# SUMMARY:
# MANAGEMENT SOLUTIONS FOR LEACHATE BIOGEOCHEMICAL CLOGGING

**Daniel E. Meeroff (PI)[1]**
**Bishow Shaha[2]**

In 2018, the Bill Hinkley Center for Solid and Hazardous Waste Management funded a followup study to continue work on leachate clogging control technologies and understanding of leachate clogging mechanisms. Clogging of leachate collection systems can cause potentially catastrophic failures in landfill operation. The primary cause of clogging is calcium carbonate precipitation, which forms inside the pipe around a nucleus of silt, sand, microbial colonies, or other particles, although the trigger mechanism is not well understood. Over the past 4 years, FAU Laboratories for Engineered Environmental Solutions (Lab.EES) has teamed up with University of Florida and the Solid Waste Authority of Palm Beach County to conduct scientific studies on possible strategic solutions to combat biogeochemical rocking in the leachate collection system (LCS) including dilution, acid addition, and carbon dioxide offgassing. This research is needed to identify the best preventative measures and removal techniques to keep leachate collection systems clear of clogging.

Several ideas for dealing with preventative maintenance in the LCS have been proposed. These include 1) leachate dilution with ambient groundwater from the interceptor well system or other sources of fresh water, 2) acid addition, 3) disinfection, and 4) air stripping technologies. As landfills continue to expand, new cells and LCS components will be installed. It may be helpful to consider design changes for future cells that would allow for more comprehensive scale control measures such as the ability to introduce acid, dilution water, pressurized jets, or antiscalants directly into the laterals near the center of the landfill, where leachate first collects. Other engineering modifications could include utilizing shorter distances between manholes and steeper slopes for the LCS laterals or pressurizing the collection system at each header rather than relying on the use of gravity.

The objective of this study will be to determine the impacts of varying the flow regime in leachate collection pipes, applying disinfection to eliminate biofilms, and adjusting the pH to mobilize mineral deposits to determine if any of these preventative measures will negatively impact downstream disposal.

---

[1] Professor & Associate Chair, Dept. of Civil, Environmental & Geomatics Engineering, Florida Atlantic University, 777 Glades Road, 36/206, Boca Raton, FL 33431-0091, Phone: (561) 297-2658, E-Mail: dmeeroff@fau.edu

[2] PhD candidate, Dept. of Civil, Environmental & Geomatics Engineering, Florida Atlantic University, E-Mail: bshaha2015@fau.edu

# PROGRESS REPORT
(April 2019)

**Project Title:** MANAGEMENT SOLUTIONS FOR LEACHATE BIOGEOCHEMICAL CLOGGING
**Principal Investigator:** Daniel E. Meeroff, Ph.D.
**Affiliation:** FAU
**Phone number:** (561) 297-2658
**Project website:** http://labees.civil.fau.edu/leachate.html
**Student:** Bishow Shaha, PhD Candidate

## Methodology/Scientific Approach

**TASK 1. Determine impacts of flow regime**. FAU collected samples from critical locations such as manholes (MH), pump stations (PS), composite leachate prior to deep injection at the wet well (wetwell), groundwater used in dilution purposes (DIW), and the pelletizer wastewater (NEFCO). Table 1 summarizes the average water quality data.

**Table 1. Average water quality data based on 2018-2019 sampling**

| Sample Location | pH | Field Cond. (mS/cm) | TDS (mg/L) | Alkalinity (mg/L as $CaCO_3$) | Ca Hardness (mg/L as $CaCO_3$) | Field TDS (mg/L) | Temp. (ºC) | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|---|---|
| MH 5 | 6.97 | 53.56 | 28,220 | 3,800 | 3,500 | 31,700 | 30.34 | 4.88 | 2.09 | 2.79 |
| MH 6 | 6.96 | 45.86 | 27,200 | 7,400 | 900 | 26,450 | 32.30 | 5.13 | 1.83 | 3.30 |
| MH 8 | 6.87 | 39.46 | 20,670 | 2,300 | 1,875 | 23,080 | 30.39 | 5.22 | 1.65 | 3.58 |
| MH 9 | 6.94 | 37.87 | 20,150 | 3,100 | 2,675 | 22,400 | 29.00 | 4.95 | 1.99 | 2.96 |
| MH 11 | 7.03 | 58.17 | 34,900 | 4,400 | 4,075 | 34,280 | 30.37 | 4.87 | 2.16 | 2.72 |
| MH 13 | 6.32 | 31.88 | 18,000 | 880 | 3,760 | 17,800 | 29.77 | 5.65 | 0.67 | 4.97 |
| PS/A | 6.89 | 6.60 | 4,770 | 500 | 1,260 | 4,220 | 25.40 | 6.31 | 0.58 | 5.73 |
| PS/B | 6.75 | 6.87 | 3,860 | 900 | 900 | 4,160 | 28.90 | 6.12 | 0.63 | 5.49 |
| DIW | 7.15 | 1.17 | 670 | 284 | 404 | 720 | 27.44 | 6.73 | 0.42 | 6.32 |
| NEFCO | 5.28 | 7.52 | 2,445 | 238 | 1,500 | 4,070 | 35.54 | 6.32 | -1.04 | 7.35 |
| Wetwell | 7.47 | 9.74 | 6,360 | 1,425 | 1,075 | 6,240 | 25.82 | 5.96 | 1.51 | 4.45 |

Note: LSI>0.4: Supersaturated; LSI<0.0: undersaturated, and 0<LSI<0.4: Neutral

Most of the samples showed neutral pH and correlate with the historical trends found in earlier studies conducted by FAU and UF since 2012 (Townsend et al. 2016; Shaha 2016). However, the Wetwell sample had a pH of 7.47, which is almost 0.5 units higher than historical data, likely due to the operational changes in the landfill and/or leachate collection system that facilitate aeration or stagnation of leachate longer than usual.

Saturation indices (LSI and RI) indicate supersaturation with respect to calcium carbonate precipitation except for the NEFCO wastewater, which is undersaturated and corrosive in nature. Groundwater (DIW) used for dilution purposes is neutral and helps to reduce the precipitation potential by facilitating higher flow in the gravity collection system as well as diluting the key constituents of calcium and alkalinity in the leachate.

The NEFCO wastewater has an LSI value of -1.04 (corrosive) and has the potential to be an alternate source of dilution water that may reduce the dependency on the groundwater. FAU conducted several mass balance analyses with different volumetric ratios of leachate and NEFCO wastewater to estimate the optimum mixing ration that provides neutral saturation indices. A 1:1 volumetric ratio of leachate to NEFCO wastewater results in an LSI of +0.5, which indicates the neutral nature of the mixture. However, NEFCO wastewater having total suspended (TSS) solids in the range of 400 to 600 mg/L, more than double or even triple in some instances compared to leachate and the adhesive nature of the solids is a concern. FAU built a laboratory scale cyclone separator to separate the NEFCO solids. Preliminary results suggest that the unit was able to remove about 30% turbidity and 70% of the TSS in 10 minutes. Based on the 6 million gallons/month NEFCO wastewater flow with 500 mg/L of TSS and 70% TSS removal, about 580 lb/day of solids would need to be handled.

