anion Resin

1) 4 lbs NaOH/ft³ resin are required for regeneration.

2) Pounds of NaOH required for regeneration using aluminum sulfate is (4 lbs/ft³) (76 ft³) = 304 lbs of NaOH every four hours for regeneration. Using Powdered Carbon; (4 lbs/ft³) (13 ft³) = 52 lbs of NaOH every four hours for regeneration.

3) Sodium hydroxide is transported at 50% strength in 55 gallon drums. The amount used in one regeneration cycle is then:

\[
\text{Amount} = (2.13 \text{ sp.g.})(62.4 \text{ lbs/ft}^3 \text{ H}_2\text{O}) \times \frac{35.31 \text{ ft}^3}{264.2 \text{ gal}} = 17.76 \text{ lbs/gal}
\]

Using Aluminum Sulfate:

\[
(304 \text{ lbs})(1/17.76 \text{ lbs/gal})(1/.5) = 5.8 \text{ gal of solution}
\]

2.2.6.2.5 Regenerant usage during day.

Assume that the last half of the regenerant volume is saved for next backwash (concentration is 200 percent of theoretical). Daily chemical usage of regenerate chemicals would then be amounts calculated in 2.2.4.2.2.4.

2.2.6.2.6 Water required for backwash and rinse.

(a) Half of regeneration cycle water is supplied from previous wash. If two backwashings are required each day, the daily water requirement is the water used for one regeneration cycle.

(b) Rinse and backwash requires 50 gallons per cubic foot of resin bed.

(c) Cation resin rinse and water requirements are:

\[
(50 \text{ gal/ft}^3)(54 \text{ ft}^3) = 2700 \text{ gal}
\]

(d) Anion resin rinse and water requirements are:

1) Using Aluminum as coagulant: (50 gal/ft³) (76 ft³) = 3000 gal

2) Using Powdered Carbon as coagulant: (50 gal/ft³) (13 ft³) = 650 gal.
2.2.6.2.2.7 Resin bed cost.

(a) Cation resin.
1) Resin cost is $20/ft³ in 1970.
2) Cost using economic indicators for Dec 1975 is:

\[
\left(\frac{\$20/ft^3}{(54 \text{ ft}^3)}\right) \left(\frac{(186.6)}{(125.7)}\right) \text{ Dec 1975} = \frac{1600}{1970}
\]

(b) Anion resin
1) Resin cost is $80/ft³ in 1970.
2) Costs using economic indicators for Dec 1975 is; using aluminum as coagulant:

\[
\left(\frac{\$80/ft^3}{(76 \text{ ft}^3)}\right) \left(\frac{(186.6)}{(125.7)}\right) \text{ Dec 1975} = \frac{9000}{1970}
\]

Using Powdered Carbon as coagulant:

\[
\left(\frac{\$80/ft^3}{(13 \text{ ft}^3)}\right) \left(\frac{(186.6)}{(125.7)}\right) \text{ Dec 75} = \frac{1350}{1970}
\]

= $1,550.

2.2.6.2.2.8 System Cost.

Using table in Reference 1, cost for ion exchanger system is $23,000 in 1972. Cost of ion exchanger system by Dec 1975 is then:

\[
\left(\frac{\$23,000}{(186.6)}\right) \left(\frac{(137.2)}{(125.7)}\right) \text{ Dec 1975} = \frac{31,000}{1972}
\]

2.2.7 Chlorine Disinfection

2.2.7.1 Assumptions.

2.2.7.1.1 Solution feed equipment costs are $500 if cylinder mounted.
If using calcium hypochlorite, cost of equipment is between $100 and $1000 for 1970 costs.

2.2.7.1.2 Free available chlorine required for disinfection is .2 mg/lit at pH of 6 to 8.

2.2.7.1.3 To produce residual of .2 mg/lit, feed chlorine is rate of .5 mg/lit.
Dotted lines indicate backwashing.

FIGURE 2-2.
Water Balance on 70,000 gal/day Wastewater Treatment Facility.
2.2.7.2 Calculations.

