Abstract for Cleanser, Detergent, Personal Care Product Pretreatment Evaluation

The purpose of the Cleanser, Detergent, Personal Care Product, and Pretreatment Evaluation & Selection task is to identify the optimal combination of personal hygiene products, crew activities, and pretreatment strategies to provide the crew with sustainable life support practices and a comfortable habitat. Minimal energy, mass, and crew time inputs are desired to recycle wastewater during long duration missions. This document will provide a brief background on the work this past year supporting the ELS Distillation Comparison Test, issues regarding use of the hygiene products originally chosen for the test, methods and results used to select alternative products, and lessons learned from testing.

Cleanser, Detergent, Personal Care Product, and Pretreatment Evaluation

Niklas Adam[1]
NASA Johnson Space Center, Houston, Texas,, 77058

Chris Carrier[2]
ESCG - Barrios Technology, Houston, Texas, 77058

Leticia Vega[3] and Michael Casteel[4]
ESCG - Jacobs Technology, Houston, Texas, 77058

Chuck Verostko[5]
Wyle Life Science and Technology, Houston, Texas, 77058

and

Karen Pickering, Ph.D.[6]
NASA Johnson Space Center, Houston, Texas, 77058

The purpose of this evaluation is to identify the optimal combination of personal hygiene products, crew activities, and pretreatment strategies to provide a crew with sustainable life support practices and a comfortable habitat. Minimal energy, mass, and crew time inputs are desired to recycle wastewater during long-duration missions. This article will provide a brief background on the work this past year supporting the Exploration Life Support Distillation Comparison Test, issues regarding use of hygiene products originally chosen for the test, methods and results used to select alternative products, and lessons learned from testing.

I. Introduction

FOR long-duration lunar missions it will be necessary to recycle water from wastewater for human consumption and activities. Personal care products, whether cleansers, toothpastes, shaving products, or skin conditioners, will likely end up in the wastewater on a lunar base. Since it is imperative to recover water from wastewater, it is important to determine how the numerous compounds in the personal care product formulations, when combined, will affect a water recovery system. This is especially critical as water is removed from wastewater and the components are concentrated, increasing the likelihood of solids formation. In 2009, engineers performing rotary evaporator testing of wastewater at the Marshall Space Flight Center (MSFC) in support of the Exploration Life Support (ELS) Distillation Comparison Test discovered one of the wastewaters to be tested had noticeable solids and flocculates, which would hinder processing in a distillation-based water recovery system. To determine the likely cause of this phenomenon, additional tests were carried out at Johnson Space Center (JSC). These tests consisted of three parts: bench-top compatibility of unused products, rotary evaporator testing to distill used products, and stability testing of wastewater solutions.

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[1] Physical Scientist, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop EC311.
[2] Scientist, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop JE77.
[3] Project Engineer, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop JE77.
[4] Project Manager, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop JE77.
[5] Scientist, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop JE77
[6] Water Element Lead, 2101 NASA Parkway, Houston, Texas, 77058, Mail Stop EC311

II. Objective

The primary goal of this project is to develop a suite of personal hygiene, detergent, and cleaning products for lunar surface systems applications. The effort required to specify products can be categorized as follows:

- Requirements development
- Product survey
- User evaluations
- Physical evaluations
- Integrated waste stream evaluations
- Final product selections

This report summarizes the accomplishments to achieve these goals in fiscal year 2009 (FY09) as the project will continue into the next fiscal year. Not all of these subcategories were covered in this year of testing.

During this reporting period, the test team at JSC provided alternatives to the baseline personal care products used during the distillation comparison test. Replacement products were chosen from a list of alternatives generated by the test team in consultation with engineers at MSFC and JSC. Shelf life, reduction of solids formation, and reduction of foaming were all characteristics considered when potential replacement products were evaluated. Once the potential products were selected, the chemical and microbial stability of the used products in combined wastewater solutions were tested. This testing was performed to determine which products produced the least amount of solids and the changes in wastewater composition if the wastewater is stored for a period of time.

III. Methodology

A. Test 1: Preliminary Bench-top Testing of Candidate Personal Care Products in a Combined Waste Stream

MSFC personnel made several observations when a combined waste stream, containing urine, humidity condensate, and hygiene wastewater, was dewatered using a rotary evaporator. After several replicates, it was apparent solids formed in recoveries, defined as the amount of water removed from the initial wastewater volume, as low as 40%. Since the targeted recovery rate during the distillation comparison test was at least 90%, it was assumed these solids could cause problems in the water recovery systems. JSC was tasked with determining when these solids formed and with which products or combination of products. Once the components of the waste stream that would cause significant difficulties were identified, alternative products, techniques, or strategies could be investigated to mitigate these difficulties.

The waste stream formulation tested is outlined in the ELS Distillation Comparison Test Plan.[1] This test plan was designed to consolidate test parameters among several competing wastewater reclamation distillation systems so the performance of each system could be compared. In the test plan, two waste streams are described. Solution 1 consists of pretreated urine and humidity condensate. Pretreatment consists of an aliquot of sulfuric acid to lower the pH of the solution to 2 and an amount of oxone, an oxidizer, to oxidize organics that may crystallize or precipitate at that pH. Humidity condensate is the water condensed as a result of human metabolic processes and volatile compounds produced by instruments in a closed cabin atmosphere. Evaporated sweat, respiration water, and other easily condensable metabolic fluids comprise humidity condensate. Solution 1 was designed to determine the ability of a distillation system to reclaim the water from a basic wastewater load. For Solution 2, hygiene water is added to pretreated urine and humidity condensate per Table 1 formulation. Hygiene water is a solution comprised of shower, hand wash, tooth-brushing, and shaving wastewaters together with the accompanying rinse water and the pretreatment chemicals of oxone and sulfuric acid. This wastewater was considered more complex due to the organic load and formulation of personal hygiene products. MSFC personnel made the discovery of solids formation during rotary evaporation while testing Solution 2.

Solution 2 has four components of hygiene wastewater: shower, hand wash, toothbrush, and shave wastes. The products originally chosen for the Distillation Comparison Test were No-Rinse® Body Wash as the personal cleanser for showers and hand washes, Crest® Cavity Protection Regular Paste as the toothpaste, and Edge® Gel – Sensitive Skin as the shaving product. These products were selected because they are currently manifested on the International Space Station (ISS) for use by the crew. The percent contribution of each hygiene event in the total wastewater load is shown in Table 1.[1]

Table 1. Solution 2 Combined Waste Stream.

Waste Stream Component	kg/event	events/CM-d	kg/CM-d	kg/crew-d	% by volume
Pretreated Urine	N/A	N/A	1.5	6	14.0%
Humidity Condensate	N/A	N/A	1.95	7.8	18.2%
Hygiene	N/A	N/A	7.24	28.95	67.8%
Oral	0.1	2	0.2	0.8	1.9%
Hand Wash	0.125	8	1	4	9.4%
Shower	6	1	6	24	56.1%
Shave	0.15	1/4	0.038	0.15	0.4%
Total			**10.69**	**42.75**	**100**

To quickly determine the problematic components of hygiene wastewater, a survey of the hygiene wastewater components at various concentrations, with and without the pretreatment chemicals oxone and sulfuric acid, was devised at JSC. Each hygiene product (No-Rinse® Body Wash, Crest® Cavity Protection Regular Paste toothpaste, and Edge® Gel – Sensitive Skin) was tested alone, with one other hygiene product, and with both products, with and without pretreatment.

The amounts of the products were scaled into 1 L of wastewater for testing. The amount of each product used per liter of wastewater is shown in Table 2. Reduced volumes of water were used with the same amounts of hygiene products to simulate distillation and determine at what point solids formation occurred. Simulated water recoveries tested were 0%, 30%, 50%, 70%, and 90%. Humidity condensate wastewater and pretreated urine were simulated with deionized water in this survey, as testing was to determine the solids formation components of the hygiene water. When pretreatment chemicals were required with any of the tests, pretreatment was added at concentration of 1.0 g of oxone and 0.22 g of sulfuric per liter of hygiene water, 5.0 g of oxone and 2.3 g of sulfuric acid per liter of urine, and 0.5 g of oxone and 0.11 g of sulfuric acid per liter of humidity condensate.

Table 2. Mass of Each Hygiene Product for 1 Liter of Wastewater.

Hygiene event	Product	Number of events per crewmember-day	Mass of product used per hygiene event (g)	Mass of product per crewmember-day (g)	Mass of product per liter of wastewater (g)
Hand washing	No-Rinse® Body Wash	8	1.5	12	1.12
Showering	No-Rinse® Body Wash	1	25	25	2.34
Tooth-brushing	Crest® Cavity Protection Regular Paste	2	1	2	0.19
Shaving	Edge® Gel – Sensitive Skin	1	0.8	0.8	0.07

B. Test 2: Rotary Evaporator Testing of Used Personal Care Products in a Combined Waste Stream

Rotary evaporation was used to test Solution 2 to compare with MFSC tests and investigate further precipitate formation in more detail. The rotary evaporator is a laboratory instrument that uses moderate heat, a vacuum, and a cooling loop to rapidly distill liquids. The vacuum on the system makes it possible to boil the desired solution at a

lower temperature, causing the system to be safer, more time-efficient, and more energy-efficient. An evaporating flask filled with solution to be distilled is lowered into a warm water bath of about 60°C (140°F). The flask rotates, allowing a thin layer of solution to coat the flask's surface all the way around. This provides additional surface area for evaporation. A vacuum of 72 mbar is pulled on the entire system when distilling water from a solution. As the water evaporates from the solution, water vapor flows through a vapor duct into the condensing chamber. An enclosed cold water loop flows through the condensing chamber. The hot water vapor comes in contact with the cool glass surface of the cold water loop, which is kept at 20°C (68°F) by a chiller, and condenses. As the condensed water vapor collects, it drips down into the distillation flask. Temperatures and pressures can be adjusted on the rotary evaporator, but those described above are the temperatures and pressures that were used with this testing. The equipment used for this test is a Buchi Rotavapor® 215. Figure 1 shows the system without the vacuum pump or water chiller.

Figure 1. Buchi Rotavapor® 215 (not pictured: vacuum pump and chiller).[3]

1) Toothpaste Testing

Since toothpastes containing hydrated silica and titanium dioxide are insoluble materials, a study was designed to test alternative toothpastes without those ingredients listed on their packaging. The solution was formulated as in Table 1, with deionized water taking the place of humidity condensate and pretreated urine being used in every test. Shaving products were also removed from the formulation, as those products that contained insoluble ingredients that also produced solids.

Seven alternative toothpastes were tested as human-used products incorporated into the Solution 2 waste stream with the use of the rotary evaporator. The rotary evaporator operating conditions of testing were described above. The solution was distilled to 90% water recovery, with interruptions at 30%, 50%, 75%, and 90% to take wet chemical measurements and observe solids formation. The wet chemical analyses were pH, conductivity, turbidity, and physical observations. Measurements of feed, brine, and distillate were taken at each interruption. At 90%, an additional test, which measured suspended solids, was performed to obtain the quantity of solids present in the Solution 2 brine.

The seven alternative toothpastes tested were: Arm and Hammer Dental Care®, Orajel® Toddler Training Toothpaste, Tom's of Maine® Natural Toothpaste, Desert Essence® Tea Tree Oil Toothpaste, Thursday Plantation® Tea Tree Oil Toothpaste, and Desert Essence Sea Toothpaste. These toothpastes were determined to be free of any known solids in their formulation.[2] In a later test, a tooth-brushing event performed only with water was also incorporated into testing for suspended solids.

2) Shaving product testing

In the bench-top testing, the Edge® Gel – Sensitive Skin shaving gel formed some solids at the higher recovery concentrations. To eliminate known solids-forming products, alternative shave products were also tested. Shaving product testing, which was similar to the toothpaste testing previously described, was performed with pretreated urine in a simulated Solution 2 formulation to 90% water recovery, again with deionized water taking the place of humidity condensate. The formulation was prepared at the same concentrations as documented in Table 1. Testing did not include toothpaste in the formulation since toothpaste was known to form solids. Wet chemical analyses, which were also similar to the toothpaste testing, were performed at 0%, 30%, 50%, 75%, and 90% water recoveries. These analyses were pH, conductivity, turbidity, and physical observations. At 90%, a suspended solids measurement was performed to measure the solids content in the brine.

Alternative shaving products selected for testing were Barbasol® Original Shaving Cream, Kiss My Face® Shaving Cream, Neutrogena® Shaving Cream, Shave Secret™ Shaving Oil, HydroGlide Waterless Shaving Solution, and Van der Hagen Glycerin Shaving Soap. These were selected because they comprised the various types of commercially available products for shaving. Barbasol® is a shaving foam product; the Kiss My Face® and Neutrogena® products are unpressurized and non-foaming shave creams; the Shave Secret™ is a shaving oil; the Van der Hagen product is a shaving soap, the HydroGlide is a waterless shaving solution; and the Edge®, which was the baseline product, is a shaving gel.

C. Test 3: Stability Studies of Hygiene Water and Solution 2

To understand the stability of the used personal care products employed in hygiene water and Solution 2, several tests were performed. Formulations of the wastewaters are shown in Table 2. These tests were performed to obtain information on the chemical and microbial breakdown of the wastewater streams as well as to observe the effect of pretreatment chemicals on the waste streams. This testing was performed with hygiene water independently and the Solution 2 combined wastewater stream as mentioned. Each test was performed with and without pretreatment chemicals to understand the effect of these chemicals on the stability of solutions. The only exception to this formulation was that urine was always pretreated in the Solution 2 formulation. The reasoning for this is that urine is pretreated during the distillation comparison test to prevent urea degradation into ammonia. This testing was performed in triplicate at each sample point. Samples were taken at day 0, 1, 9, 15, 23, and 28 for the hygiene water study. For the Solution 2 testing, solutions were taken at the 0-, 1-, 14-, 21-, and 28-day points. Hygiene solutions for both the hygiene test alone and the hygiene portion of the Solution 2 test were collected from the Waste Water Collection and Transportation System (WWCTS). The WWCTS is a shower and hand-washing facility integrated into a bathroom. Desired personal cleansing processes are performed by volunteers, and the waste water is collected into a tank. From the waste water collection tank, the batch was split into pretreated and untreated portions. These portions were then divided into autoclaved sample containers for storage. The containers were stored in an incubator that maintained a temperature of 20°C (68°F) ± 5°C (41°F) prior to chemical analysis. When the samples were to be analyzed, sample containers were removed from the incubator and divided into containers for each analysis. Analyses performed on these samples were pH, conductivity, ion chromatography, total organic carbon (TOC), total inorganic carbon (TIC), total nitrogen (TN), turbidity, and heterotrophic plate count (HPC).