**TASK 2. Determine impacts of biological activity trigger mechanisms.** To simulate insitu disinfection conditions, FAU conducted field and laboratory experiments using a UV disinfection unit to determine the effects of radiation exposure dose on HPC (heterotrophic plate count/ bacterial colony) total plate counts. A laboratory experiment using a laboratory scale UV source with 2.1 $mJ/cm^2 \cdot s$ (**Figure 1**) achieved an almost 3-log reduction of HPC count within 30 minutes of exposure.

**Figure 1. Photocatalytic Safety Cabinet used to disinfect leachate in the laboratory**

FAU installed an inline UV treatment unit with 40 $MJ/cm^2 \cdot s$ fluence to disinfect the leachate in one side of the field scale pipe network in the landfill. An onsite leachate reservoir was set up with about 6-7 ft of head to facilitate gravity flow. In addition, 2 one-inch dia removable pipes were retrofitted in both sides of the outlet to measure the precipitation in both sides (control vs. exposed).

**Figure 2. Field scale pipe network at the landfill (left), UV unit installation (right top), leachate storage unit (right bottom)**

The following steps were followed during the field experiment:

- Measured initial weight of 1-inch dia 1-ft long pipe sections from both sides
- Maintained flow about 26-28 lpm in each side (control and UV disinfected)
- Flow through 1-inch bypass was estimated to be about 6 lpm
- Sample was collected at 0, 15, 30, 60, 90, and 120 minutes
- Samples were stored in at 4°C and transported to FAU for HPC count within 4-6 hours of sampling

**Table 2** represents the leachate quality variation during the field experiment duration (120 minutes). Leachate water quality remains constant over the experiment duration. **Table 3** shows the HPC count of control and disinfected leachate collected at 30, 60, and 90 minutes. It is evident that the UV unit was not performing as expected. Precipitation in the 1-inch dia removable pipe section was also measured and did not follow the expected trend.

**Table 2. Average water quality parameters from the control and treated side during 120 min experiment**

| Parameters | Control | | UV treated | |
|---|---|---|---|---|
| | Average | St. dev | Average | St. dev |
| pH | 7.09 | 0.05 | 7.07 | 0.03 |
| Cond. (mS/cm) | 44.01 | 0.99 | 44.21 | 0.44 |
| Sp. Cond. (mS/cm) | 40.06 | 0.28 | 40.14 | 0.11 |
| TDS (g/L) | 26.05 | 26.05 | 26.09 | 0.07 |
| Temp (ºC) | 30.17 | 30.17 | 30.37 | 0.41 |

**Table 3. HPC count for treated and untreated samples**

| Sample ID | HPC/mL |
|---|---|

| | |
|---|---|
| Control | 24,000 |
| UV_30 (30 minutes) | 20,000 |
| UV_60 (60 minutes) | 22,000 |
| UV_90 (90 minutes) | <20,000 |

A total of three field experiments were conducted, and essentially no disinfection was observed. This might be related to low transmittance due to high TSS, color, turbidity, and humic/fulvic acid (NOM) content in the leachate.

To further investigate the biological trigger, FAU continued disinfecting the leachate using heat sterilization in the laboratory. The first experiment using heat sterilization was conducted with pump station A leachate, and the initial water quality parameters of the sample are tabulated in **Table 4**. This sample was diluted with groundwater and therefore TDS, alkalinity, calcium are lower than the typical samples. However, the saturation indices indicate that this sample is still scale forming in nature (LSI > +0.4).

**Table 4. Pump station A leachate water quality parameters and precipitation potential**

| **Parameter** | **Control** | **To be sterilized** |
|---|---|---|
| pH (standard unit) | 7.24 | 7.25 |
| Temp. (ºC) | 19.43 | 19.48 |
| TDS (g/L) | 7.756 | 7.759 |
| Cond. (mS/cm) | 10.66 | 10.68 |
| Sp. Cond. (mS/cm) | 11.93 | 11.93 |
| Ca. hardness (mg/L as CaCO3) | 650 | 700 |
| Alkalinity (mg/L as CaCO3) | 1050 | 1050 |
| **LSI** | **0.82** | **0.86** |
| **RI** | **5.60** | **5.53** |

The following steps were followed during the experiment:

- Two 800 mL samples were prepared in 1L glass beakers
- Hardness, alkalinity, COD, TDS, and TSS were measured initially
- One beaker was heat sterilized for 15 min at 100°C (boiling point), while the other sample was kept as the control
- The sterilized sample was cooled to room temperature, and then analyzed for the water quality constituents previously measured
- Three 200 mL sample from each 1L sample was taken and kept in an incubator for 7 days at 35ºC to accelerate precipitation
- Measured final water quality parameters, precipitate weight (floating, attached to the surface), and sample volume were measured at the end of the time period

**Figure 3. Boiling leachate (left), and visual comparison of sterilized and control leachate (right)**

After 7 days of incubation and water quality measurement, the dry weight of beaker was measured to estimate the adherent precipitation/scale attached to the beaker surface. **Figure 4** depicts the visual differences between the control samples (from left: 1st and 2nd beaker) and the sterilized samples (from left: 3rd and 4th). It was visible that the sterilized sample had less adherent precipitation. **Figure 5** shows the changes in LSI at different stages of the experiment. It is evident that after 7 days of incubation both the control and sterilized samples reached neutral LSI value (0<LSI<0.4). Therefore, the total precipitation during the experiment for both sets of samples was similar. However, the difference observed in **Figure 4** might be because of the absence of microbes that may provide the adhesive character.

