Out-of-the-Box Approach to Sustainable Water Reclamation

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AGENDA

• OBJECTIVE
• SCOPE OF WORK
• RESULTS
• LESSONS LEARNED
• CONCLUSIONS
Water Production and Consumption

1. FIND SOURCE
2. PURIFY
3. DELIVER
4. CONSUME
5. WASTE WATER

Process flow is one-way
Force Provider Module (Case Study)

Remote ROWPU

33% EFFICIENT

Chlorine Minerals

Raw Water

Potable H₂O

Brine

Transport

22,625 gpd potable water required

Treatment/Disposal Site

20,155 gpd waste water produced

Laundry 5200 gpd
Kitchen 1925 gpd
Latrine 2700 gpd
Drinking 1800 gpd
Shower/Shave 11,000 gpd

NDIA E2S2, New Orleans, LA, May 9-12, 2011
Force Provider Module (Reclamation)

Raw Water

Remote ROWPU

Transport

EWRS

2,470 gpd water required

99% EFFICIENT

Laundry 5200 gpd

Kitchen 1925 gpd

Latrine 2700 gpd

Drinking 1800 gpd

Shower/Shave 11,000 gpd

20,155 gpd reclaimed

Treatment/Disposal Site
Objective

- Develop a method for reclaiming clean water from waste water in inhospitable environments like those faced by military forces and disaster relief agencies.
- Method should reduce or eliminate the logistics support requirement that is typical of the traditional coagulation, filtration and disinfection processes.

Out-of-the-Box Approach -
Use the change in the properties of water that occur when it is exposed to a high pressure and high temperature environment to (1) precipitate inorganic material and (2) oxidize organic material.
SCOPE OF WORK
Scope of Work

- Build 15 gph proof-of-concept unit
- Convert greywater to potable water.
- Evaluate concept of operation and key components.
- Pay special attention to energy recovery and personnel safety.
- Run experiments to identify “best” temperature, pressure, and residence time.
- Measure performance against TB MED 577 water quality standards.
**Water Quality Standard**

**TB MED 577, Sanitary Control and Surveillance of Field Water Supplies, Dec 2005.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TB MED 577 [15 L/day]</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5 - 9</td>
<td>-</td>
</tr>
<tr>
<td>Turbidity</td>
<td>1</td>
<td>NTU</td>
</tr>
<tr>
<td>Total dissolved solids (TDS)</td>
<td>1000</td>
<td>mg/L</td>
</tr>
<tr>
<td>Color</td>
<td>50</td>
<td>TCU</td>
</tr>
<tr>
<td>Odor</td>
<td>3</td>
<td>TON</td>
</tr>
<tr>
<td>Coliform</td>
<td>0</td>
<td>CFU/100 mL</td>
</tr>
<tr>
<td>Chloride</td>
<td>600</td>
<td>mg/L</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.1</td>
<td>mg/L</td>
</tr>
<tr>
<td>Cyanide</td>
<td>2</td>
<td>mg/L</td>
</tr>
<tr>
<td>Lindane</td>
<td>0.2</td>
<td>mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>30</td>
<td>mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>100</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Development and Evaluation

• Two prototype units were built
  – 1 for process evaluation, 1 for process automation
• Wastewater processed
  – Sewer water (Ft. Eustis, VA)
  – “RO test” water
  – “Protein” water
• Operating points
  – 3800 - 4200psig, 390 - 435°C
• Water processing rate
  – 3 and 6gph
Prototype Unit

FRONT VIEW

REAR VIEW

LEFT SIDE VIEW

RIGHT SIDE VIEW
• Water quality in terms of TDS, TSS, pH, turbidity and coliforms is very good.
• Significant decrease in inorganic material.
• Precipitated material is mostly calcium and iron, but also phosphorus, sulfur, silicon and magnesium.
• Key electrolytes are retained, sodium and potassium.
• Laxatives are reduced, sulfate and magnesium.
• Low pH, may be due to entrained CO$_2$.
• No coliforms present in the product water.
• “High” TOC, likely due to carbonic and acetic acid.
Water – Before and After

Water quality is significantly improved.

Sewer Water  \rightarrow  Processed Water
pH, turbidity and TDS of product water meet TB MED 577 guidelines.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw</th>
<th>Processed</th>
<th>Raw</th>
<th>Processed</th>
<th>Raw</th>
<th>Processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB MED 577</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>5 - 9</td>
<td>5.22</td>
<td>6.14</td>
<td>6.23</td>
<td>5.25</td>
<td>5.46</td>
</tr>
<tr>
<td>Turbidity [NTU]</td>
<td>≤1</td>
<td>100</td>
<td>0.55</td>
<td>0.60</td>
<td>1.00</td>
<td>0.90</td>
</tr>
<tr>
<td>TDS [mg/L]</td>
<td>≤1000</td>
<td>658</td>
<td>146</td>
<td>194</td>
<td>138</td>
<td>134</td>
</tr>
<tr>
<td>TSS [mg/L]</td>
<td>n/a</td>
<td>56</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>VSS [mg/L]</td>
<td>n/a</td>
<td>54</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>TOC [mg/L]</td>
<td>n/a</td>
<td>413</td>
<td>141</td>
<td>169</td>
<td>261</td>
<td>233</td>
</tr>
</tbody>
</table>

NDIA E2S2, New Orleans, LA, May 9-12, 2011
Inorganic materials are precipitated.

