SUMMARY: SUSTAINABLE MANAGEMENT OF POLLUTANTS UNDERNEATH LANDFILLS

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Elevated levels of iron have been observed in groundwater and soils around municipal solid waste landfills in Florida. The levels have been attributed to reductive dissolution of the native chemistry in the soil perhaps caused by a shadowing effect of the landfill liner, which inhibits the reaeration of the shallow aquifer beneath a properly lined landfill. In this study, the research team will refine a preliminary list of potential engineering management alternatives for controlling the release of contaminants in-situ and conduct laboratory experiments on management methods for dealing with this issue. In a previous research grant, "*Management of subsurface reductive dissolution underneath landfills*," funded by the Hinkley Center, an innovative groundwater circulation well technology was investigated for control of iron releases in-situ.

The source of the elevated iron contaminations has not been verified yet, but is potentially caused by either one or both of the following mechanisms: 1) direct release of iron from the municipal solid waste leachate, or 2) naturally-occurring iron mobilized from the soil due to changes in soil chemistry or local hydrology. It is clear from our previous literature review as part of the previous project, "*Management of subsurface reductive dissolution underneath landfills*," that if the fate of released iron depends on the biogeochemistry, then we would see a strong influence of pH, redox, and microbial conditions on iron speciation. If the main cause of iron mobilization is microbially-mediated, then the natural organic material in the soils will be the primary food source that is consumed by microorganisms that will utilize all of the available oxygen in the subsurface leading to reducing conditions that foster iron mobilization. If the landfill gas (CO_2 + CH_4) is entering the system and somehow displaces the oxygen and adds organic matter to the soil, then this could stimulate the microbially-mediated reductive dissolution of iron. Finally, if the presence of the landfill cuts off recharge of oxygen to the subsurface, this would have the effect of artificially boosting the mobilization of iron in the subsurface.

Regardless of the source of the elevated iron, the next step is to develop an effective strategy for remediation. The research team will focus on identifying viable engineering alternatives that will minimize the potential disturbance to the system, limit treatment costs, and produce the most effective results. The goal of this research is: 1) to investigate the key parameters governing reductive dissolution of iron; 2) to develop a list of engineering management alternatives for controlling the release of iron in-situ; and 3) to conduct laboratory experiments on methods for iron and co-contaminant removal from groundwater at landfill impacted sites.

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PROGRESS REPORT
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Project Title: Sustainable Management of Pollutants Underneath Landfills
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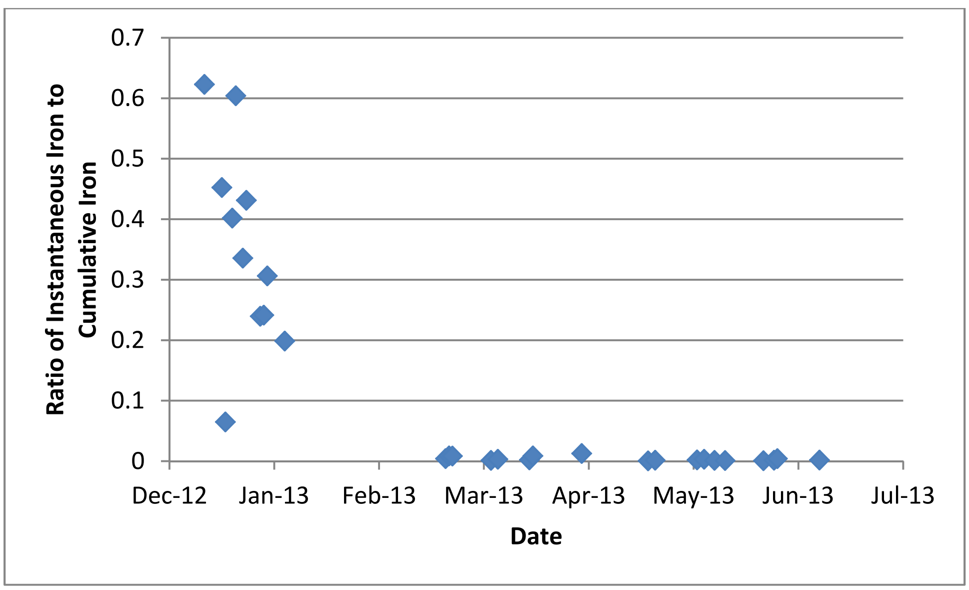
Progress to Date:

- **Task 1**. **Conduct a literature search of key parameters governing reductive dissolution**. Ahmed Al Basri is conducting a review of the historical data from landfills experiencing iron dissolution problems as well as the known causes of reductive dissolution such as: biogeochemical, microbial, hydrologic, soil chemistry (pH, Eh, iron sequestration, iron mobility), and leachate pollution. Al Basri is also investigating literature on the co-liberation of toxic metals with iron to evaluate the potential problem of arsenic levels. The landfill can create an effect that increases the iron mobility by blocking the oxygen from percolating in the soil in addition to potentially feeding the soil with high level of organics from leaks involving leachate, which increase microbial consumption of the existing dissolved oxygen and increase redox potential. However, unpredictable factors can play a vital role in increasing the redox potential. In addition, information about the microbiological profile of the soil underneath landfills to confirm this is not available.