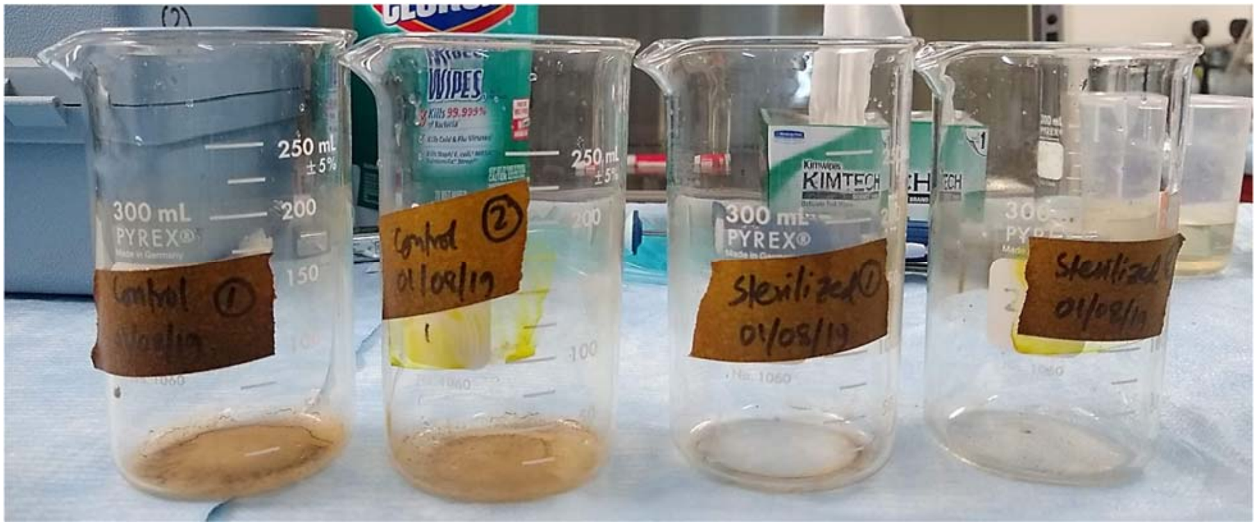

**Figure 4. Visible adherent scale formation in 250 mL beaker for control (1st and 2nd from left) and sterilized sample (3rd and 4th from left)**

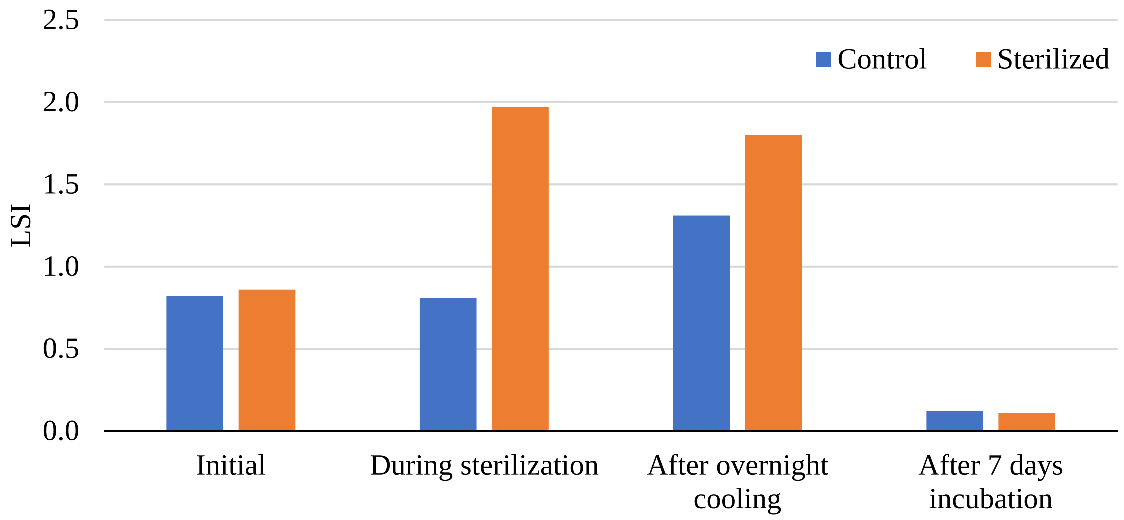

**Figure 5. Changes in langelier Saturation index (LSI) during different stages of experiment**

Precipitation rate was calculated for both sterilized and control samples. The non-adherent scale is the floating and loose precipitate at the bottom separated by filtration using a 4.5-micron filter. The adherent scale is the precipitate strongly attached to the vessel surface. **Figure 6** shows the comparison of adherent and nonadherent scale formation between control and sterilized sample and confirms that sterilized sample produces less adherent scale/precipitate as observed in visual inspection (**Figure 4**). Although the total precipitation rate is a function of the saturation state of the leachate, the observed difference is important to understand the impacts on microbes in scale formation.

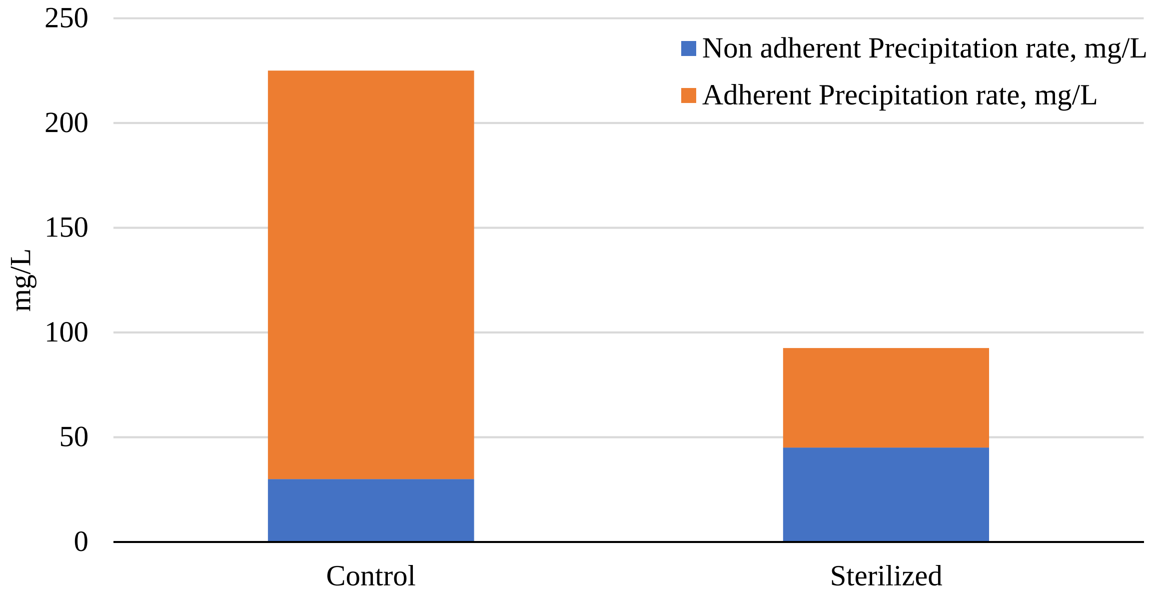

**Figure 6. Precipitation rate obtained from trial 1**

One of the setbacks of the first experiment was the loss of leachate due to evaporation during the sterilization process. For better control of evaporation loss and disinfection efficiency, it was decided to perform autoclaving at 121ºC for 30 minutes or sterilizing in an oven at 150ºC. To check the disinfection using autoclave and oven, the HPC plate count was measured for samples sterilized both ways. There was no growth in HPC plate for the autoclaved samples (**Figure 7**). However, some growth of bacteria and molds have been observed in the oven-sterilized samples at 48-72 hours incubation at 35ºC (**Figure 8**). It was suspected that spore formation occurred during the process. In addition, HPC count was also measured after storing the samples in the incubator for 10 days and HPC count for autoclaved samples found to be zero (**Figure 9**). However, oven-sterilized samples showed too numerous to count (TNTC) colonies at 1:1 sample dilution.