IV. Results

A. Test 1: Preliminary Bench-top Testing of Candidate Personal Care Products in a Combined Waste Stream

This test was performed to determine the causes of solids formation from the ingredients selected for the baseline of the distillation comparison test. The test was executed so that substances in the combined waste stream would reveal the ingredient or combination of ingredients that caused the solids formation observed in MSFC testing. Each product was tested individually and combined with one or both of the other two hygiene products. From visual results, as single components, toothpaste was the major contributor of solids in the waste stream, especially as less water was added, simulating distillation. Shave gel also formed a solid, but not as rapidly or as much as the toothpaste. The soap did not form a solid even when in a concentrated solution. When two components were combined, the toothpaste and all other combinations produced a solid, while the remaining combinations did not. The combination of all three components produced a fine, rapidly settling solid that increased in size when pretreatment was added. The results are shown in the photographs in Fig. 2. In each picture, the leftmost vial is at the concentration that would be in the initial Solution 2 waste stream, 0% water removal. The next vials are 30%, 50%, 70%, and 90%, from left to right respectively. The bottom rightmost picture, which shows the pretreatment, shows the toothpaste without pretreatment has little effect on the solid formation of the toothpaste.

On closer review of the toothpaste components, two insoluble chemicals were found in Crest® Cavity Protection Regular Paste: silica dioxide (hydrated silica) and titanium dioxide. These two components were causing the solids in the combined waste stream. The Edge® Gel – Sensitive Skin also had solid formation with the addition of pretreatment chemical as the water was removed from the mixture.

Figures 3 through 8 show the effect of water removal on the pH and conductivity of the solutions with single components, two components, and all three components.

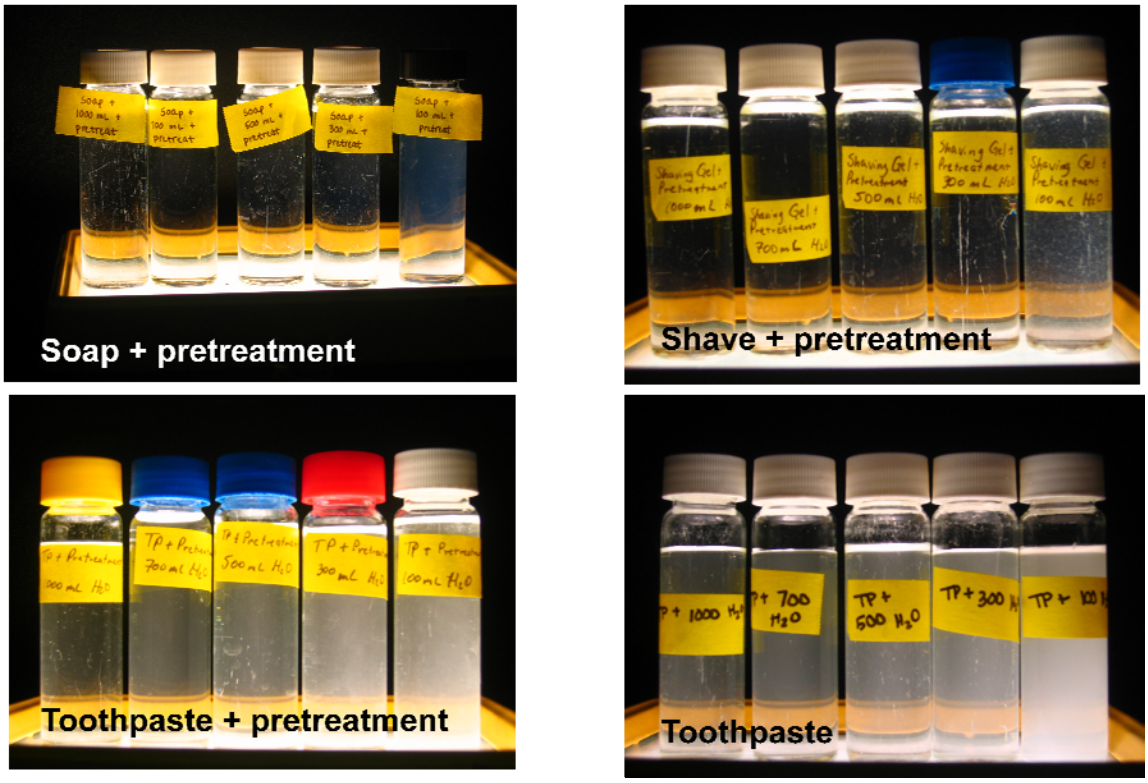

Figure 2. Photographs of bench-top testing of individual personal care products. The leftmost vial is at the concentration that would be in the initial Solution 2 waste stream, 0% water removal. The next vials are 30%, 50%, 70%, and 90%, from left to right respectively.

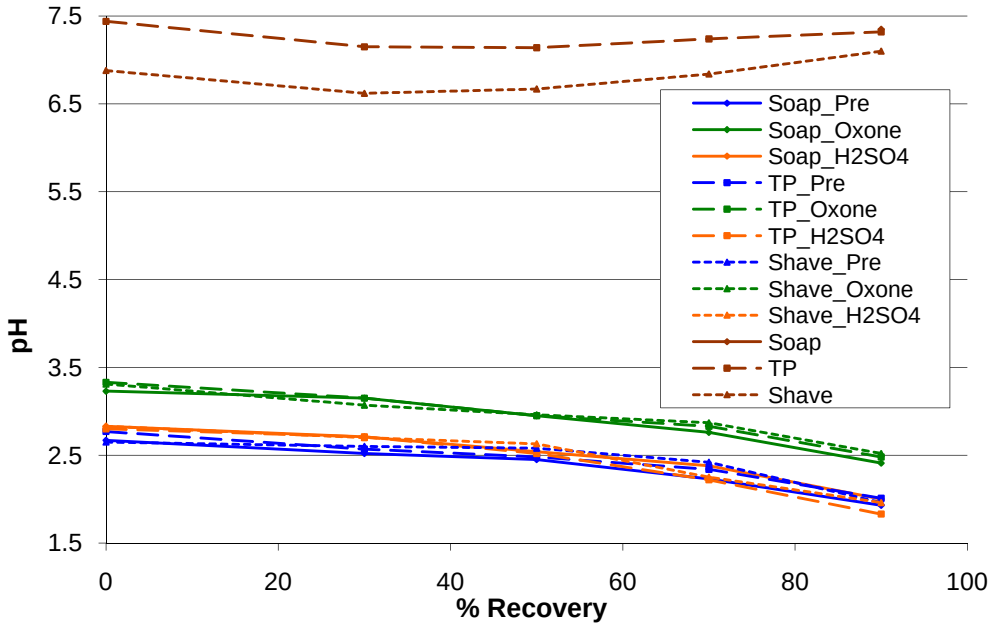

Figure 3. Bench-top pH results for a single product in a simulated distilled solution. "Pre" represents samples that contain oxone and sulfuric acid, "oxone" and "H2SO4" represent samples containing oxone or sulfuric acid only. "TP" represents toothpaste.

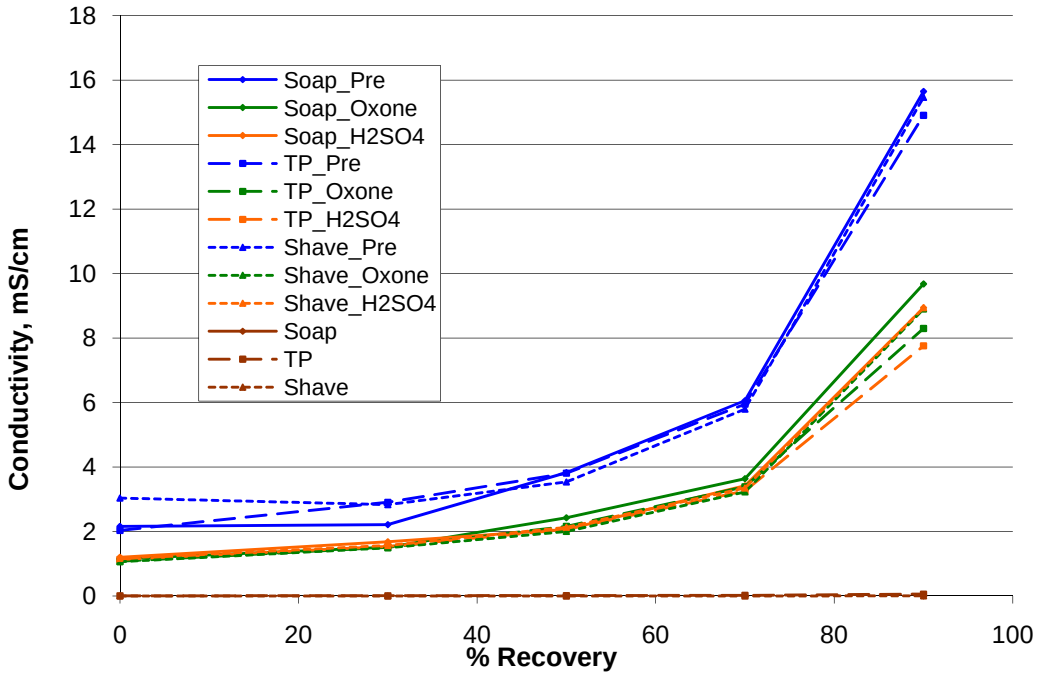

Figure 4. Bench-top conductivity results for a single product in a simulated distilled solution.

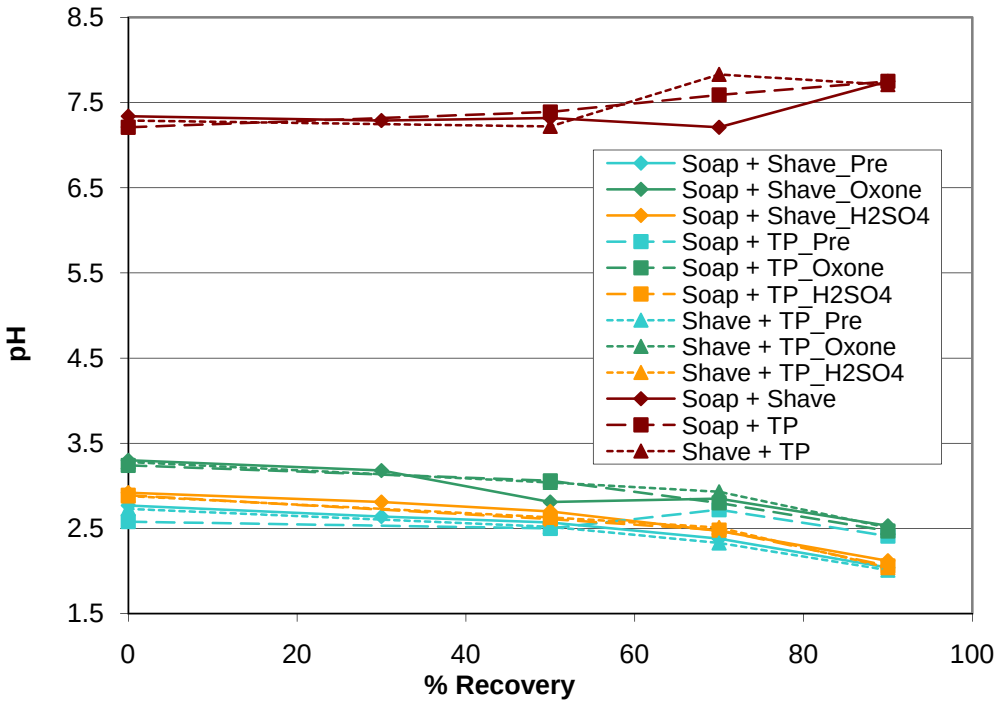

Figure 5. Bench-top pH results for two products in a simulated distillation solution.

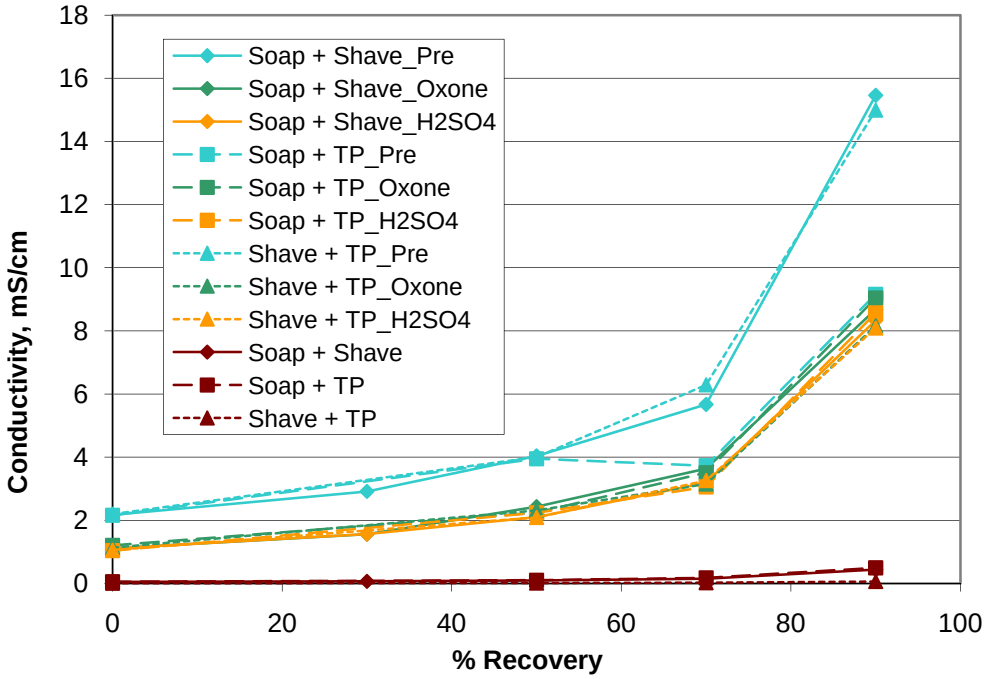

Figure 6. Bench-top conductivity results for two products in a simulated distillation solution.