2.2.7.2.1 Chlorine bottled gas required: (.0005 gr/lit) (3.785 lit/gal) (lbs/454 gr) = 4.1685 X 10^-6 lbs/lit/gal) 70,000 gal/day (4.1685 X 10^-6 lbs Cl2/gal) = .3 lb chlorine required each day.

2.2.7.2.2 Calcium hypochlorite required: Ca(OCl)2 4 H2O = 215 lb/lb-mole (normal commercial form) For 100% dissociation (.3 lbCl) lb-mole = 

\[
\frac{0.0084 \times \text{lb-mole Cl}, \text{or} (0.00423 \times \text{lb-mole Cl}_2) (215 \text{ lb/lb-mole}) (0.00423 \text{ lb-mole})}{35.45 \text{ lb}} = 9 \text{ lb calcium hypochlorite required each day.}
\]

2.2.7.3 Cost of system.

2.2.7.3.1 Chlorine gas $500 (\frac{186.6}{125.7}) Dec 1975 = $750

2.2.7.3.2 Calcium Hypochlorite $700 (\frac{186.6}{125.7}) Dec 1975 = $1,000

2.2.8 Wastewater and Clear Holding Tanks.

2.2.8.1 Assumptions.

2.2.8.1.1 Total volume of tanks and process equipment should be able to retain the water used during the day over periods when laundry is not in use.

2.2.8.1.2 Wastewater holding tank should be able to retain influent waste during heaviest loading period.

2.2.8.1.3 Wastewater holding tank should be large enough so that the wastewater from different cycles are well mixed. This is required so that influent waste concentrations are constant and temperatures are constant to minimize heat gradients within the clarifier and chemical feed fluctuations.

2.2.8.2 Calculations.

2.2.8.2.1 The average washing cycle including both wash and rinse cycles takes approximately one hour. During an eight hour day no more than eight
washing cycles could be done on each piece of equipment. Taking into
account the amount of time required to load and prepare a cycle, the minimum
number of cycles within a day would be approximately five. Consequently only
1/5 to 1/8 of a day's water supply is being used at any one time. As a
conservative estimate each tank should be able to retain 1/5 of the daily water
supply or 15,000 gal capacity. Detention time in wastewater holding tank
would be about 1.5 hours, long enough to mix the influent wastes.

2.2.8.2.2 Using Means Handbook, cost data for 1975, a precast 15,000 gallon
cement septic tank costs about $4350. Total cost of holding tanks is
then $8,700.

2.2.9 Piping Estimate.

Using a scale drawing, the amount of piping is estimated as follows;
186 feet 6 inch diameter cast iron piping for process flow and 90 feet of
4 inch piping for secondary flows of slurried sludges. Estimated costs
using Means Handbook, for 1975 is $1700 and $480 respectively. Total cost
for piping is then $2,180.

2.2.10 Pumping Estimate.

Volumetric flow is 146 gpm. Assumed pressure head should range between
20 and 100 feet of water. The cost of a cast iron centrifugal in line pump
with motor is between $300 and $600 for comparable pressures using the
Chemical Engineering Deskbook from October 1971. For estimation purposes
the average pump for a laundry wastewater system will cost $400 each. A
total of six major pumps are required for process flow. The cost for 1971
is then 6(400) = $2400. Using Chemical Engineering economic indicators,
price in December 1975 is then: $2400 (209.1) = $3,800.
2.2.11 Building Site.

Floor space for wastewater system is estimated at 60 x 40 feet. Using 1975 Means Handbook, cost for covered area (warehouse/storage building) is $33,000.

2.2.12 Auxiliary Equipment.

Figure 2-7 is a flow diagram of the proposed wastewater treatment facility. Each day 20,000 gallons of the 70,000 gallons entering would be used to slurry away flocculants from the clarifier and the salts from the ion exchanger. Part of the waste effluent leaving the clarifier, about 3500 gallons daily could be recovered using a holding tank with a large detention period or by using a dewatering filter. Neither would be economical to install unless the operating and amortized costs were less than the recovered water and sewage charges. Recovering 3500 gal/day was not considered economically practical in this report. The other effluent waters from backwashing the ion exchangers contain large amounts of ionic salts. These are removable only by more exotic methods of waste recovery and would also not be practical. Special care would be required in monitoring the pH of the backwash water from the ion exchangers.