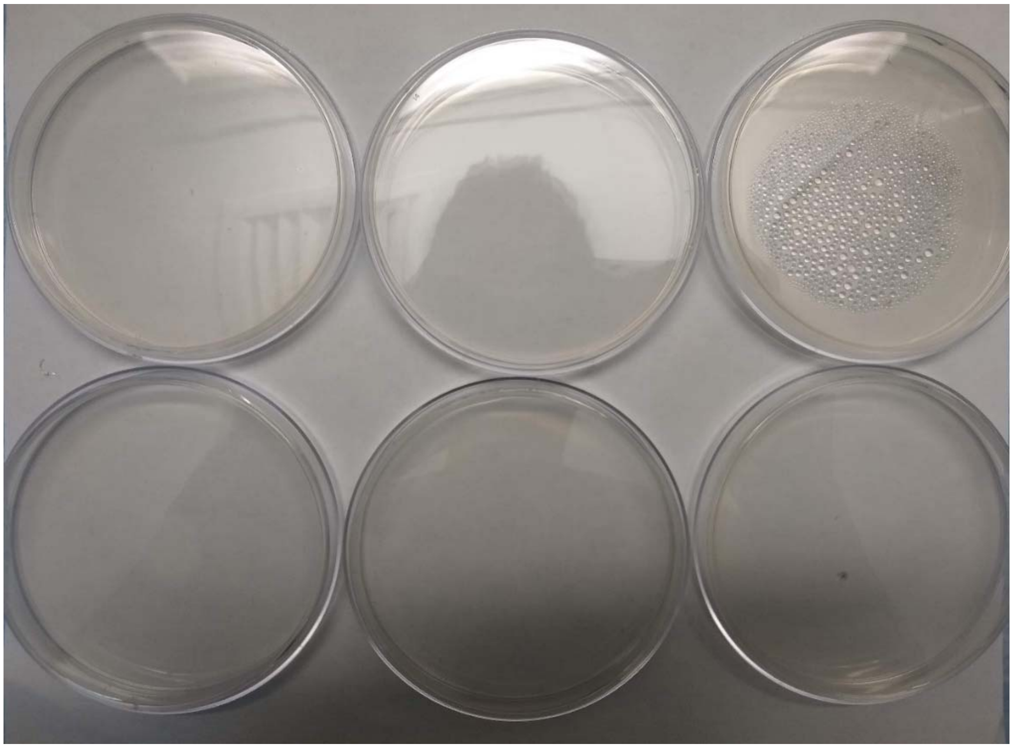

Figure 7. HPC plates after incubation at 35°C for 48-72 hours (Autoclaved sample)

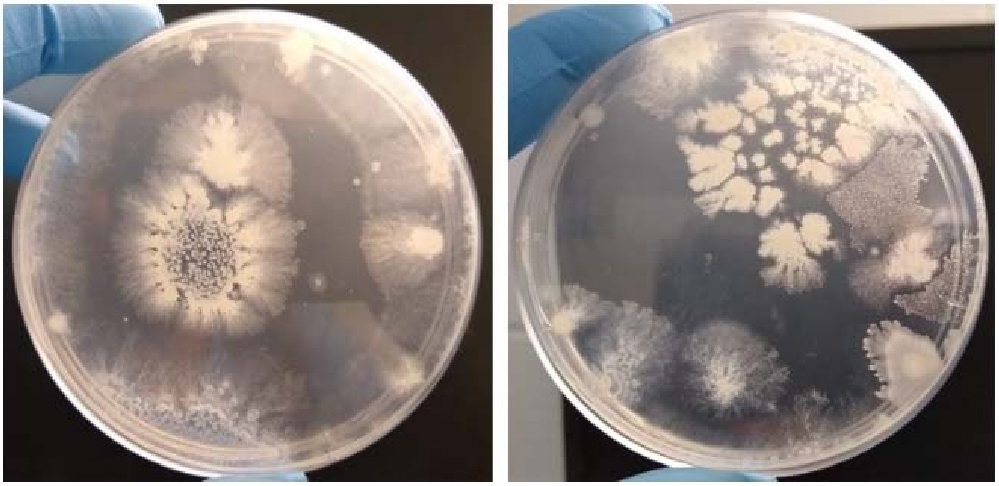

Figure 8. HPC plates after incubation at 35°C for 48-72 hours (Oven sterilized sample)

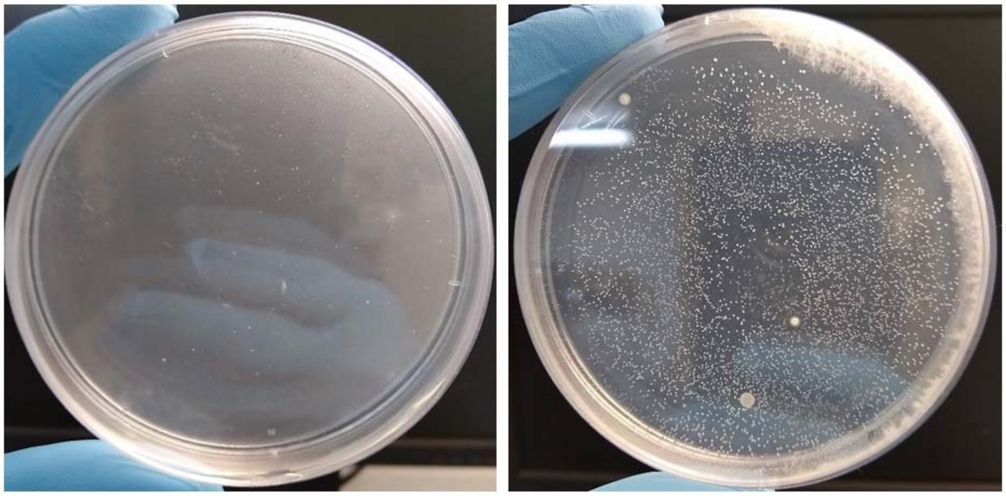

**Figure 9. HPC plates and bacteria growth in 48 hours after with samples stored 10 days at 35°C (Autoclave: left; Oven sterilized: right)**

The visible precipitate formation in the bottle was observed for all samples. However, the adherent scale was less in the case of autoclaved samples (**Figure 10**).