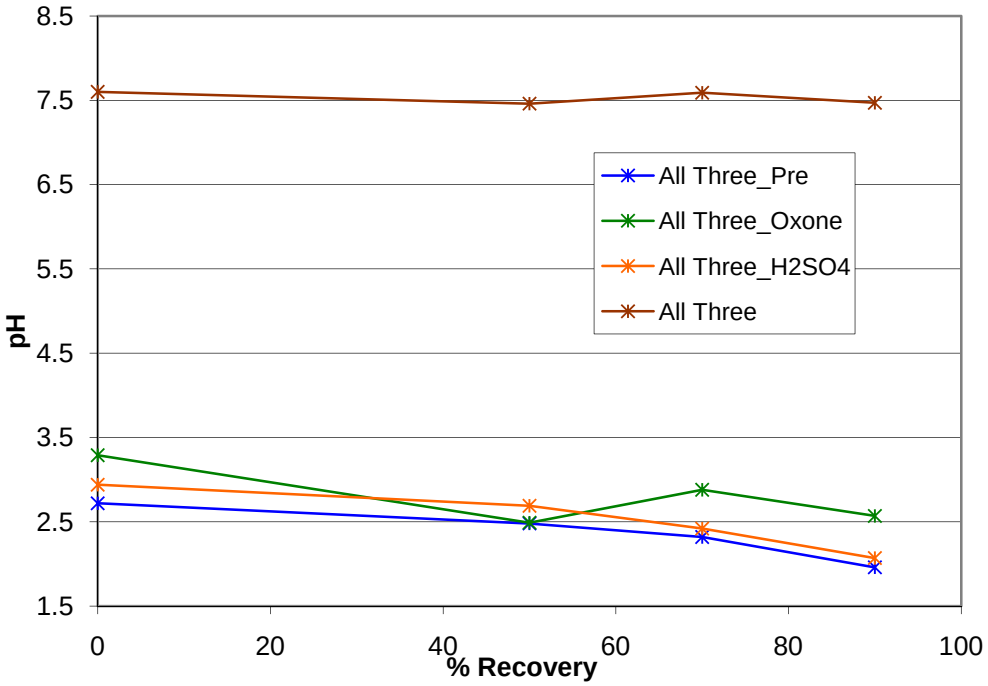

Figure 7. Bench-top pH results for all products in a simulated distillation.

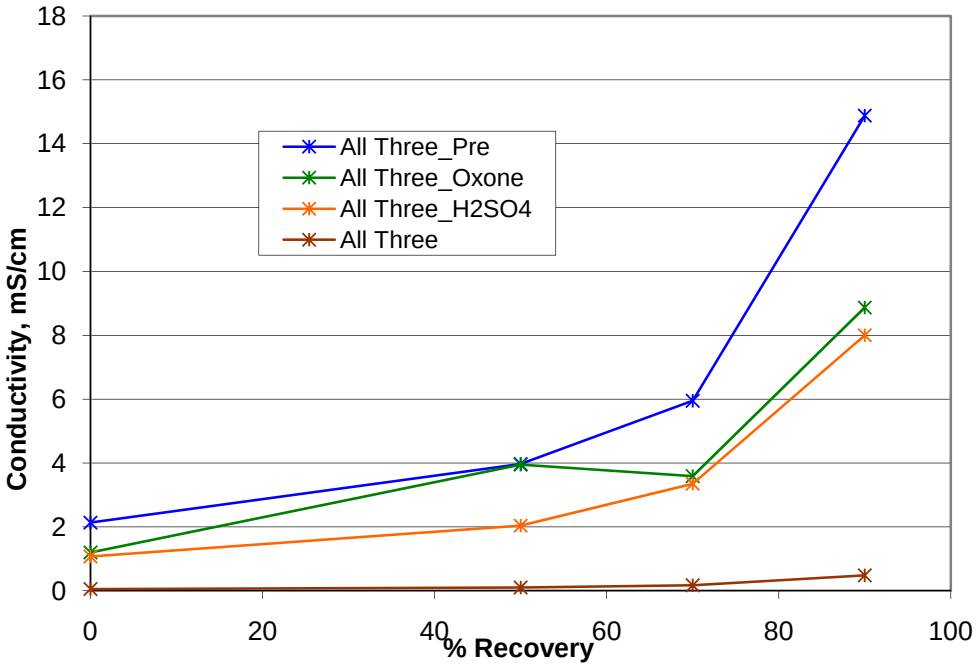

Figure 8. Bench-top conductivity results for all products in a simulated distillation.

B. Test 2: Rotary Evaporator Testing of Used Personal Care Products in a Combined Waste Stream

1) Toothpaste Testing

Measurements taken through the rotary distillation tests show that, as all the toothpaste solutions are distilled, the pH of the solution being distilled decreases. This is expected as distillation concentrates acid in the solution, lowering the pH. The conductivity of the solution also increases, as would be expected of a solution being concentrated. The procedure removes water, which concentrates the nonvolatile salts and acids, increasing conductivity. In the brine solution, the turbidity also increases, indicating that small insoluble materials are being concentrated. As the distillate solution increases as a result of distillation, the pH is lowered. This indicates some of the acids are entering the gas phase during distillation and are being condensed into distillate solution. Likewise, the conductivity increases, which could also be from distillation and condensation of gas-phase acids. Most of the distillate turbidities stay about the same during distillation, so it can be concluded that the distillate turbidity is not affected by any compounds crossing over into the distillate.

The most important data for deciding on toothpaste compatible for distillation testing are the suspended solids. In every test, there was some appreciable amount of suspended solids. This result was a bit unexpected. Solids were present even in the water brush test, which was performed by a volunteer brushing his/her teeth with a toothbrush and water only; this indicates that particles from the brushing process of the human mouth, such as plaque, epithelial cells, or food particles, supply appreciable solids to the waste stream. Solids, although to a lesser extent, were also present in the wastewater without an oral hygiene event. This indicates the solution does have some inherent solids, whether from urine, the showering process, or both. These data are shown in Fig. 9. There is only one set of data for the water brush as it was only performed once. The water brush test was recognized as a missing test parameter after the first round of rotary evaporation was completed to understand the nature of the wastewater stream. The Desert Essence® Sea Toothpaste total solids was not measured a second time as the rotary evaporator glassware was broken prior to performing that test. From these data and the results of a separate taste test of volunteers, it was determined that Orajel® Toddler Training Toothpaste would be the representative toothpaste for the Distillation Comparison Test. Orajel® had the least amount of solids of the over-the-counter toothpastes and, of the low-solids toothpastes, had the most acceptable taste. Figures 10 through 12 show analyses of the brine at specified water recovery points. Likewise Figs. 9, 13, and 14 show analyses of toothpaste distillate at specified water recovery points. Figure 15 shows the suspended solids of two replicates at 90% water recovery, with the exception of the water brush and the Desert Essence® Sea Toothpaste, which were performed once due to broken rotary evaporator glassware.

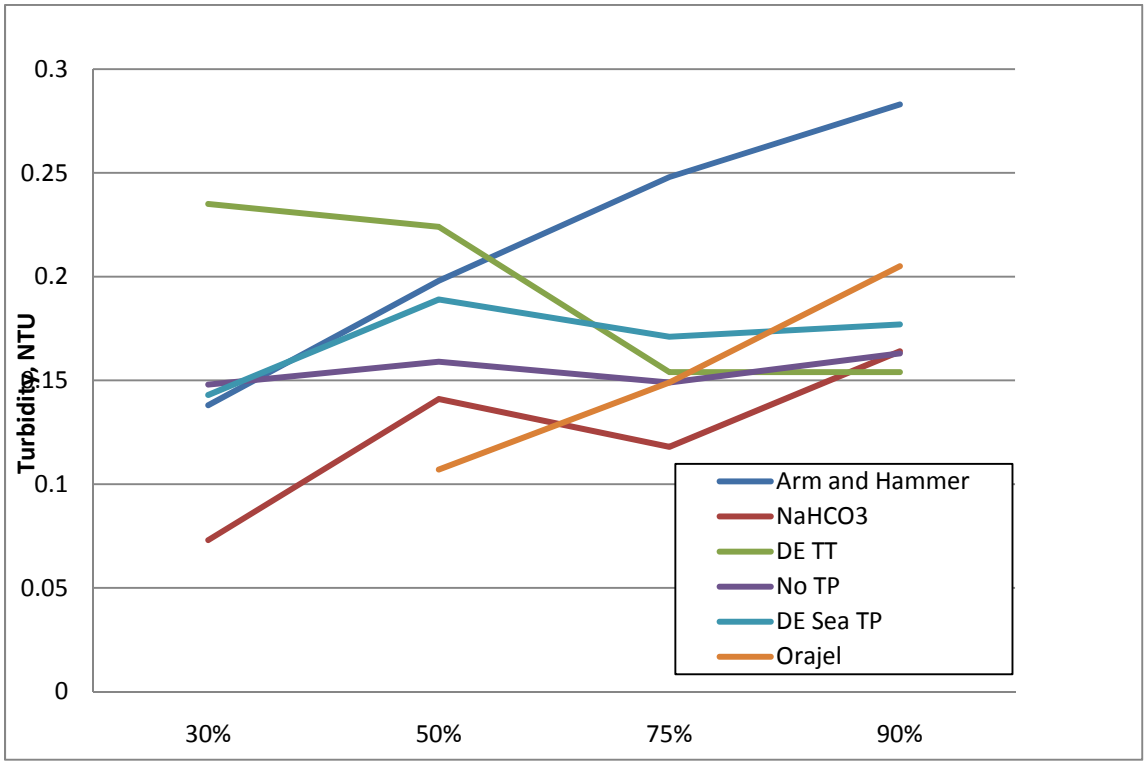

Figure 9. Distillate turbidity of toothpaste wastewater during distillation.

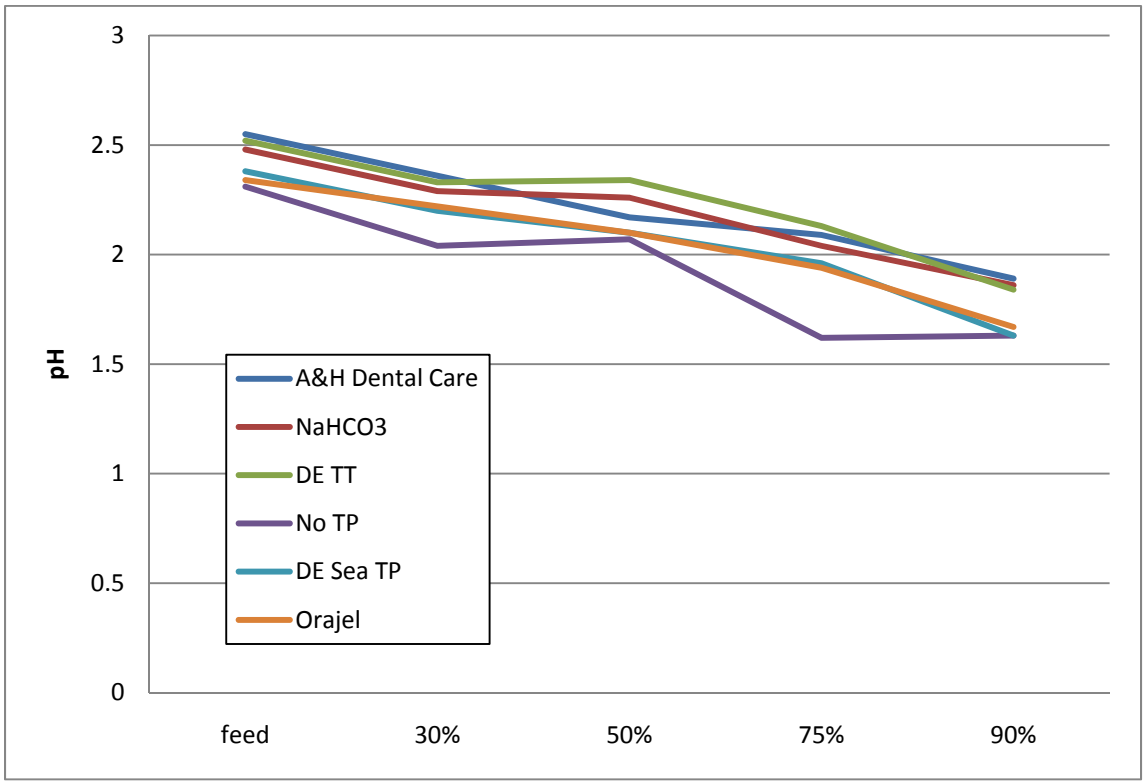

Figure 10. Brine pH of toothpaste wastewater during a rotary distillation process.