2.3 Cost Analysis.

2.3.1 Total equipment and installation cost.

Table 2-5 is a compilation of estimated equipment costs from the previous sections.
Table 2-5.
Estimated Costs of Chemicals for Laundry Wastewater Recovery.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Tank</td>
<td>$4,350</td>
</tr>
<tr>
<td>Upflow/Clarifier</td>
<td>38,100</td>
</tr>
<tr>
<td>Sand/Mixed Media Filter</td>
<td>6,900</td>
</tr>
<tr>
<td>Ion Exchange</td>
<td>31,000</td>
</tr>
<tr>
<td>Chlorine disinfection</td>
<td>750</td>
</tr>
<tr>
<td>Holding Tank</td>
<td>4,350</td>
</tr>
<tr>
<td>Piping</td>
<td>2,200</td>
</tr>
<tr>
<td>Pump</td>
<td>3,800</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>$91,450</td>
</tr>
<tr>
<td>Building</td>
<td>33,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$124,450</td>
</tr>
</tbody>
</table>

A private contractor in September 1973 proposed to build at Fort Jackson a 1.44 x 10^5 gpd laundry wastewater reclamation system. The cost in 1973 money for the system was $75,000 for equipment supplied by the contractor and $60,960 for installation by a different firm. Total cost of the system was then $135,960. The following is a listing of the equipment that would have been supplied by the contractor:

1. Engineering drawings
2. Two air operated slow speed mixers
3. Three chemical feed systems
4. Required pumping systems
5. Vacuum filter
6. Two water softeners with regeneration tank
7. Chlorine feed system
8. Control panel
Installation charges were for the following:

1. Building and concrete work
2. Equipment installation
3. Mechanical installation, i.e., piping and bracketing required
4. Electrical wiring and installation
5. Air compressor
6. Receiving, i.e., all items received and unloaded.

The estimated charge by the contractor did not include the cost of two holding tanks. Using Means Cost Data for 1975 the equipment cost and installation cost of two 30,000 gallon cement holding tanks would be approximately $18,000. Using Economic indicators from Chemical Engineering to update the estimate by the contractor gives the following for Dec 1975 prices.

Contractor equipment estimate: \( \frac{75,000 \times (186.6)}{144.1} \) Dec 75 = $97,100.

Contractor installation estimate: \( \frac{$60,960 \times (186.6)}{144.1} \) Dec 75 = $78,900.

Total estimated cost is then $97,100 + $78,900 + $18,000 = $194,000.

Installation costs for the 70,000 gpd treatment facility are determined by using the ratio of contractor estimated installation costs over the total cost estimate.

Installation estimate: \( \frac{(91,450) \times 78,900 + 2,400}{194,000} \) = $38,300.

The additional $2,400 is for installation of the holding tanks. Adding 15% for A&E costs, the total cost for the 70,000 gpd treatment facility would be: 1.15 ($38,300 + $91,450) = $150,000
Figure 2-3 shows total cost of plant versus capacity for a laundry wastewater treatment facility.

![Graph showing total cost of plant versus capacity](image)

**Plant Capacity for Wastewater Treatment (10^3 qpd).**

**Figure 2-3.**

**Estimated Laundry Waste Treatment Plant Cost Versus Plant Capacity**

2.3.2 Chemical Costs.

Table 2-6 is a compilation of estimated chemical costs. Chemicals are of commercial grade and bought in small quantities. Prices are twice the value of literature prices for bulk quantities in 1975 and F.O.B. Prices have been doubled to account for the small quantities bought. Cost of chemicals are tabulated in increments of 1000 gallons of recovered wastewater.
Table 2-6.