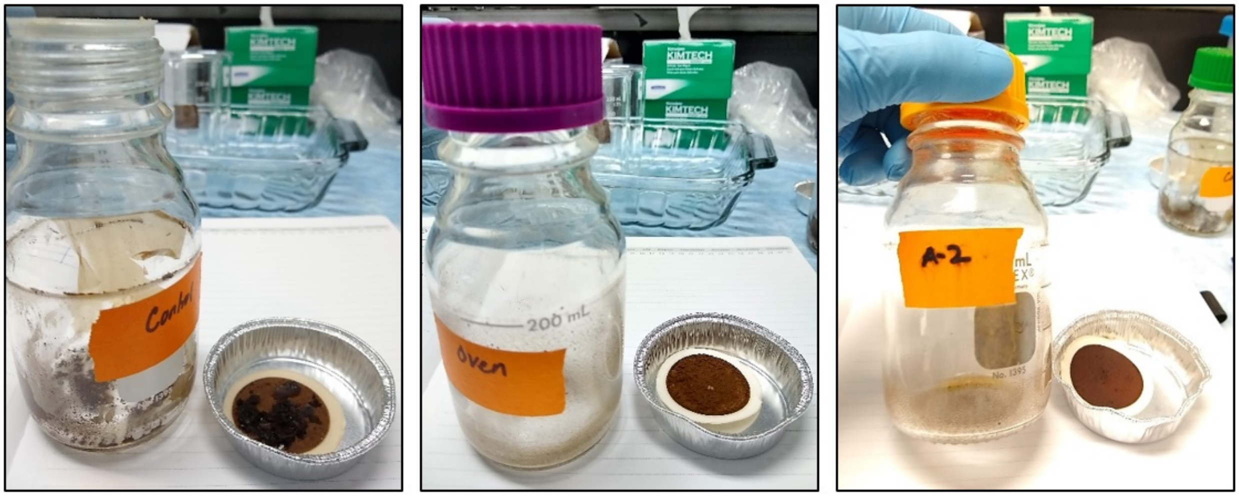

**Figure 10. precipitate in the vessel surface and 4.5-micron filters for control, oven sterilized and Autoclaved leachate sample from left to right respectively**

The second trial of sterilization experiment was conducted with stronger leachate (TDS: 33,890 mg/L, Ca: 2750 mg/L as $CaCO_3$, alkalinity: 5250 mg/L as $CaCO_3$). The results are presented in **Figure 11**. The total rate of precipitation was lowest (2390 mg/L) for autoclaved samples whereas the oven sterilized was the highest (3460 mg/L) and approximately similar to the control sample (3300 mg/L). However, adherent precipitation was maximum for the control sample (2465 mg/L) and lowest for the oven sterilized sample (985 mg/L). D

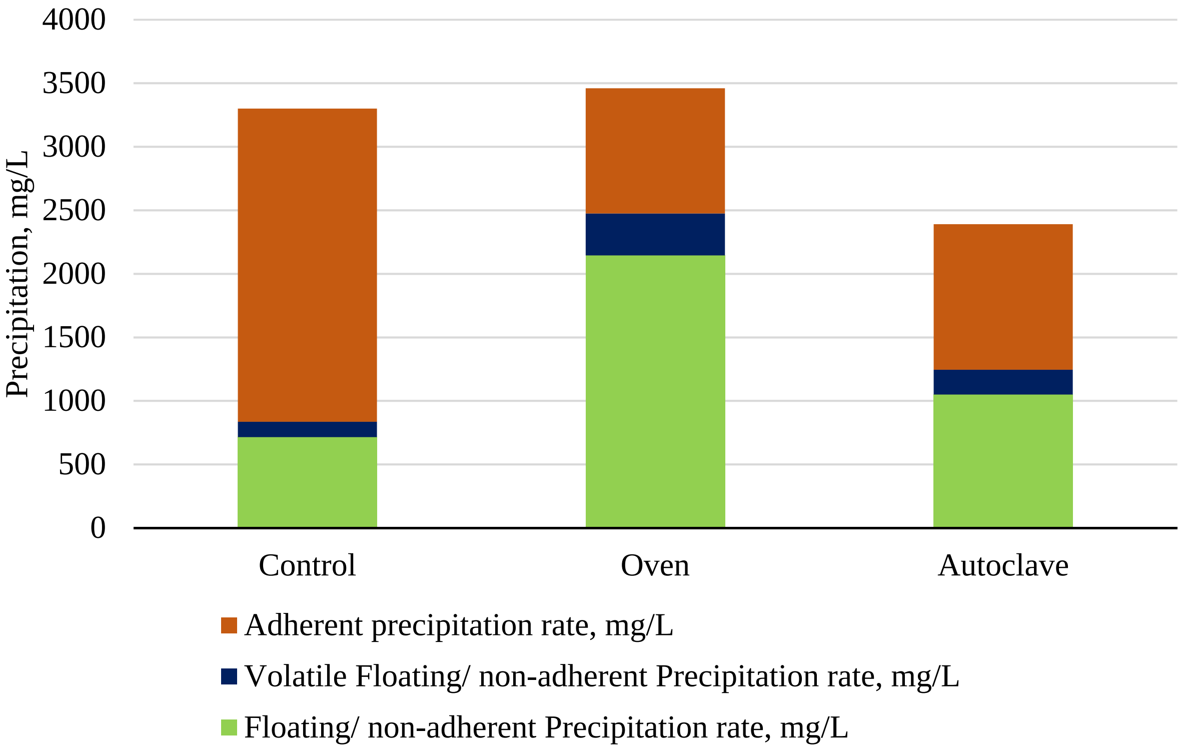

**Figure 11. Precipitation rate obtained from trial 2 with much stronger leachate compared to trial 1.**

In summary, it is evident from the result of trial 1 and trial 2 that the sterilization process reduces the rate of adherent precipitation that is difficult to remove. However, further investigation is necessary to better understand the phenomenon.

**TASK 3. Determine impacts of pH adjustment for precipitation control**. FAU investigated the different factors (**Table 5**) that influence changes in pH of leachate, which impact the precipitation/scale formation, including addition of $CO_2$, exposing to air, mechanical turbulence (500 rpm), as well as aeration with air.

**Table 5. factors that impacts pH changes in leachate**

| Factors | Change in pH |
|---|---|
| Addition of $CO_2$ | - |
| Addition of acid (HCl) | - |
| Sitting in open air | + |
| Turbulence (500 rpm) | + |
| Aeration | + |
| Addition of base (NaOH) | + |

The results are presented in **Figure 12**, **Figure 13**, **Figure 14**. Addition of $CO_2$ reduces the pH by almost 0.5 standard units regardless of the rate of addition, whereas keeping the leachate in contact with air and external turbulence increases the pH. In case of exposing leachate to air, pH increases and stabilizes within 30 minutes. However, external turbulence increased the pH almost linearly until 50 minutes in this study. Aeration increases the pH of leachate by almost 1.0 standard units found in previous studies conducted by FAU and UF (Townsend et al. 2016; Shaha 2016).