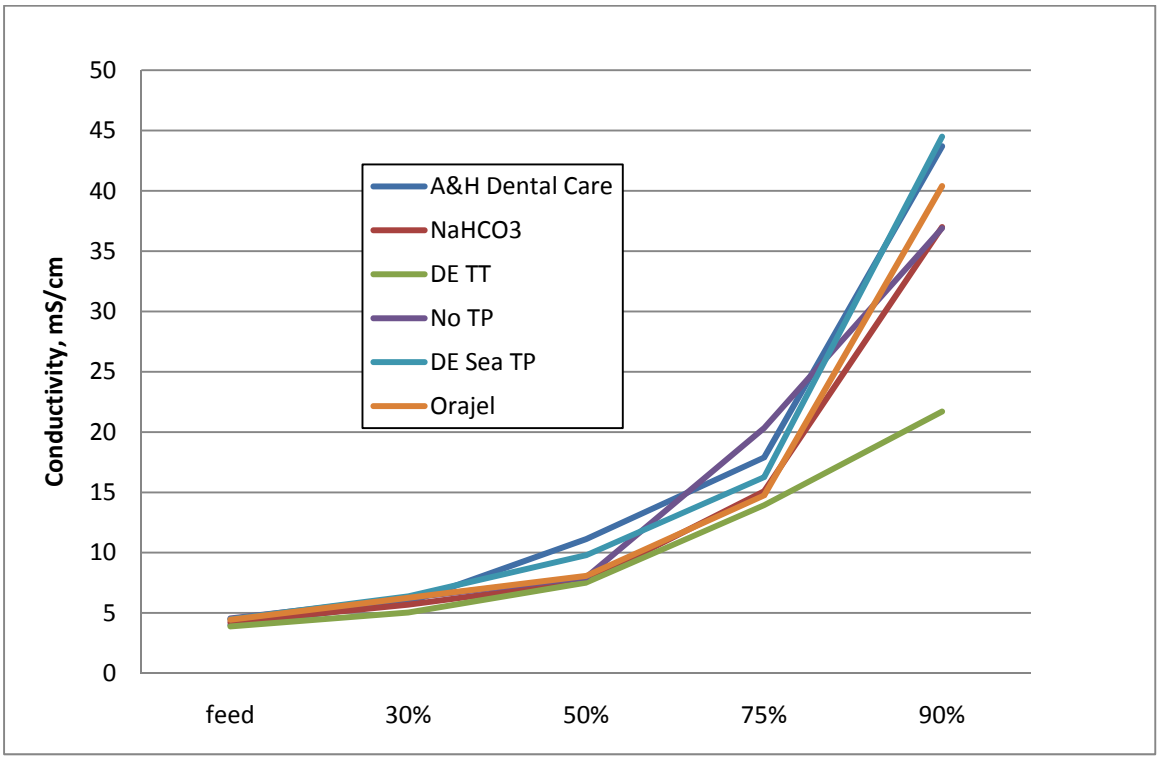

Figure 11. Brine conductivity of toothpaste water during distillation.

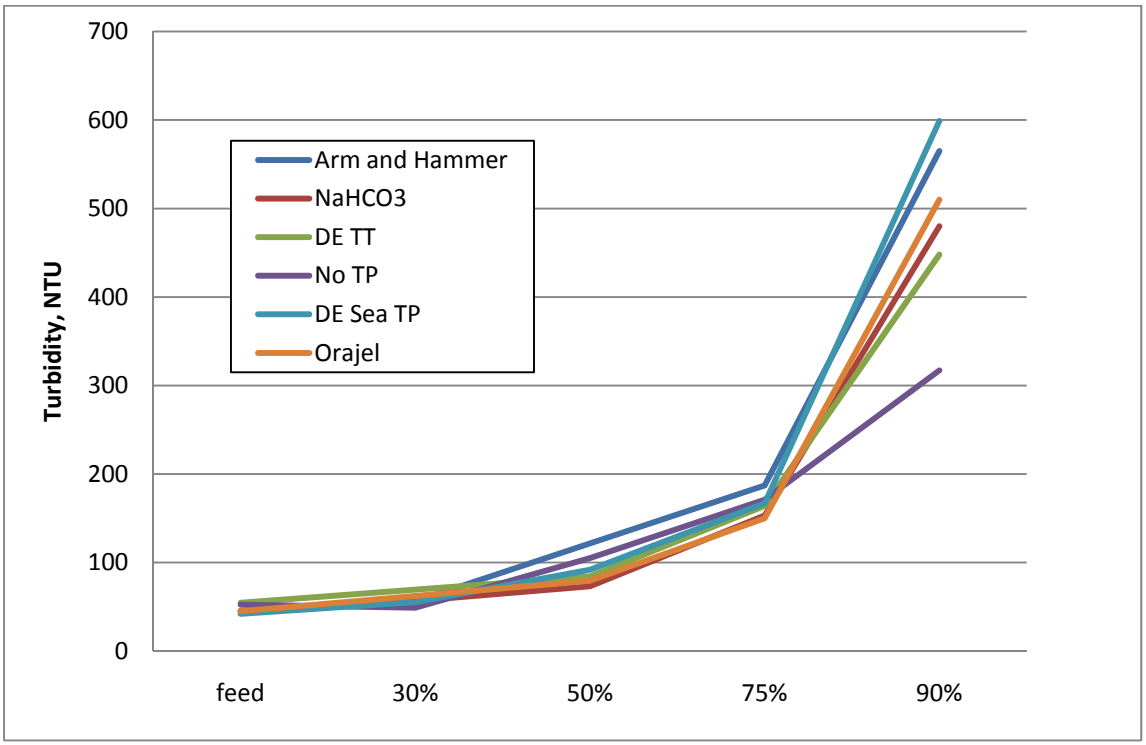

Figure 12. Brine turbidity of toothpaste wastewater during distillation.

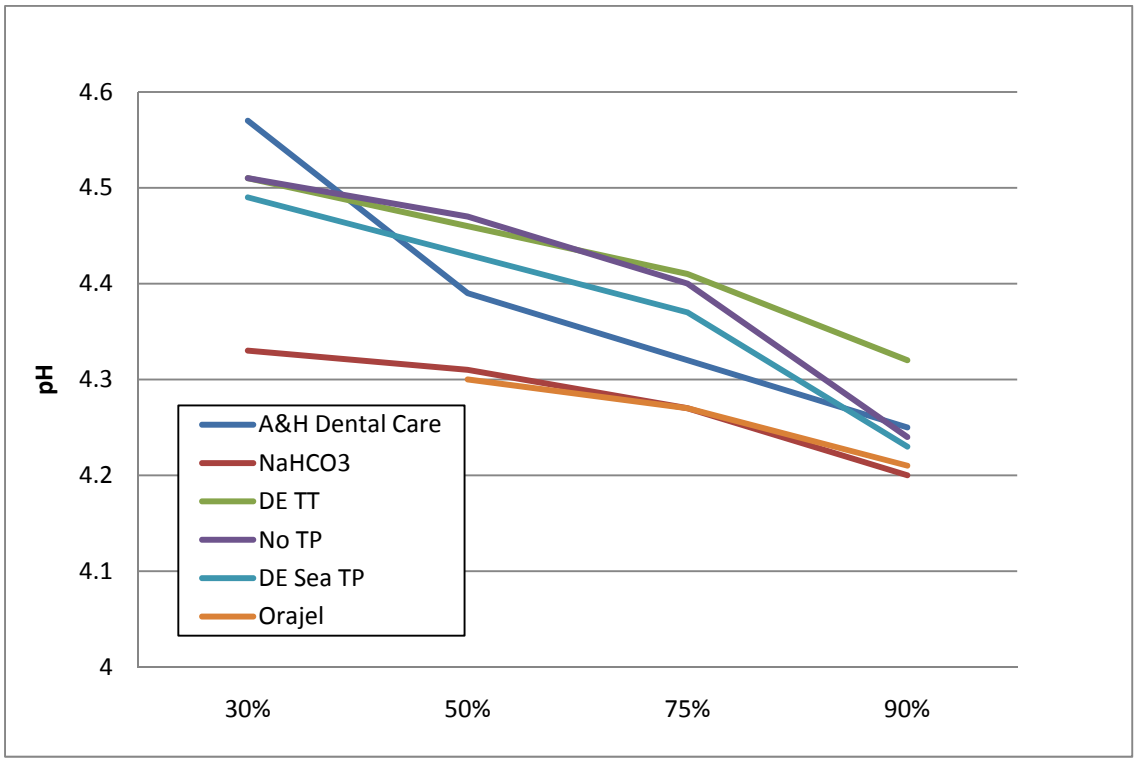

Figure 13. Distillate pH of toothpaste wastewater during distillation.

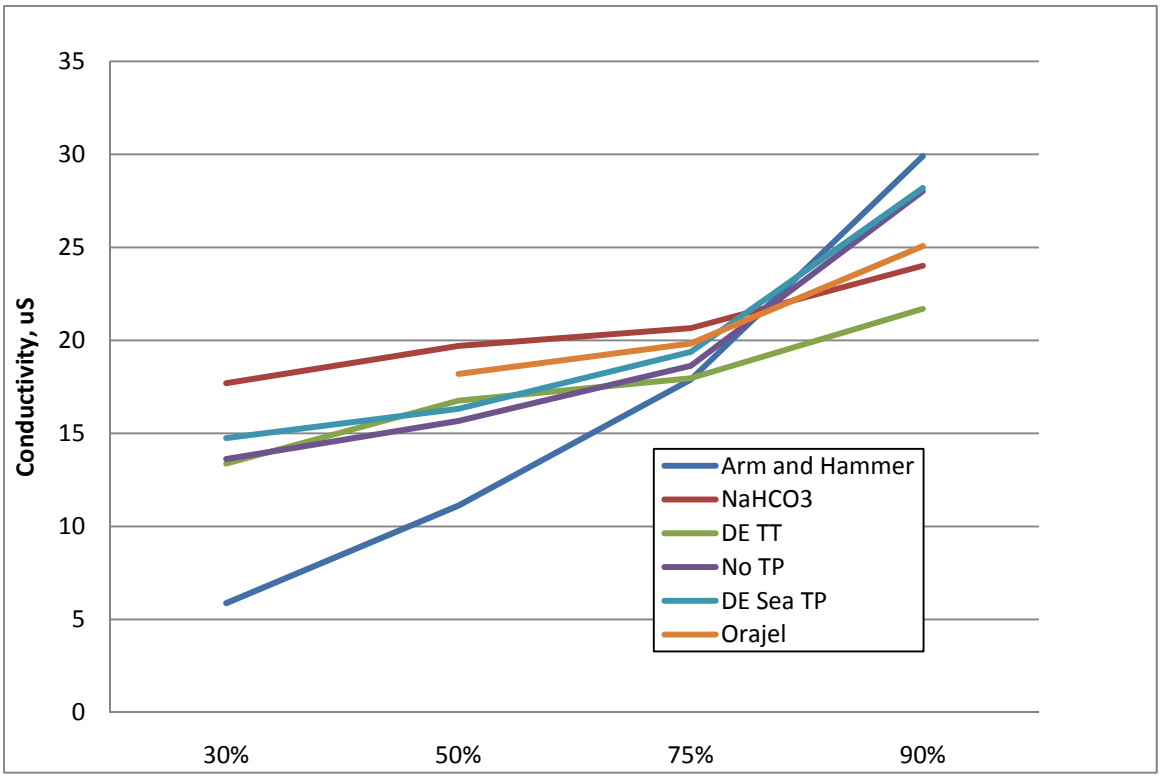

Figure 14. Distillate conductivity of toothpaste wastewater during distillation.

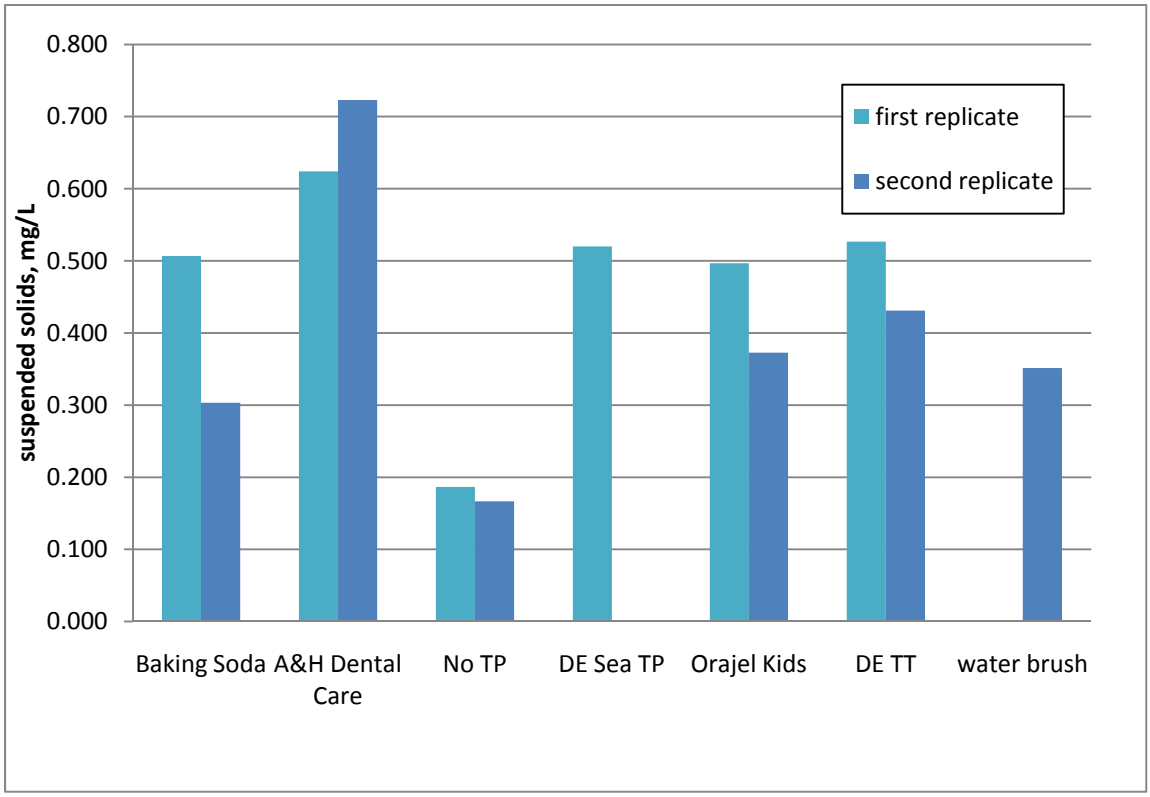

Figure 15. Toothpaste wastewater brine solids with 90% water recovered. The water brush and Desert Essence® Sea Toothpaste samples were performed once.

2) Shaving Product Results

Shaving product testing was performed in the rotary evaporator as well. Since the amount of solids produced from the rotary evaporation process was much less than from the toothpaste, the brines were taken to 90% without the intermittent measurements performed during the distillation of the toothpaste samples. Therefore, the data presented only show the feed, brine, and distillate solutions at 90% water recovery. In selecting a shaving product to be used for the Distillation Comparison Test, suspended solids were considered the most important analysis, since the likelihood of fouling the distillation hardware would increase with more solids present in the influent and, subsequently, the brine. Figures 16 through 18 show the pH, conductivity, and turbidity results of the feed, brine, and distillate samples of each of the shaving products. The suspended solids results of brine at 90% water recovery are given in Fig. 19. From these data, Neutrogena® Shaving Cream was selected as the representative shaving product.

