**Memorandum**

To: Kevin R. Gilmore, P.E.

From: CENG Laboratory Team Devinci: Deborah Sills, Matt Higgins, and Kevin Gilmore

Date: August 30, 2011

Re: Results of Marcellus Shale Wastewater Treatment Evaluation

**INTRODUCTION**

Marcellus Shale is a rock formation found approximately one mile beneath the northeastern United States (New York Times, June 29, 2011). The formation contains significant reserves of natural gas, which constitutes a valuable natural resource for the U.S. (Kargbo et al., 2010). This natural gas is extracted by drilling and fracturing the shale with high-pressure water, which allows the gas to flow out of the well. However, large quantities of water are needed for this process, and the wastewater that is generated is very salty. The challenge for Pennsylvania is to recover this natural resource without causing environmental damage.

The objective of this experiment was to determine if a treatment process was effective in reducing the amount of salt in the wastewater. It is hypothesized that the chemical treatment process employed should result in a significant reduction in salt.

**METHODS**

Samples of Marcellus wastewater, before and after the treatment process of interest, were evaporated to leave only residual salt. The masses of four replicates of each sample (container plus dry salt) were measured using an analytical balance, and the masses of the empty containers were subtracted to determine the masses of salt. Mass values were converted to concentration by dividing by the initial sample volume. An example calculation is shown in Appendix A. Results were recorded, and statistical analysis was performed using spreadsheet software (Microsoft Excel, Redmond, WA).

**RESULTS AND DISCUSSION**

The results of the measurements are shown in Figure 1 (with raw data provided in Appendix B). As can be seen from the data, the average concentration of salt in the treated samples was significantly less than the average in the untreated samples (P<0.05). Thus, the hypothesis was confirmed, that the treatment process significantly reduced the salt content of the samples. Visual observations of the dry samples also suggested that the treatment process had an effect on the samples, as the untreated samples had a brown, rust-like color while the treated samples did not. It is possible that the treatment process removed the iron and other heavier metals from the wastewater, causing the change in color. Both sample sets had nearly identical variability, with confidence intervals of less than 1% of the mean for both sets.

On the other hand, even though the treatment resulted in a significant reduction in salt content of the samples, the concentration of salt is approximately two orders of magnitude larger than the concentrations allowed to be received by Publicly Owned Treatment Works (POTWs) in Pennsylvania. In addition the data presented in Figure 2 demonstrate that the reduction in salt concentrations due to treatment is not practically significant.

**Figure 1. Average salt content of untreated and treated wastewater samples. Error bars represent 95% confidence intervals.**

*…or, if you chose to present this summary data as a table ( note location of titles )…*

**Table 1. Average salt content of untreated and treated wastewater samples.**

|  |  |
| --- | --- |
| **Sample Type** | **Average TDS Concentration, mg/L** |
| Untreated | 115,217 (+/- 604) |
| Treated | 113,207 (+/- 606) |

a Values in parentheses represent 95% confidence intervals, alpha = 0.05.

**CONCLUSIONS**

By confirming the effects of the treatment process, the objective of the experiment was achieved. However, the treated samples still have much more salt than is allowed in wastewaters received by POTWs, so additional treatment should be investigated. Furthermore, the economic viability of the process must be investigated prior to broader implementation.

**APPENDIX A: SAMPLE CALCULATION**

Mass of salt in sample, g = Dry mass of crucible & salt after drying, g – Initial dry mass of empty crucible, g

Example, Crucible 1: 66.1044 g – 62.4533 g = 3.6511 g

**APPENDIX B: RAW DATA**

Untreated Samples

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Crucible # | Initial Dry Mass, g | Dry Mass With Salt, g | Mass of Salt, g | Average Mass of Salt, g | Standard Deviation, g | 95% Confidence Interval, g |
| 1 | 62.4533 | 66.1044 | 3.6511 | 3.80 | 0.14 | 3.80 +/- 0.13 |
| 2 | 66.4692 | 70.3421 | 3.8729 |
| 3 | 66.8384 | 70.7031 | 3.8647 |
| 4 | 64.1416 | 68.1044 | 3.9628 |

Treated Samples

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Crucible # | Initial Dry Mass, g | Dry Mass With Salt, g | Mass of Salt, g | Average Mass of Salt, g | Standard Deviation, g | 95% Confidence Interval, g |
| 5 | 65.3160 | 67.9100 | 2.5940 | 2.20 | 0.51 | 2.20 +/- 0.44 |
| 6 | 65.0877 | 66.3995 | 1.3118 |
| 7 | 64.9616 | 67.3220 | 2.3604 |
| 8 | 64.5363 | 66.8237 | 2.2874 |

**REFERENCES**

Last Name, First Name. (Year) Title of journal article or equivalent document. J. Haz Waste and Soc. Volume(**Issue Number**): startpage – end page.

Kargbo, D. M., Wilhelm, R. G., Campbell, D. J. (2010) Natural gas plays in the Marcellus shale: challenges and potential opportunities. *Environ. Sci. Technol*. **44**(2): 5679-5684.

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