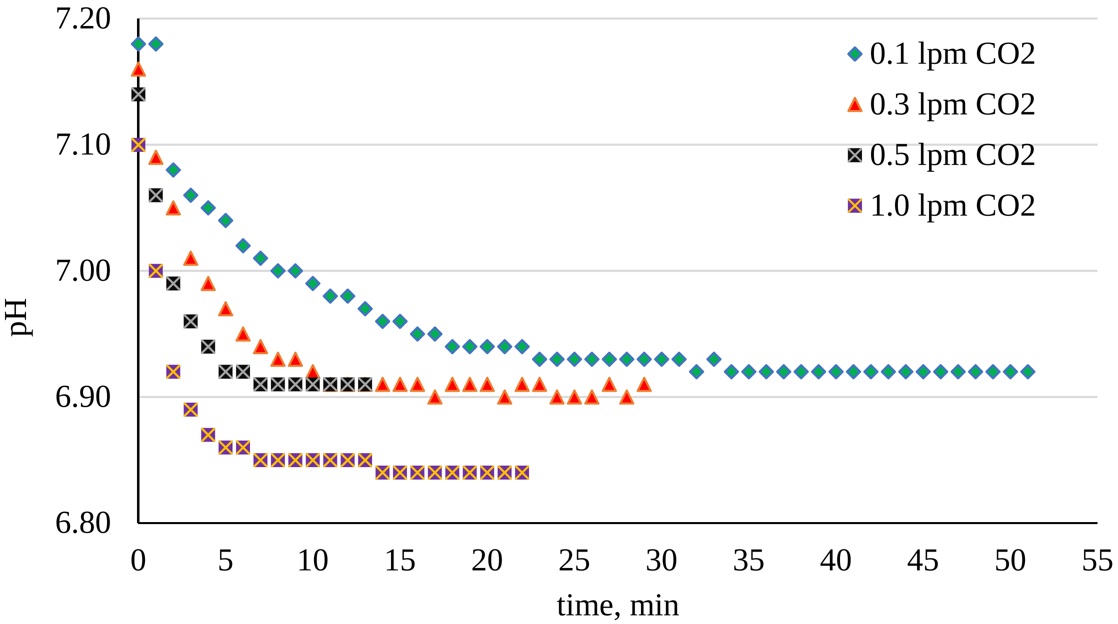

**Figure 12. Changes in pH due to addition of $CO_2$ at different rates**

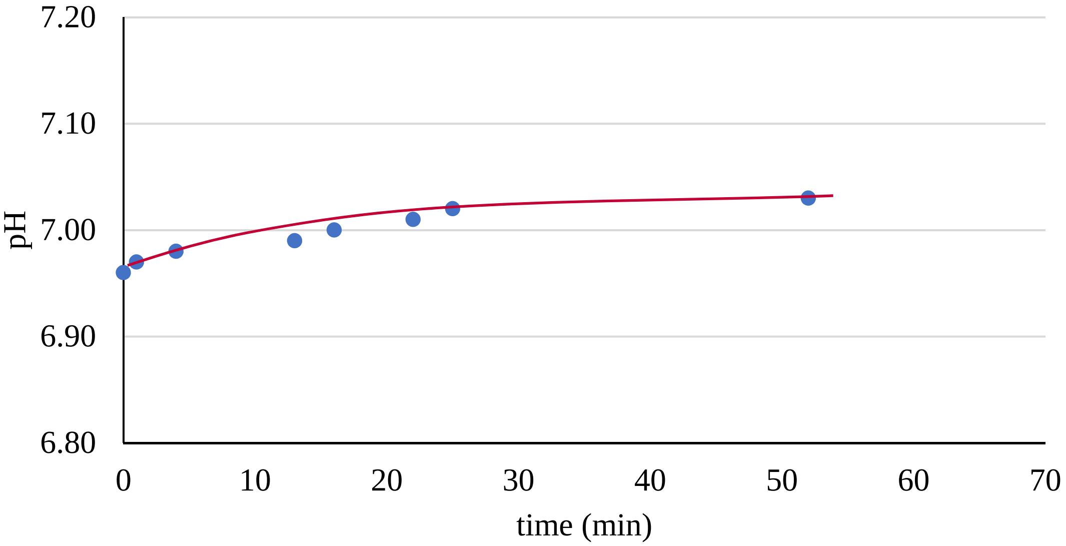

**Figure 13. Changes in pH by exposing leachate to open air**

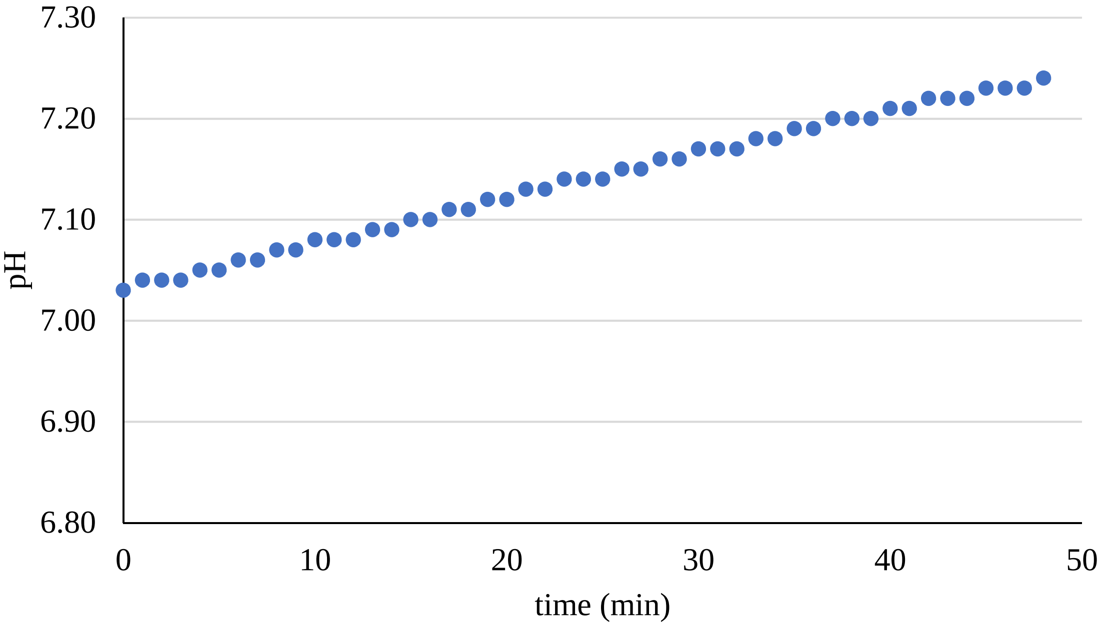

**Figure 14. Changes in pH by external turbulence (500 rpm)**

A laboratory experiment was conducted to quantify the impacts of pH changes to the overall leachate chemistry and the propensity for scaling. Leachate samples (200 ml) were pH-adjusted using various means (addition of air or $CO_2$ at different rates) and incubated at 35°C for 7 days to observe $CaCO_3$ precipitation rates. Initial and final volume of leachate was measured using a 200-ml graduated cylinder to account for the loss of leachate due to evaporation. Leachate water quality parameters (pH, conductivity, TDS, calcium, alkalinity, sulfate, sulfides, temperature) were measured at day 0 and day 7. Two different types of scale formation were observed during this process: 1) "Loose scale," which formed a thin, floating layer (**Figure 15**), and 2) "Hard scale," which attached to all surfaces of the vessel (**Figure 16**). Scale rate was calculated only using the mass of the hard scale attached to the surfaces and expressed in gram per liter of leachate (g/L). It was evident that initial higher pH resulted in higher "hard" scale rate and was difficult to remove (**Figure 16**).