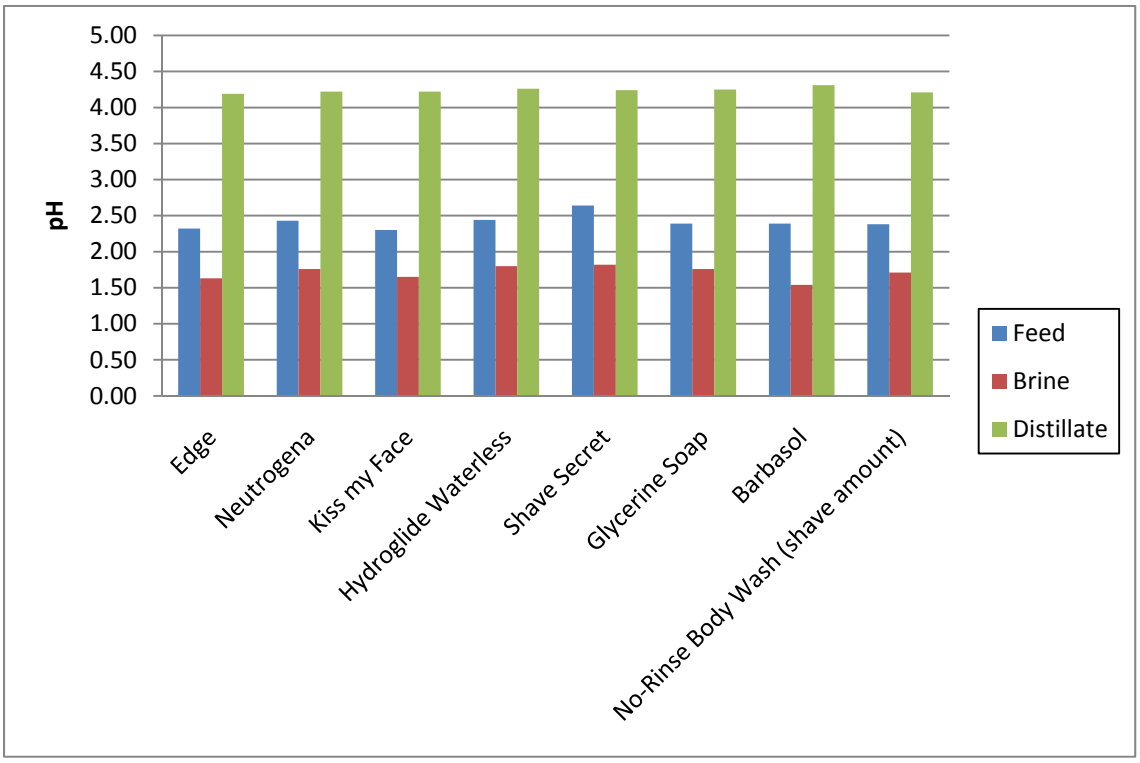

Figure 16. Shave product wastewater pH.

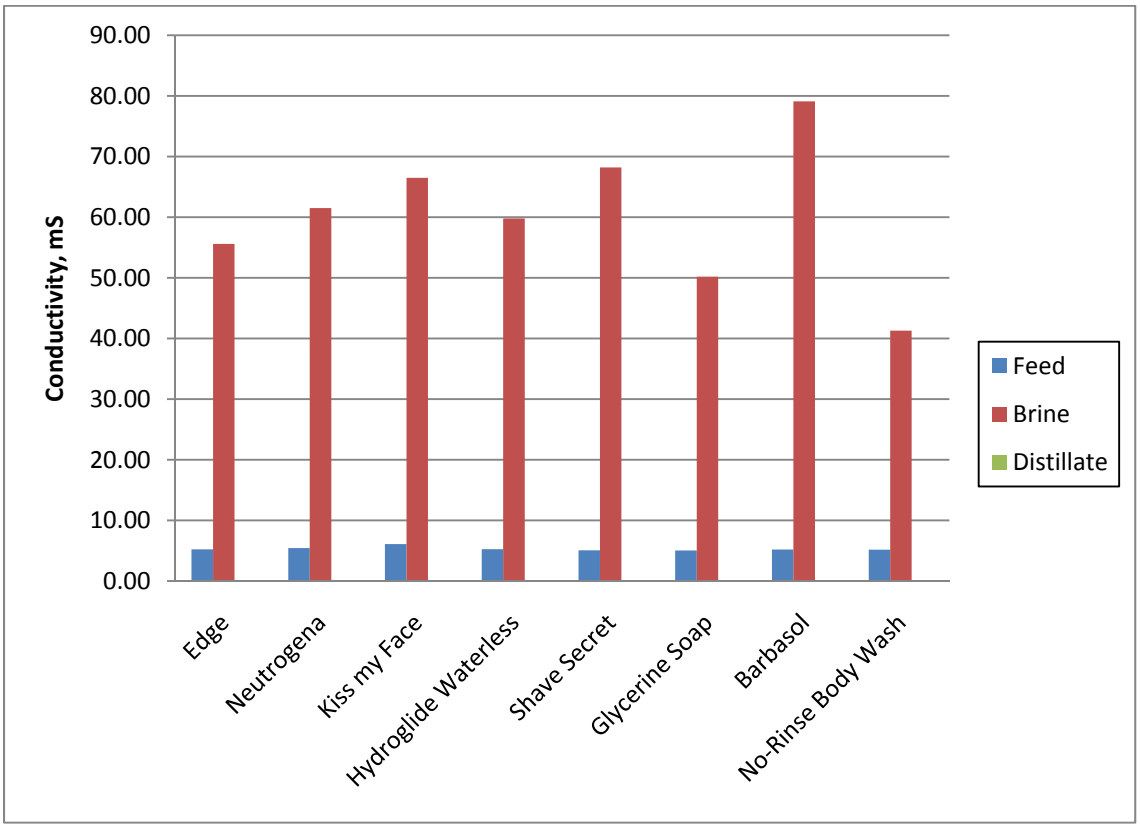

Figure 17. Shave product wastewater conductivity.

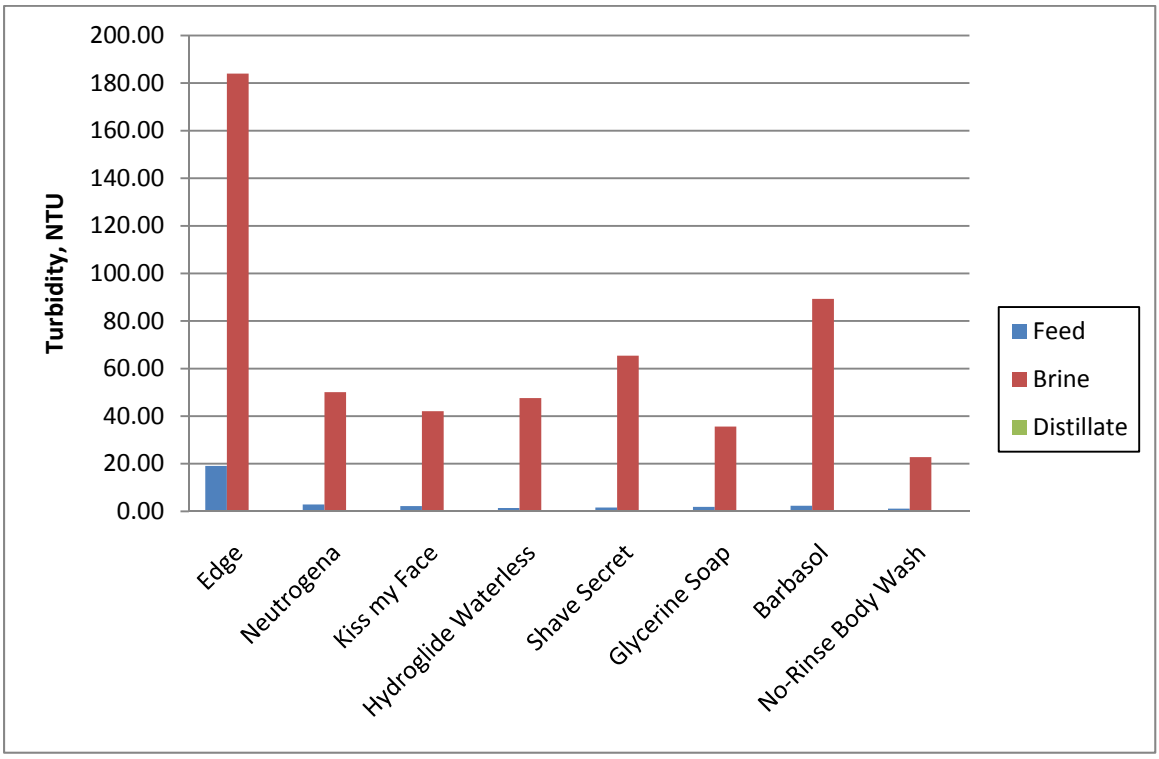

Figure 18. Shave product brine turbidity.

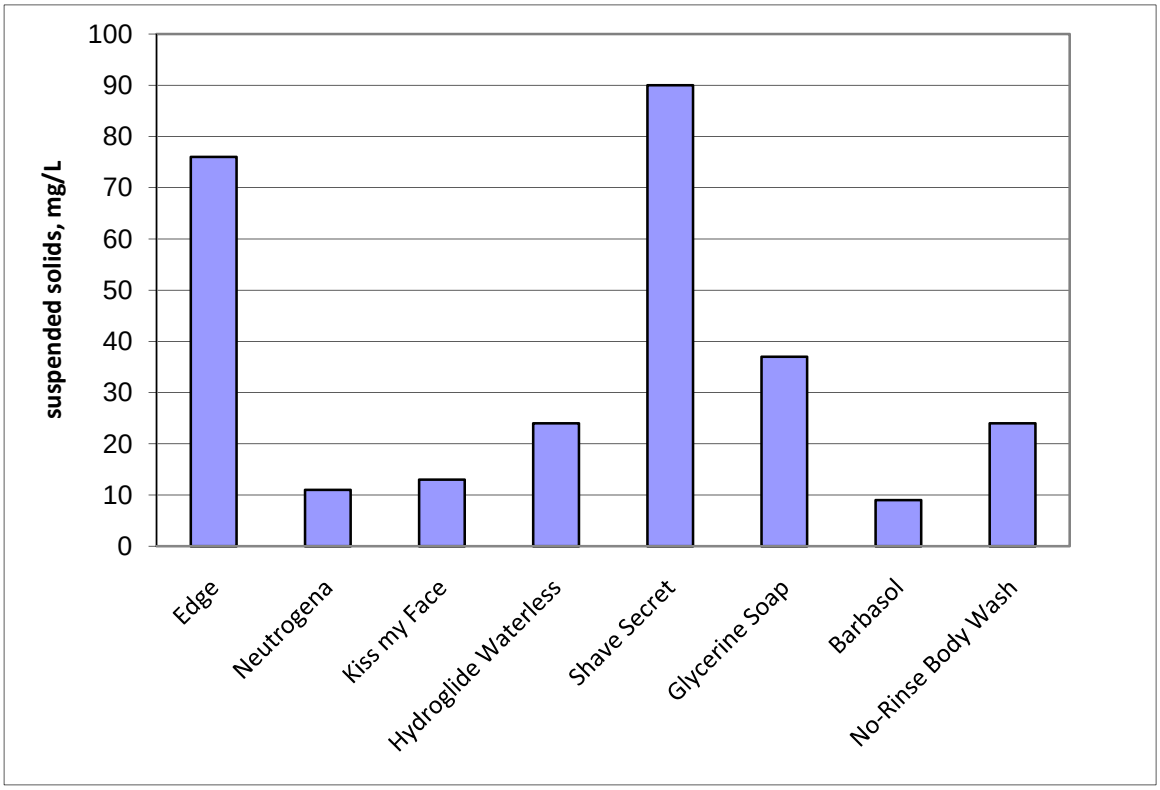

Figure 19. Shave product brine suspended solids.

C. Stability Testing Results

Hygiene water stability results are shown in Figs. 20 through 26. Throughout the testing, the parameters of pH, conductivity, turbidity, and sulfate remained relatively stable in both the pretreated and the untreated hygiene solutions. Potassium concentrations varied a little with the untreated solutions, but pretreated solutions showed very little change over the progress of the test.

The TOC results are the most puzzling because, in the pretreated samples, the TOC was consistently higher than in the untreated samples. This is puzzling as no TOC should have been added by pretreatment chemicals. The data also did not seem to follow a trend as expected. It was assumed that if there were a change in TOC, the untreated samples would lose TOC incrementally due to bacterial use of the organics in the hygiene products as food while the TOC in the pretreated samples would remain constant as there would be no bacterial activity. In reality, however, the TOC hovered around 150 mg/L throughout the test. The reason for this is not understood at this time.

The most change in data was seen in the HPCs. Pretreated hygiene solutions showed little growth throughout the test. However, untreated hygiene solutions showed growth in all of the samples between 1×10^5 to 1×10^6 CFU [colony-forming unit]/mL.