Estimated Costs of Chemicals for Laundry Wastewater Recovery.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Form</th>
<th>Cost</th>
<th>Concentration Used</th>
<th>Cost 1000/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Sulfate</td>
<td>100 lb bag</td>
<td>$7.00</td>
<td>$8.3 \times 10^{-3}$ lbs/gal</td>
<td>$.82</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td>55 gal drum</td>
<td>$53.00</td>
<td>34.2 gal/day for Aluminum Sulfate Coagulation</td>
<td>.66</td>
</tr>
<tr>
<td></td>
<td>50% strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>55 gal drum</td>
<td>$50.00</td>
<td>18.6 gal/day</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>60% strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer</td>
<td>Liquid</td>
<td>--</td>
<td>Trace Amount</td>
<td>.03</td>
</tr>
<tr>
<td>Powdered Carbon</td>
<td>100 lb bag or</td>
<td>$10.00</td>
<td>$8.3 \times 10^{-3}$ lbs/gal</td>
<td>1.17</td>
</tr>
<tr>
<td>Activated Charcoal</td>
<td>Cannister</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The total chemical charge using aluminum sulfate as a coagulant to treat 1000 gallons of wastewater is then $1.82. Using powdered carbon as the coagulant the total charge is $1.65 to treat 1000 gallons of wastewater.

2.3.3 Operating Costs.

Operation and maintenance is estimated to be 3% of the initial capital investment or $4,500 per year.

2.3.4 Total Cost.

Table 2-7 is a summary of estimated costs required to install and maintain a 70,000 gpd treatment facility. The yearly cost for equipment and installation was determined using a capital recovery factor, a 25 year plant life with no salvage value, and money at 10 percent.
Table 2-7.
Summary of Costs for 70,000 gpd Wastewater Treatment Facility.

<table>
<thead>
<tr>
<th>Type of Expense</th>
<th>Total Cost</th>
<th>Yearly Cost</th>
<th>Cost/1000 gal*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment &amp; Installation</td>
<td>$150,000</td>
<td>$16,500</td>
<td>$1.27</td>
</tr>
<tr>
<td>Chemical cost using Aluminum Sulfate for Coagulation</td>
<td>--</td>
<td>$23,700</td>
<td>$1.82</td>
</tr>
<tr>
<td>Chemical cost using Powdered Carbon as Coagulation</td>
<td>--</td>
<td>$21,500</td>
<td>$1.65</td>
</tr>
<tr>
<td>Operation &amp; Maintenance</td>
<td>--</td>
<td>$ 4,500</td>
<td>$ 0.35</td>
</tr>
</tbody>
</table>

*Cost 1000 gal is determined from water that is recycled or 50,000 gal/day.

Using the lowest chemical charge, powdered carbon, the annual expense of maintaining a treatment facility recycling 50,000 gpd of laundry wastewater would be $42,500.

The breakeven point for water and sewage charges would then be $3.21 per 1000 gallons of treated wastewater.

By a similar procedure the breakeven point for the plant size recommended by the contractor is $2.66 per 1000 gallons of treated wastewater.

Figure 2-4 is the estimated breakeven line for water and sewage charges versus daily plant capacity.

![Figure 2-4. Breakeven Line for Plant Capacity Versus Water and Sewage Charge.](image-url)
3.0 DISCUSSION.