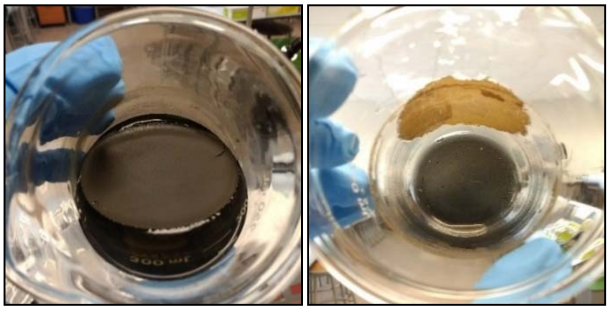

**Figure 15. pH adjustment and the impact on CaCO3 precipitation rate: loose scale. A visible floating layer (left) and the layer attached to the beaker surface after pouring out leachate from the beaker (right) (7 days)**

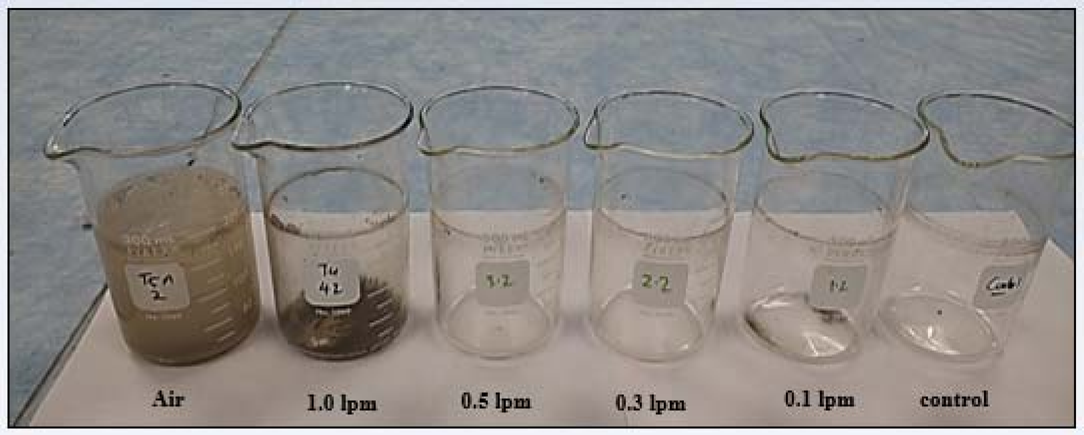

**Figure 16. pH adjustment and the impact on CaCO3 precipitation rate: hard scale attached to the surface (7 days)**

A small piece of loose floating scale was magnified 400 times and visualized under a microscope (

Figure **17**).

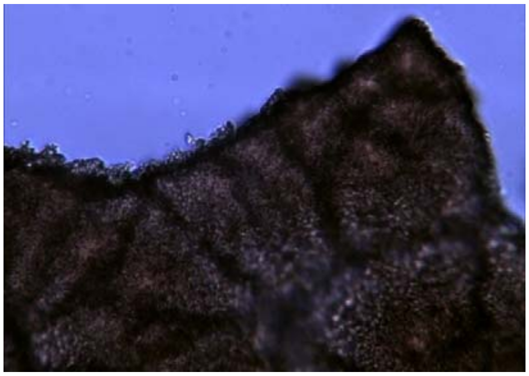

**Figure 17. Loose scale under microscope (x400)**

Precipitation of $CaCO_3$ by increasing pH using concentrated NaOH was magnified 400 times and photographed under the microscope as shown in **Figure 18**. The edges of the loose floating scale (

**Figure 17**) have reasonable similarity with the scale formed at higher pH (**Figure 18**). XRD/XRF analysis along with Rietveld analysis suggests that the precipitate formed are calcium carbonate.

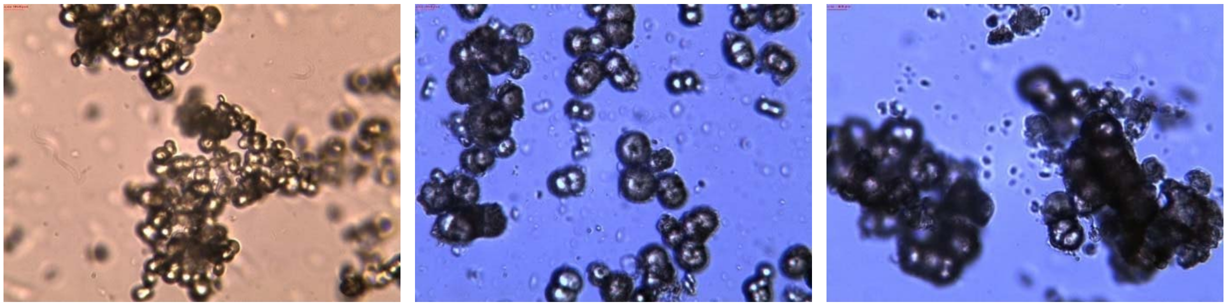

**Figure 18. Enhanced precipitation of CaCO3 with pH adjustment using NaOH**

**TASK 4. Determine downstream impacts to leachate disposal**. Using the data developed in Tasks 1-3, an assessment will be conducted to evaluate the impacts to ultimate disposal of leachate. FAU monitored each flow stream at the wet well prior to final discharge to the deep injection well. FAU also updated the mass balance chart to compare the estimated LSI based on flow and water quality of each individual streams with actual LSI calculated from the wet well leachate sample. A summary of the mass balance is presented in **Error! Reference source not found.**

**Table 6. A summary of the mass balance based on individual waste streams going to the injection well**

| Water Source | AVG monthly Q 2017-2018 MG/month | Min monthly Q 2017-2018 MG/month | MAX monthly Q 2017-2018 MG/month | pH | TDS mg/l | Alk mg/l as CaCO3 | Ca mg/l as CaCO3 | Cond mS/cm | Temp ºC | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **P/S A** | 3.0 | 0.6 | 6.8 | 7.04 | 17,400 | 1,574 | 3,330 | 24.19 | 28.7 | 5.46 | 1.58 | 3.88 |
| **P/S B** | 3.5 | 1.3 | 7.3 | 6.85 | 6,670 | 3,058 | 630 | 12.04 | 34.2 | 5.76 | 0.70 | 5.50 |
| **P/S C** | 1.4 | 0.7 | 2.7 | 7.61 | 3,561 | 1,750 | 775 | 7.39 | 31.1 | 5.85 | 1.80 | 4.10 |
| **P/S D** | 1.3 | 0.6 | 2.2 | 7.03 | 3,608 | 2,100 | 600 | 8.52 | 30.0 | 5.9 | 1.10 | 4.80 |
| **DYER** | 1.7 | 0.6 | 3.8 | 7.11 | 2,303 | 1,618 | 565 | 3.55 | 28.4 | 5.99 | 1.10 | 4.80 |
| **CISW** | 0.8 | 0.1 | 1.4 | 6.95 | 1,015 | 371 | 404 | 1.29 | 29.0 | 6.65 | 0.30 | 6.35 |
| **ISW** | 1.8 | 0.2 | 3.4 | 6.95 | 1,015 | 371 | 404 | 1.29 | 29.0 | 6.65 | 0.30 | 6.35 |
| **Plant water** | 6.9 | 5.0 | 7.9 | 7.17 | 3,644 | 155 | 1,364 | 4.57 | 32.5 | 6.65 | 0.85 | 5.79 |
| **NEFCO** | 5.9 | 4.6 | 7.4 | 5.39 | 1,153 | 400 | 300 | 4.37 | 37.5 | 6.65 | -1.26 | 7.91 |
| **AVG** | 26.2 |  |  | 7.22 | 4,176 | 1,010 | 972 | 6.82 | 32.3 | 6.13 | 0.85 | 5.15 |
| **MIN** |  | 13.7 |  | 7.10 | 3,769 | 733 | 984 | 6.34 | 33.6 | 6.15 | 0.98 | 5.28 |