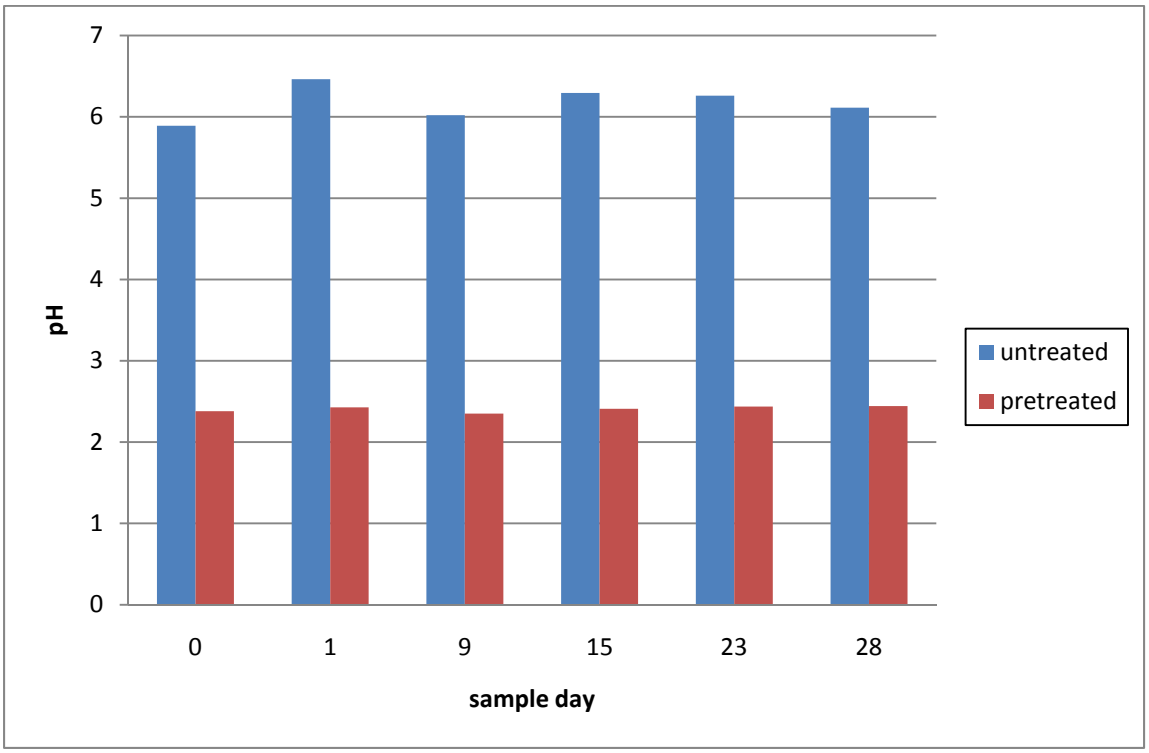

Figure 20. Hygiene water stability study pH results.

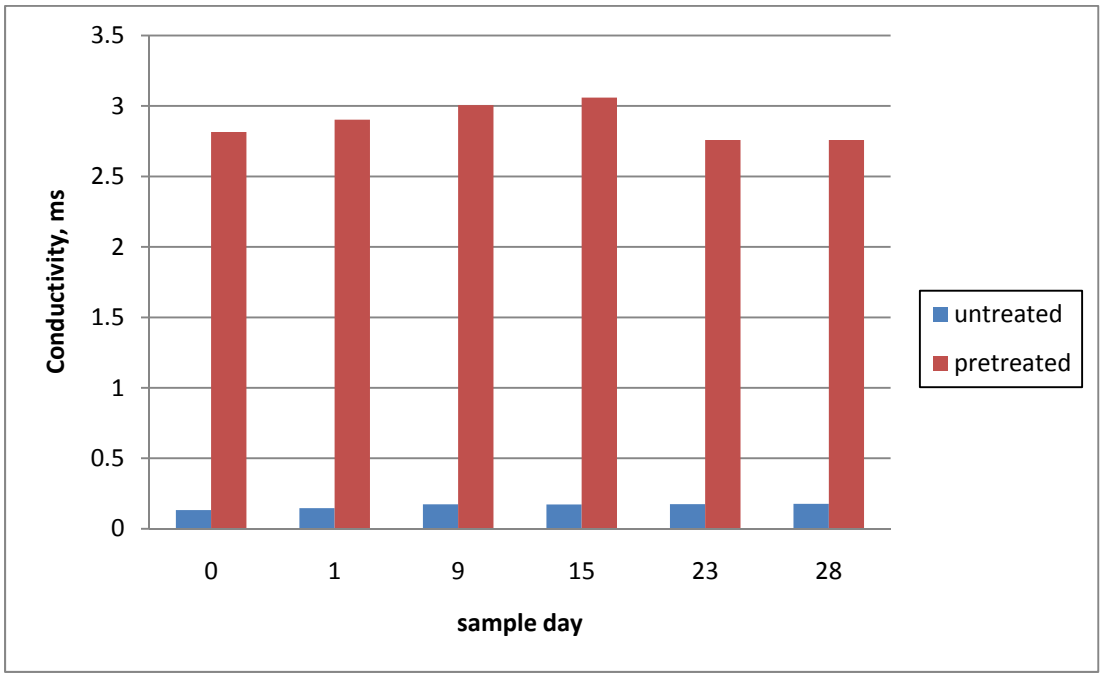

Figure 21. Hygiene water stability study conductivity results.

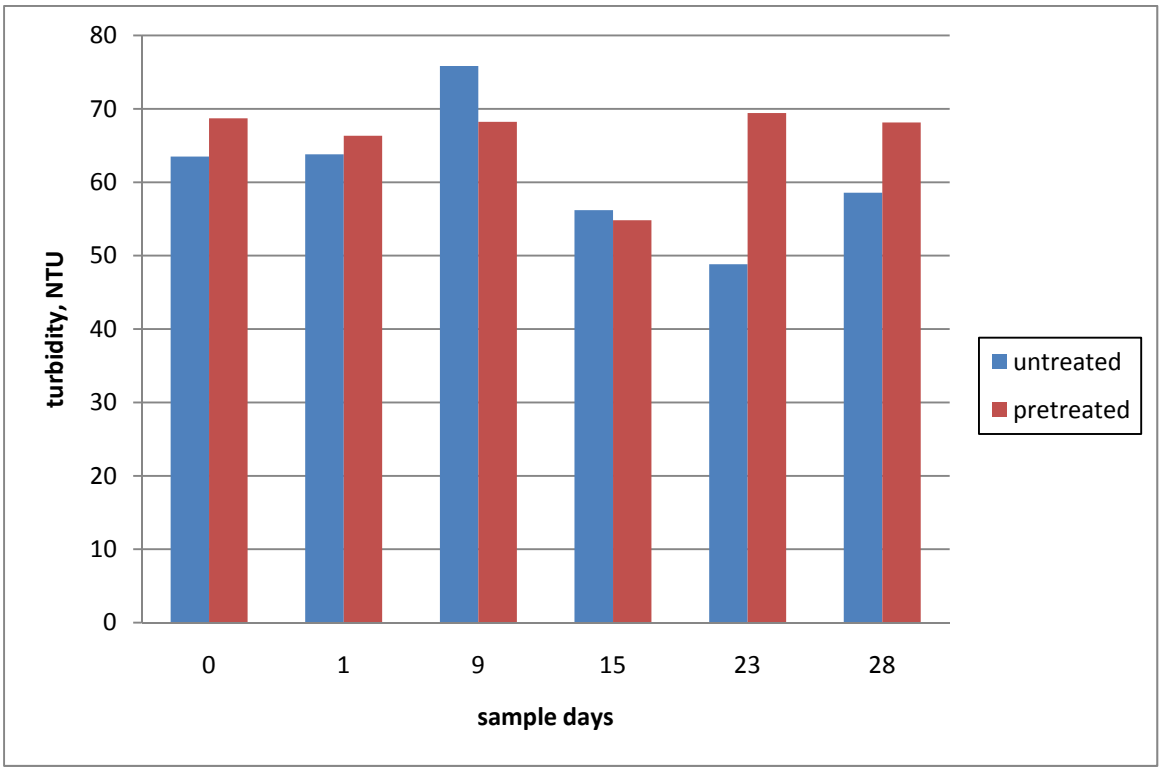

Figure 22. Hygiene water stability study turbidity results.

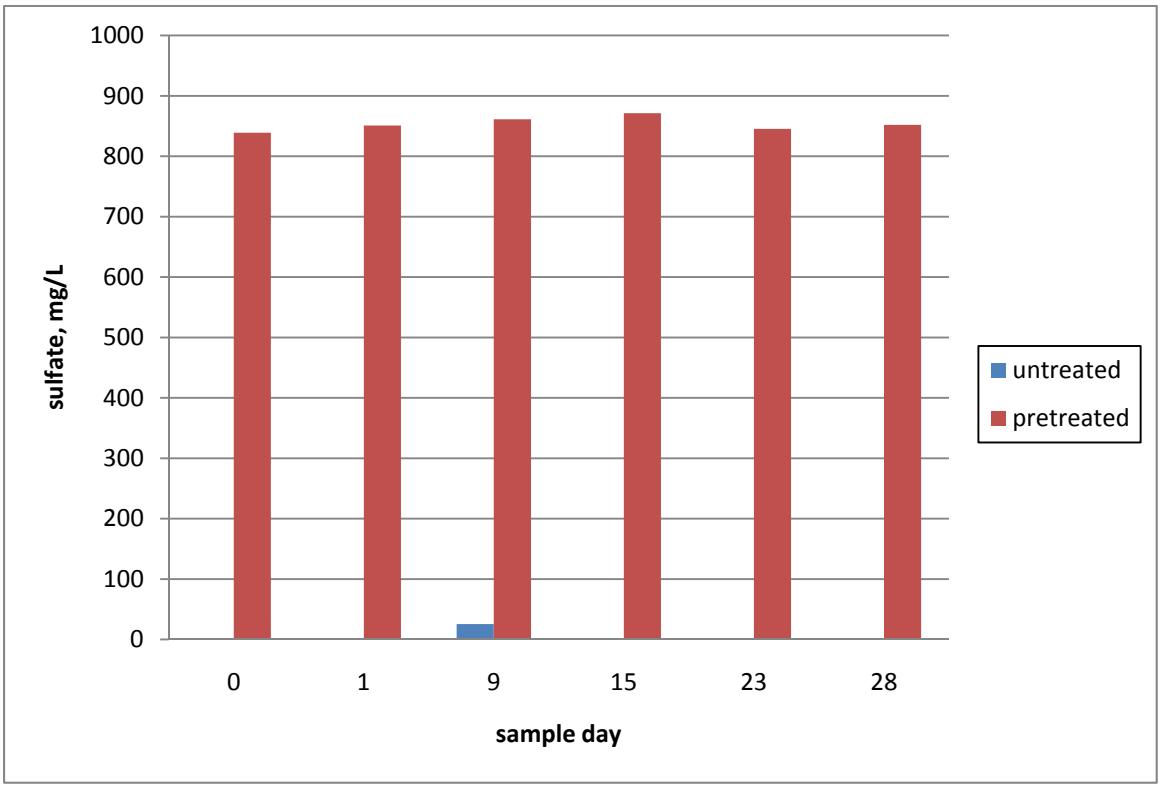

Figure 23. Hygiene water stability study sulfate results.

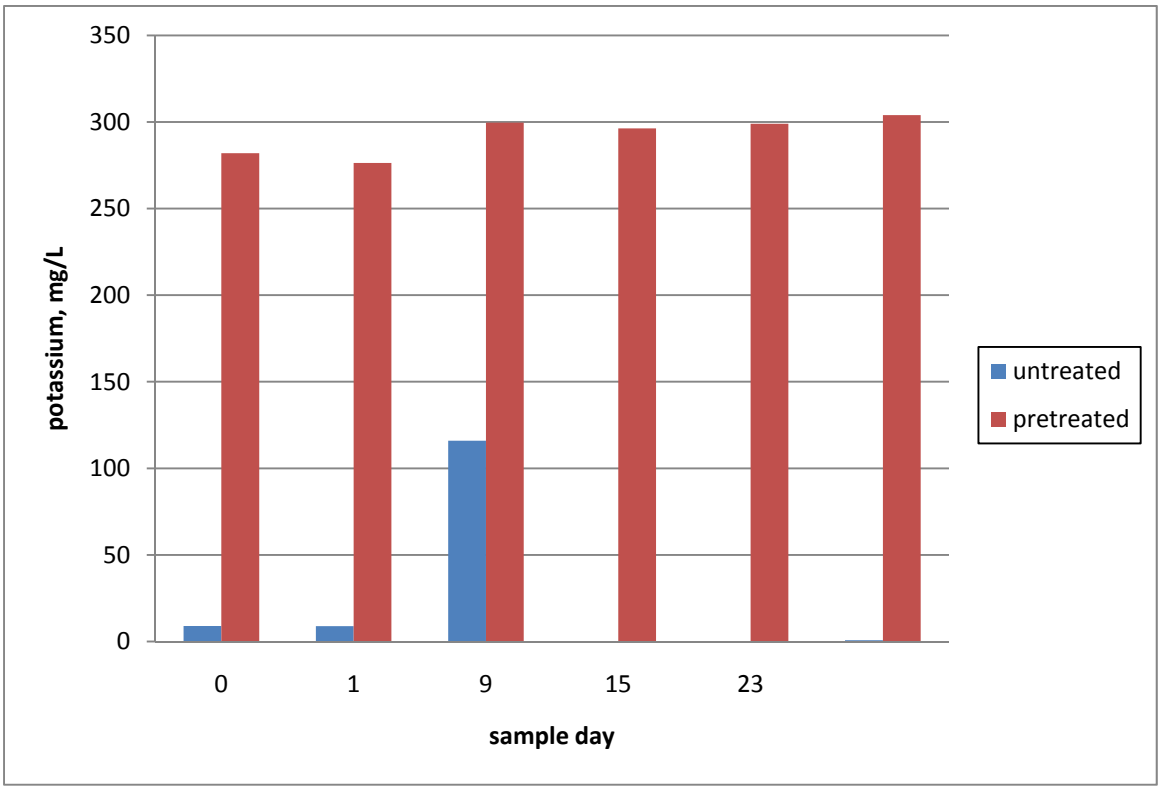

Figure 24. Hygiene water stability study potassium results.