3.1 Comparison.

The break-even point for a 70,000 gpd laundry treatment facility is $3.27/1000 gal of treated wastewater. Comparing this value against the purchased water and sewage treatment rates in Table 2-2, for the 17 largest installations by population there is no CONUS installation that warrants the use of laundry water recycle. Ft. Bragg's purchased water and sewage treatment is the nearest to the estimated break-even point at $1.60/1000 gal. Increasing plant capacity and laundry water consumption rates will decrease the cost of wastewater treatment lowering the break-even point. Using the Ft. Bragg laundry and $1.60/1000 gal as a break-even point for example, approximately 270,000 gpd of laundry wastewater would have to be recycled at the laundry to attain the break-even costs of $1.60/1000 gal. A flowrate of this magnitude amounts to four percent of Ft. Bragg's total yearly water consumption. Four percent of the yearly water consumed is much higher than what would be expected to be consumed at the Ft. Bragg laundry. About one percent or a 78,100 gpd wastewater flow had been previously estimated. Comparison of the two values would indicate that the Ft. Bragg laundry does not use the amounts of water required to be economical using the process flow described within this report. Comparing the costs and estimated wastewater flows of other installations in Table 2-2, indicates that no other installation currently has the required wastewater flow rate or purchased water and sewage rates to make the installation of a laundry wastewater recycling process economical.

A possible method of lowering the break-even value of the laundry wastewater treatment facility would be not to use the ion exchanger and
recycle only a portion of the flocculated wastewater to keep the ionic salt build-up below an acceptable limit. Figure 3-1 is a representation of the flow diagram. Using the same sized equipment and estimating procedures for a 70,000 gpd, the total installed cost would be $98,000. Letting $X$ be the amount of wastewater to be recycled per year, $1.17/1000$ gal the chemical and operating cost, $1.60/1000$ gal the purchased water and sewage charge, and $10,000$ the yearly fixed cost, the amount of water required to be recycled to break-even would be as follows:

\[
\text{Total Cost} = \text{Total Profit} \\
$10,800 + (1.17/1000 \text{ gal})(X) = (1.60/1000 \text{ gal})(X)
\]
Solving for $X$, 25,000 kgal/yr of wastewater would have to be recycled. Ft. Bragg to break-even would have to recycle at a rate of 125%. Any recycle rate above 100% is physically impossible. Consequently, this method is also not economically feasible. Even if the fixed cost were $5,000 annually, representing a installed plant cost of $45,000, the break-even recycle rate is 58% and this value intuitively is still too high.

Laundry wastewater recycling for economic reasons currently does not appear to be feasible. As seen in the previous discussion the process flows are not large enough, purchased water and sewage rates are not high enough, and equipment and installation costs are too high. It is not reasonable to expect these parameters to change rapidly. Laundry wastewater recycle at the installation quartermaster laundries will remain economically infeasible until conditions and water costs increase. Future efforts should consider the economics of recovery of the chemical treatment materials as this is a major cost item. If the activated carbon could be recovered and reused, substantial cost savings would occur.

4.0 CONCLUSION.

4.1 Conclusion.

Laundry wastewater recycling at CONUS installation quartermaster laundries is currently uneconomical to perform. There is no indication that present circumstances will change dramatically enough in the near future to warrant future study into recycling processes for installation quartermaster laundries.
Bibliography

FOOTNOTES

2. Ibid, pg. 789.
3. Ibid, pg. 789.
4. Ibid, pg. 790.
10. Ibid.
13. Ibid, note #11, pg. 1215.
16. Ibid.
17. Ibid, note #11, pg. 764.
18. Ibid, note #11, pg. 1510.
22. Ibid, pg. 40.
23. Ibid, note #11.
24. Ibid, note #6, pg. 4.
25. Ibid, note #6, pg. 4.
26. Ibid, note #6, pg. 4.
27. Ibid, note #19, pg. 46.
29. Ibid.
30. Ibid, note #11, pg. 1255.
31. Ibid, note #11, pg. 1243.
32. Ibid, note #11, pg. 1243.
33. Ibid, note #11, pg. 1243.
34. Ibid, note #11, pg. 1243.
35. Ibid, note #11, pg. 1243.
36. Ibid, note #11, pg. 1243.
37. Ibid, note #11, pg. 1243.
38. Ibid, note #11, pg. 1243.
40. Ibid, note #11, pg. 960.
41. Ibid, note #11, pg. 959.
42. Ibid, note #11, pg. 959.
43. Building Construction Cost Data, Massachusetts; Means, 1974, pg. 32.
44. Ibid, pg. 182.
45. Ibid, pg. 220.
47. Ibid, note #43, pg. 32.