| Water Source | AVG monthly Q 2017-2018 MG/month | Min monthly Q 2017-2018 MG/month | MAX monthly Q 2017-2018 MG/month | pH | TDS mg/l | Alk mg/l as CaCO3 | Ca mg/l as CaCO3 | Cond mS/cm | Temp ºC | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAX** | | | 42.8 | 7.35 | 4,721 | 1,341 | 986 | 7.50 | 31.1 | 6.05 | 0.88 | 4.91 |
| **DEEPWELL** | | | | 7.00 | 6,200 | 1,190 | 1,110 | 11.70 | 33.7 | 5.9 | 1.1 | 4.80 |

**TASK 5. Develop final recommendations and prepare publication materials**. Interim and final reports will be developed and submitted. A plan will be developed for follow-up work based on comments from reviews. Furthermore, a scholarly publication will be developed. In May 2019, the following paper was accepted for the World Environmental and Water Resources Conference in Pittsburgh, PA:

*Shaha, B.N. and Meeroff, D.E. (2019). Impacts of pH on leachate chemistry, $CaCO_3$ precipitation, and scaling potential (Oral presentation). In World Environmental and Water Resources Congress, May 2019, Pittsburgh, PA.*

## Upcoming Research Tasks

**TASK 1. Determine impacts of flow regime.** FAU will continue to collect and monitor the water quality parameters of leachate to identify any changes in the leachate and the impacts on calcium carbonate precipitation and clogging in the gravity collection system. In addition, FAU will also continue exploring the alternative source of dilution water and provide recommendations to the SWA of Palm Beach County.

**TASK 2. Determine impacts of biological activity trigger mechanisms.** FAU will continue to investigate the impacts of microbes in clogging using heat sterilization (autoclave). One of the major issues with autoclaving leachate is the drastic increase of pH during the autoclaving process due to the degasification of dissolved carbon dioxide as well as the changes in chemistry due to high pressure and temperature. Literature reviews suggest that the addition of acid prior to the autoclaving process may help to keep the pH under control. However, if the pH is still high, the addition of acid is recommended to lower the pH to its initial level. FAU will continue the experiments with pH balancing.

**TASK 3. Determine impacts of pH adjustment for precipitation control.** FAU will conduct laboratory experiments with varying pH by different means (acid, base, turbulence, and aeration) and estimate the differences in precipitation rate as well as the characteristics of the precipitates.

**TASK 4. Determine downstream impacts to leachate disposal.** Using the data developed in Tasks 1-3, FAU will keep updating the database and evaluate the impacts to ultimate disposal of leachate.

**TASK 5. Develop final recommendations and prepare publication materials.** Interim and final reports will be developed and submitted.

**PROJECT METRICS:**

1. List graduate or postdoctoral researchers **funded** by **THIS** Hinkley Center project.

| **Last name, first name** | **Rank** | **Department** | **Professor** | **Institution** |
|---|---|---|---|---|
| Shaha, Bishow | PhD Candidate | CEGE | Meeroff | FAU |

2. List undergraduate researchers working on **THIS** Hinkley Center project.

| **Last name, first name** | **Department** | **Professor** | **Institution** |
|---|---|---|---|
|  |  |  |  |
|  |  |  |  |

3. List research publications resulting from **THIS** Hinkley Center project.

None yet

4. List research presentations resulting from **THIS** Hinkley Center project.

*Shaha, B.N. and Meeroff, D.E. (2019). Impacts of pH on leachate chemistry, $CaCO_3$ precipitation, and scaling potential (Oral presentation). In World Environmental and Water Resources Congress, May 2019, Pittsburgh, PA.*

5. List research papers that have cited any publications (or the final report) resulting from this Hinkley Center project (use format for publications as indicated in the Hinkley Center Investigators Guide).

None so far

6. List additional research funding that has been secured due to leveraging the research results from this Hinkley Center project (give project title, funding agency, amount of funding, award date, and award period)

"Investigation of Leachate Management Solutions at the Solid Waste Authority of Palm Beach County (Year III)," Solid Waste Authority of Palm Beach County, $32,500, 10/1-2018 – 09/30/2019.

7. List submitted proposals which leverage the research results from this Hinkley Center project (give the proposal title, funding agency, requested funding, date submitted)

None yet

8. List new collaborations initiated based on this Hinkley Center project

None Yet

9. How have the results from this Hinkley Center funded project been used (not will be used) by the FDEP or other stakeholders in the solid waste field? Please note that the term “other stakeholders” is meant to broadly include any party or practitioner in the solid waste field. This includes county solid waste directors and their staff, municipal solid waste directors and their staff, solid waste facility design engineers, local/county/city solid waste management regulatory staff, federal solid waste regulatory staff, landfill owners and operators, waste haulers, waste to energy plant owners and operators, recyclers, composting plant owners and operators, yard waste operators, construction and demolition debris companies and organizations, county recycling coordinators, citizens and members of the academic community, etc. (1 paragraph maximum)

To date, the results have not been used by stakeholders yet.

**TAG members:**

Mark Eyeington, Mark Maclean, Mark Bruner, Owrang Kashef, D.V. Reddy, Craig Ash, Ravi Kadambala, Ron Schultz, Jeff Roccapriore, André McBarnette, Dan Schauer, Damaris Lugo, Amanda Krupa, Richard Meyers, Amede Dimonnay, Art Torvela, Ted Batkin

**TAG meetings:**

October 19, 2018 (Joint TAG meeting held at SWA in conjunction with UM)

## References

Shaha, B. N. (2016). *Effect of electronic water treatment system on calcium carbonate scaling*. Florida Atlantic University.

Townsend, T., Meeroff, D.E., and Schert, J. (2016). Critical examination of leachate collection system clogging at SWA disposal facilities. Final Report.