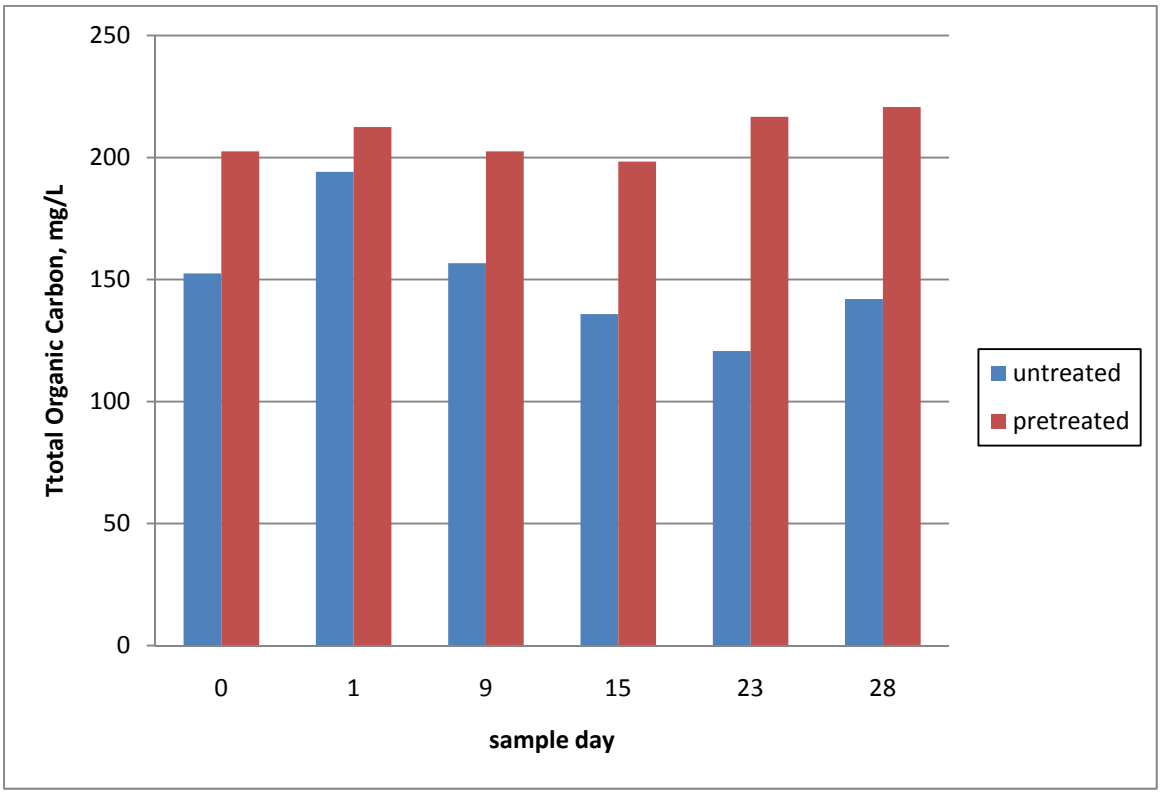

Figure 25. Hygiene water stability study TOC results.

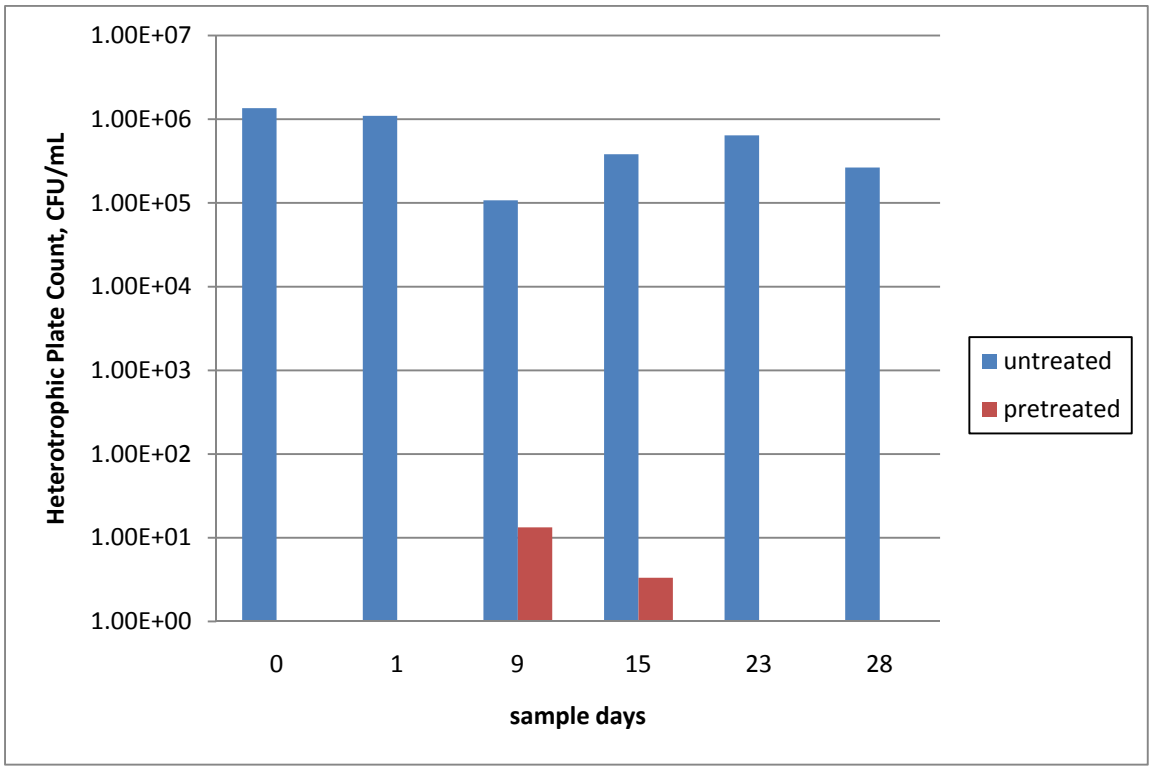

Figure 26. Hygiene water stability study HPC results.

Figures 27 through 33 contain data from the Solution 2 stability test. For the parameters analyzed (pH, conductivity, TOC, sulfate, potassium, turbidity, and HPCs), the solutions remained stable throughout the 28-day test. The pretreatment chemicals keep the solutions relatively unchanged. Even the "untreated" Solution 2 samples contain both pretreatment chemicals from the pretreated urine. This pretreatment most likely kept the solution stable for the 28-day period, which is why there is no appreciable change in any of the samples other than HPC.

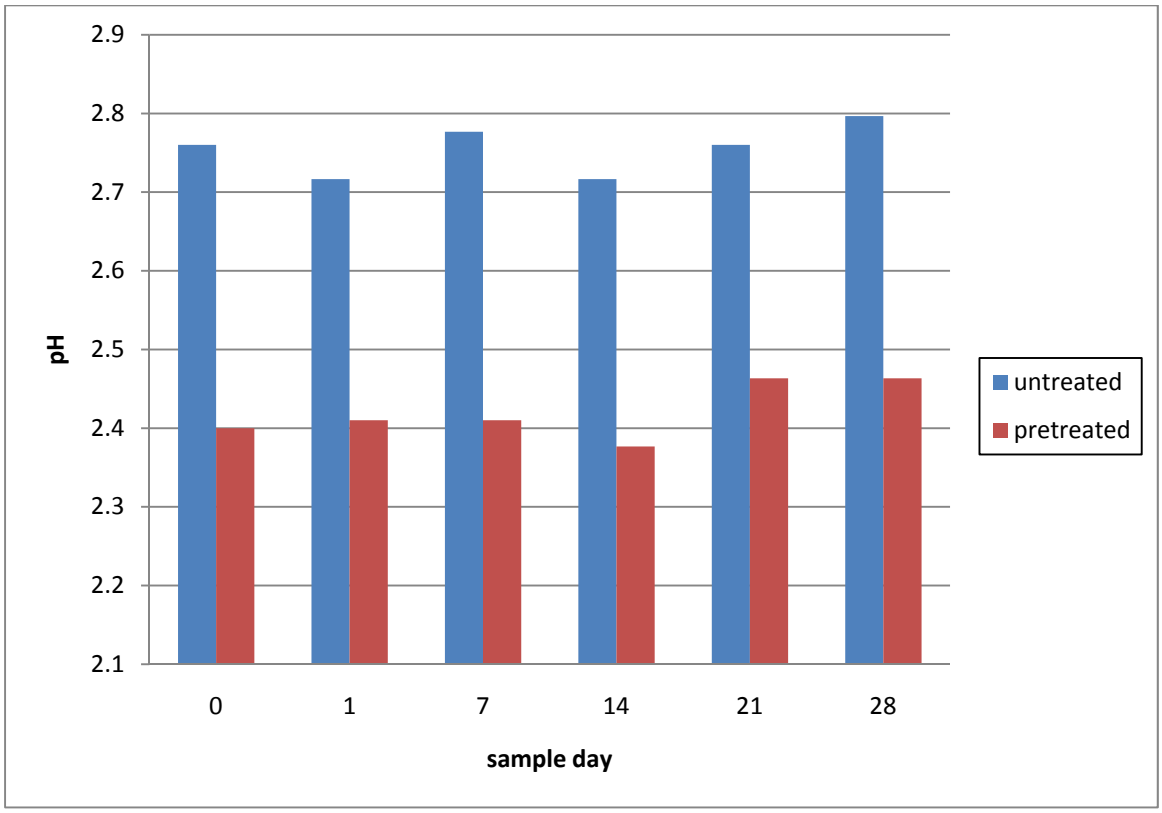

Figure 27. Solution 2 stability study ph results.

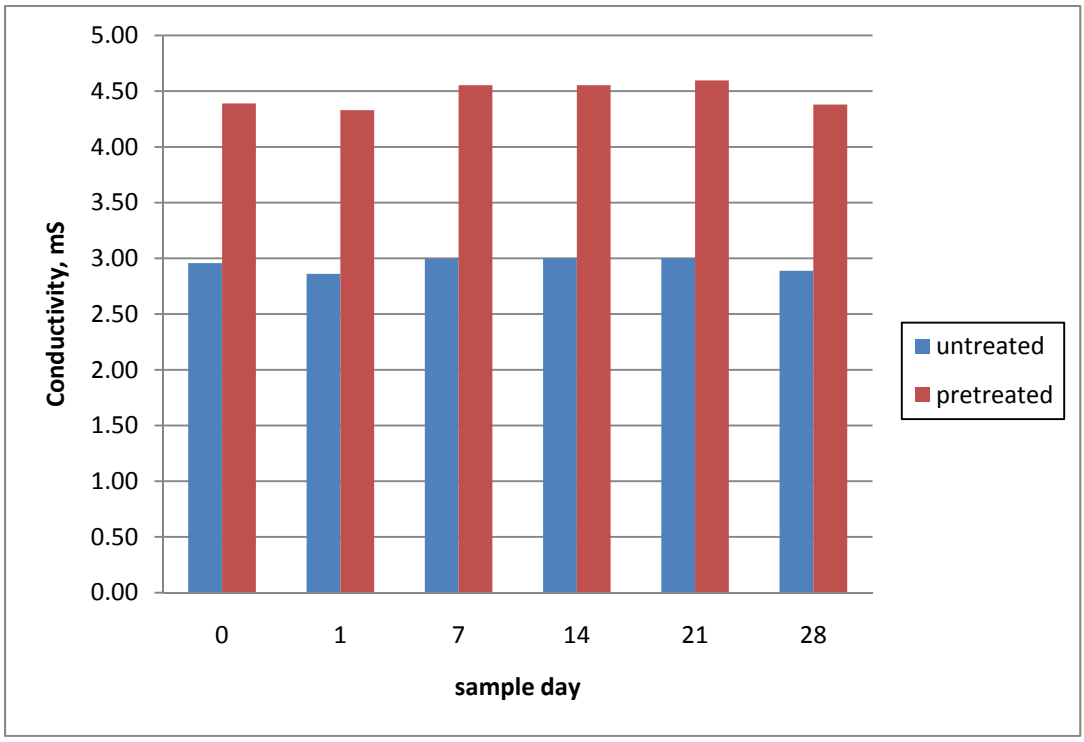

Figure 28. Solution 2 stability study conductivity results.

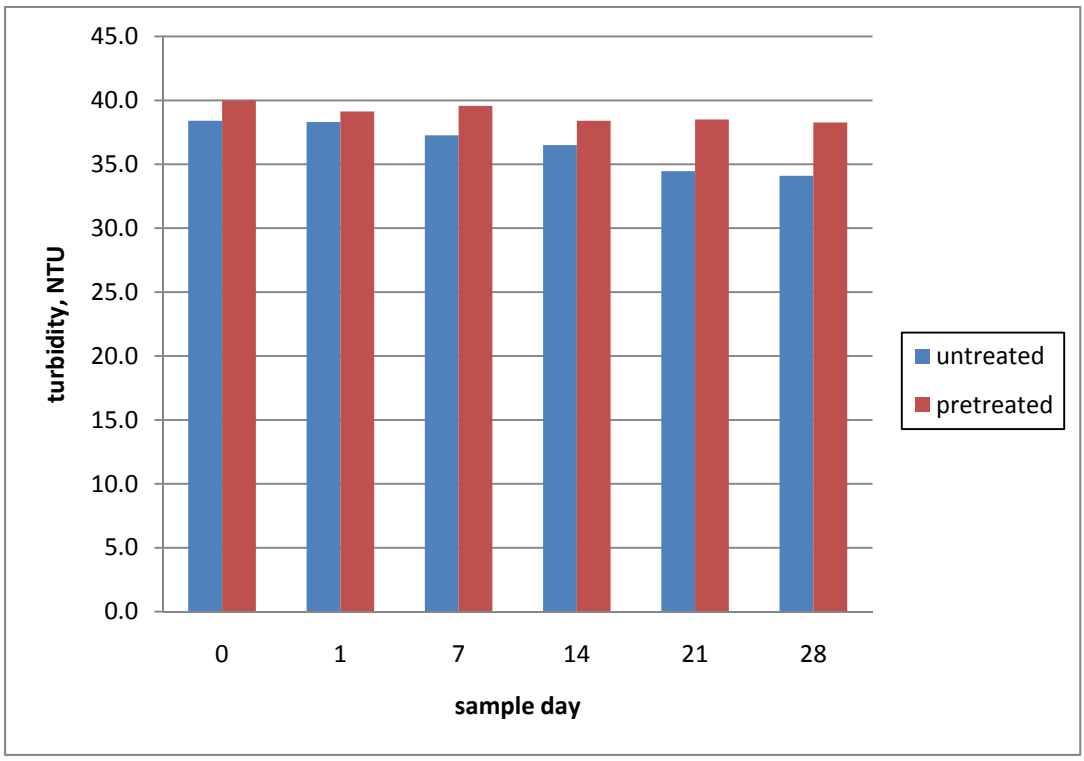

Figure 29. Solution 2 stability study turbidity results.