Element | Weight %
---|---
Magnesium | 2.46
Silicon | 3.07
Nickel | 4.30
Sulfur | 4.66
Phosphorus | 7.09
Iron | 24.26
Calcium | 54.16
Total | 100.00
Important electrolytes are retained.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Raw Water</th>
<th>Processed</th>
<th>Processed</th>
<th>Processed</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>94.70</td>
<td>1.87</td>
<td>1.70</td>
<td>1.29</td>
<td>mg/L</td>
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<tr>
<td>Sodium</td>
<td>46.37</td>
<td>51.84</td>
<td>45.90</td>
<td>46.41</td>
<td>mg/L</td>
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<tr>
<td>Iron</td>
<td>25.37</td>
<td>0.11</td>
<td>0.05</td>
<td>0.05</td>
<td>mg/L</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>16.70</td>
<td>0.40</td>
<td>0.20</td>
<td>0.20</td>
<td>mg/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>12.57</td>
<td>11.94</td>
<td>12.34</td>
<td>12.36</td>
<td>mg/L</td>
</tr>
<tr>
<td>Sulfur</td>
<td>9.80</td>
<td>0.90</td>
<td>0.40</td>
<td>0.50</td>
<td>mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>9.80</td>
<td>0.25</td>
<td>0.11</td>
<td>0.12</td>
<td>mg/L</td>
</tr>
<tr>
<td>Silicon</td>
<td>9.58</td>
<td>0.37</td>
<td>0.27</td>
<td>0.18</td>
<td>mg/L</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.54</td>
<td>0.05</td>
<td>0.06</td>
<td>ND</td>
<td>mg/L</td>
</tr>
<tr>
<td>Boron</td>
<td>0.43</td>
<td>0.51</td>
<td>0.40</td>
<td>0.38</td>
<td>mg/L</td>
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<tr>
<td>Strontium</td>
<td>0.34</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>mg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.22</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>mg/L</td>
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<tr>
<td>Manganese</td>
<td>0.19</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>mg/L</td>
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<tr>
<td>Barium</td>
<td>0.13</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>mg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>0.11</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>mg/L</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>ND</td>
<td>0.08</td>
<td>0.06</td>
<td>0.08</td>
<td>mg/L</td>
</tr>
<tr>
<td>Chromium</td>
<td>ND</td>
<td>0.23</td>
<td>0.2</td>
<td>0.2</td>
<td>mg/L</td>
</tr>
<tr>
<td>Nickel</td>
<td>ND</td>
<td>0.09</td>
<td>ND</td>
<td>0.08</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

Sodium and potassium levels are basically unchanged

Some metals are being leached from the reactor
LESSONS LEARNED
• Added a radiator to further cool product water, to protect water quality sensors.
• Reoriented the heat exchangers, to eliminate collection of precipitated material.
• Added interlocks for pumps, heaters and compressor, to enhance personnel safety.
• Placing the equipment inside a “cage” makes maintenance and modification difficult.
Process Evaluation

• The chemical composition of the feedwater needs to be a controlled variable.
  – Source and time variability affect results.

• The composition of simulated waste water must be realistic.
  – Need to go beyond simple matching of parameters like TDS, TSS and BOD.
  – Recipe that was good for an RO process proved to be corrosive for our process.
Business Development

• Difficult to “sell” a new process
  – Decision makers are comfortable with the traditional approach of coagulation, filtration and disinfection (low risk).
  – Purchase decisions are based on acquisition costs and not on life-cycle costs.
Equipment Failures

HASTELLOY WELD PINHOLE

HEAT EXCHANGER FAILURE DUE TO CONTAINMENT OF CORROSIVE SOLUTION
Equipment Failures

RUPTURE DISK CORRODED AROUND PERIPHERY

SAFETY HEAD PLUGGED BY CORRODED RUPTURE DISK
Equipment Failures

EXPANSION DRUM
BEFORE

FROM O-RING TO PLUG

LINE IN  LID

VENT

LINE IN

EXPANSION DRUM
AFTER

NDIA E2S2, New Orleans, LA, May 9-12, 2011
PISTON SEAL DAMAGE AS A RESULT OF THE GREYWATER
Conclusions

• Performance of water reclamation approach looks very promising.
• Absence of chemicals and filtration media makes it an excellent candidate for sustainable approach to water reclamation.
• Additional RDT&E work is needed to solidify design and operation.
Thank you!