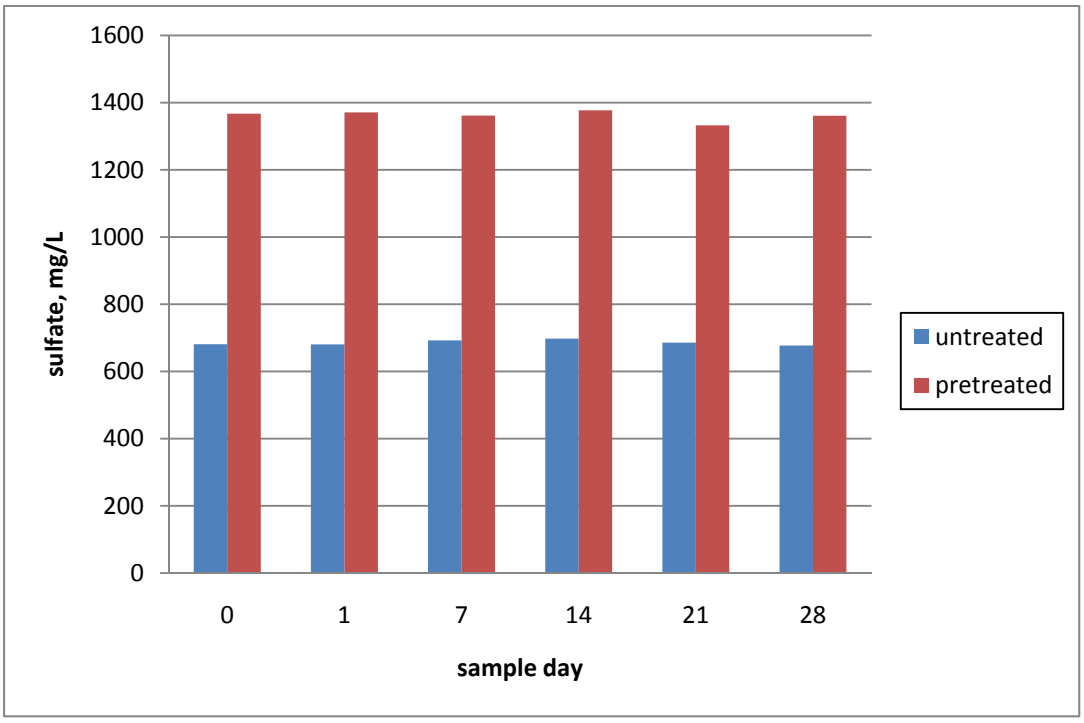

Figure 30. Solution 2 stability study sulfate results.

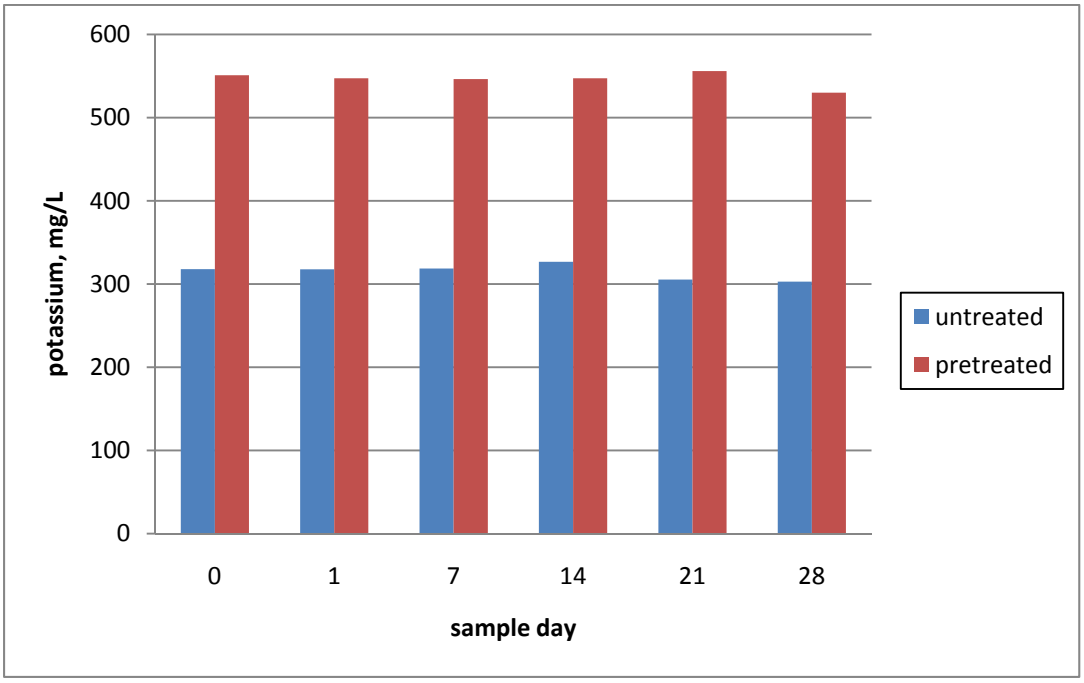

Figure 31. Solution 2 stability study potassium results.

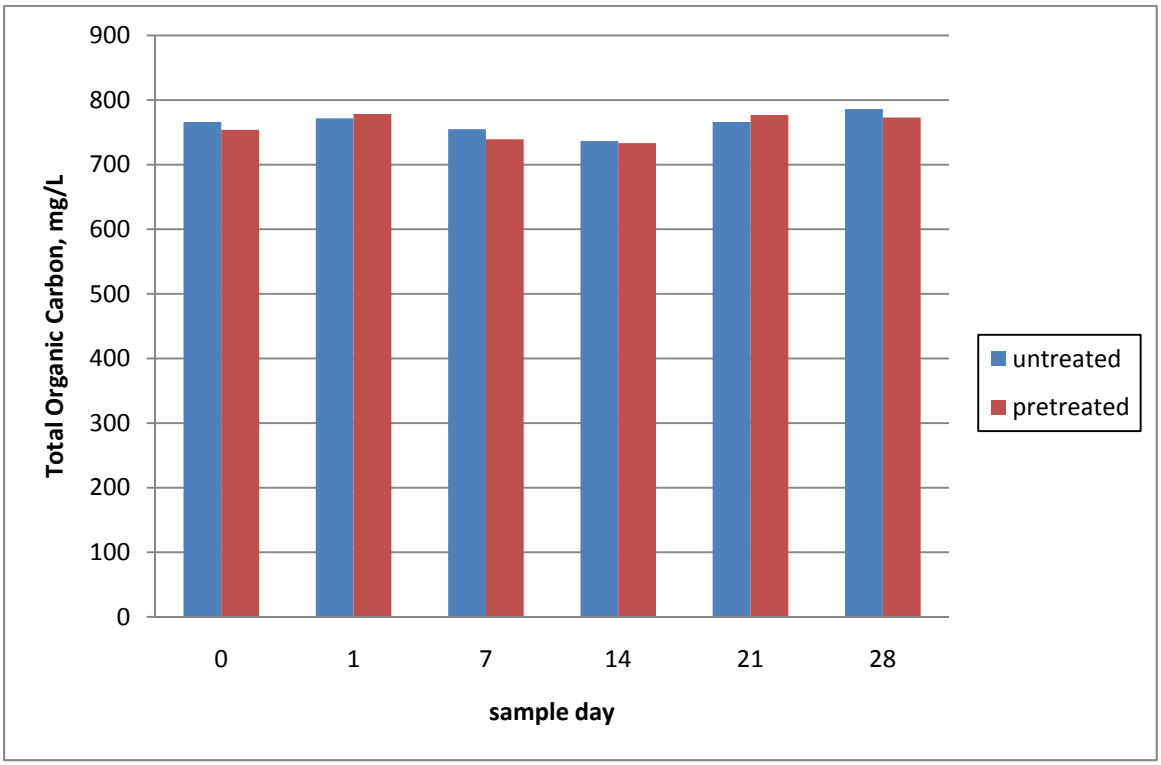

Figure 32. Solution 2 stability study TOC results.

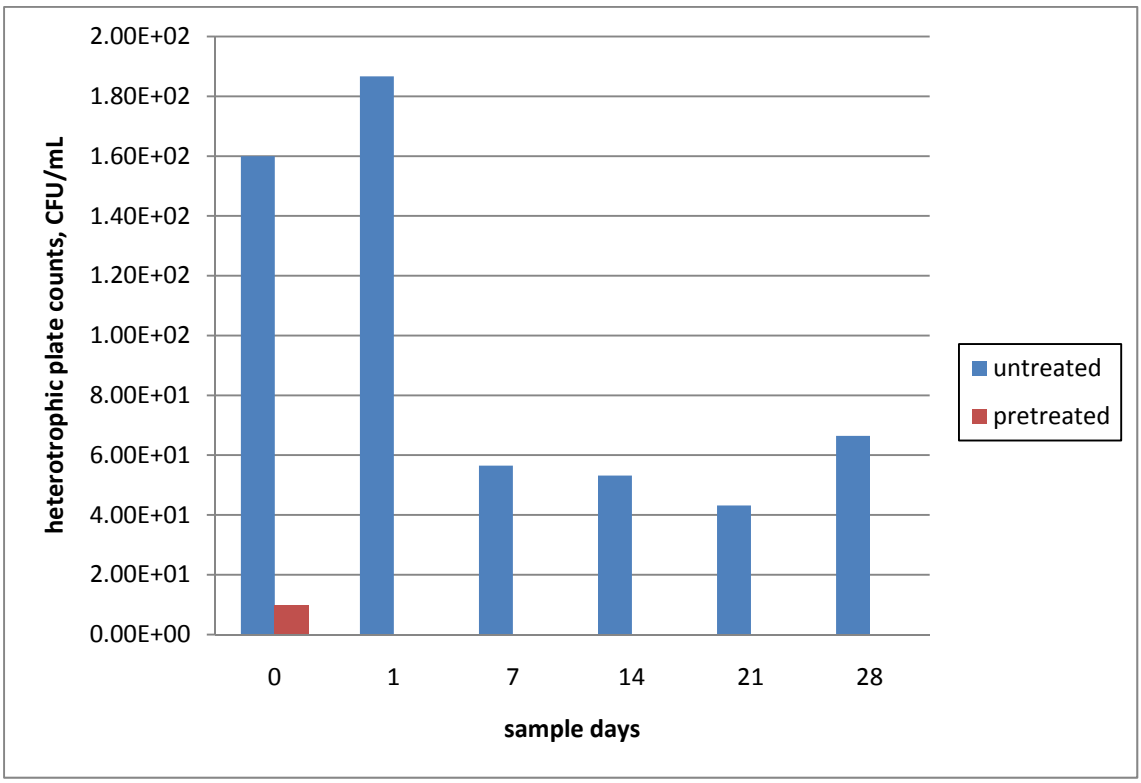

Figure 33. Solution 2 stability study HPC results.

V. Discussion

Based on the requirement to eliminate or minimize the amount of solids that form in the brine wastewater, two of the three personal care products were replaced for the Distillation Comparison Test. The Orajel® Toddler Training Toothpaste replaced the Crest® Cavity Protection Regular Paste and the Neutrogena® Shaving Cream replaced the Edge® Gel – Sensitive Skin. The No-Rinse® Body Wash was not replaced as it was shown to not contribute to solids formation in the brine. Solids still formed in used products during distillation, but those solids are believed to be a result of human by-products such as skin, hair, and oils.

The shelf-life study of hygiene water and Solution 2 showed that, when kept for 28 days, hygiene water without pretreatment would grow bacteria that would cause the wastewater to break down. Pretreated wastewater solution remained stable and did not grow bacteria. The Solution 2 shelf-life study always included pretreated urine in the formulation, which provided enough pretreatment to prevent significant bacterial growth even when no additional pretreatment was added to the solution. When more pretreatment chemicals were added to the formulation, there was no bacterial growth and no subsequent degradation of the solution. Based on these observations, to maintain both hygiene water and Solution 2 integrity, pretreatment chemicals must be added. While the amount of pretreatment chemicals in the urine portion of the formulation alone seems adequate in the Solution 2 wastewater stream, since bacterial growth is present, break down of the solution would eventually occur if the solution were stored for longer periods of time. It is recommended that, to maintain the integrity of Solution 2 while stored over a period of 28 days or more, the full recommended pretreatment amount be added to the solution.

VI. Conclusions

Based on the requirement to eliminate or minimize the amount of solids that form in brine wastewater, two of the three personal care products were replaced for the Distillation Comparison Test. Orajel® Toddler Training Toothpaste replaced the Crest® Cavity Protection Regular Paste and the Neutrogena® Shaving Cream replaced the Edge® Gel – Sensitive Skin. The No-Rinse® Body Wash was not replaced as it was shown not to contribute to solids formation in the brine. Solids still formed in the used products during distillation, but those are believed to be a result of human by-products such as skin, hair, and oils.

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A main goal of this project was to select personal care products for distillation systems. The products selected should not adversely affect the water processing system or the astronauts. For the Distillation Comparison Test, products were selected that reduced the amount of solids formation in the wastewater stream. These products were over-the-counter personal care products that were deemed acceptable by the volunteers who used them. The products would need to be evaluated by medical staff for actual use on board a spacecraft. Shelf-life stability of the personal care products would also need to be investigated.

References

[1]*FY09 ELS WRS Distillation Comparison Test Plan*, JSC-47176, NASA, 2009.

[2]U.S. Department of Health and Human Services, *Household Products Database* [online database], URL: http://householdproducts.nlm.nih.gov/index.htm [cited January 2009].

[3]Buchi Corporation., *Operation Manual Buchi Rotavapor R-210/215*, Version C, 2007.

Acronyms

CFU:	colony-forming unit
ELS:	Exploration Life Support
FY09:	fiscal year 2009
H_2SO_4:	sulfuric acid
HPC:	heterotrophic plate count
ISS:	International Space Station
JSC:	Johnson Space Center
MSFC:	Marshall Space Flight Center
TIC:	total inorganic carbon
TN:	total nitrogen
TOC:	total organic carbon
TP:	toothpaste
WWCTS:	Waste Water Collection and Transportation System