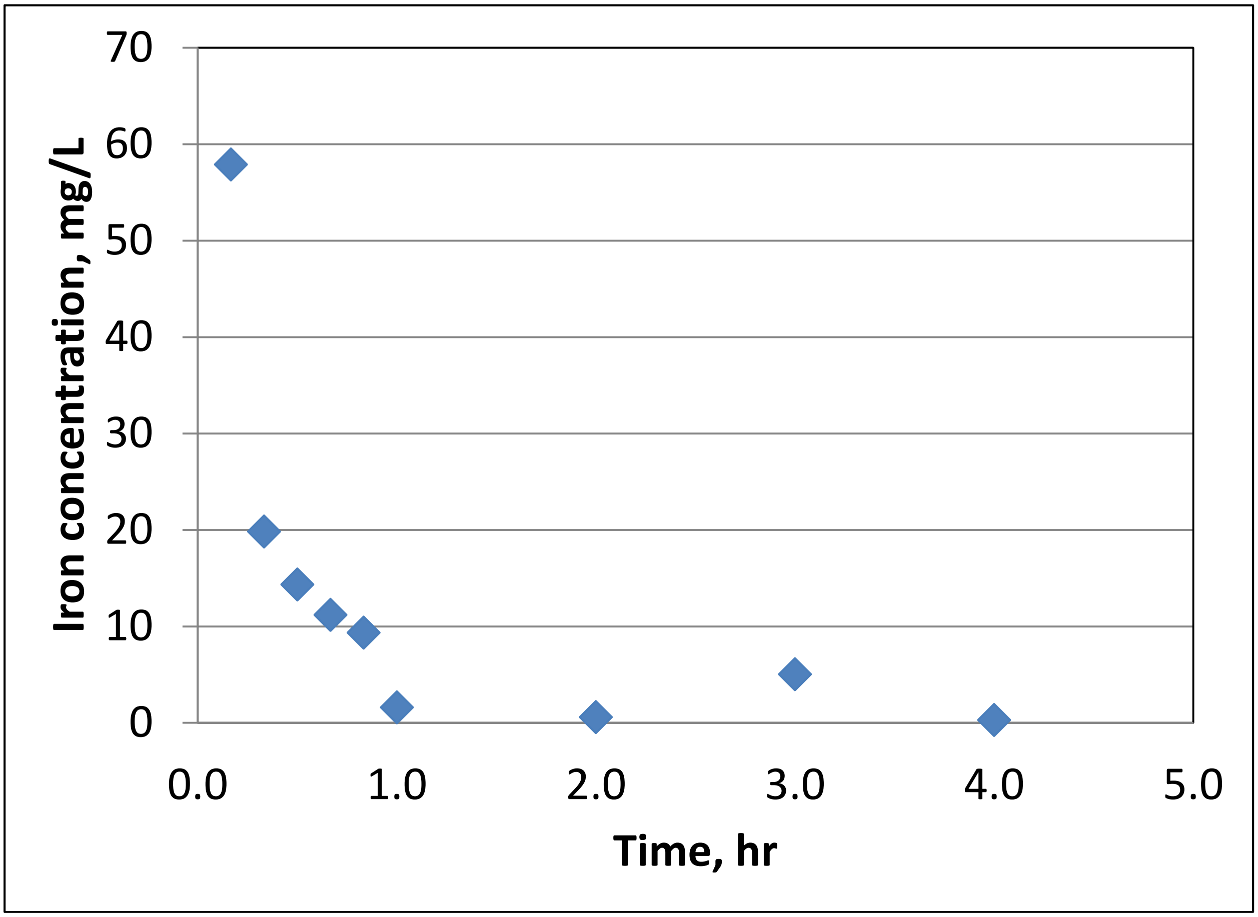
  Task 2. Refine a list of engineering alternatives for managing elevated iron levels. Ahmed Al Basri is continuing his literature review based on the previous work done by former graduate students Richard Reichenbach and André McBarnette. Mr. Al Basri has focused his search on the literature review of in-situ management methods for iron mitigation that are currently available. These include but are not limited to: aeration, oxidation agents, chelation/iron sequestration, pH control, bioprecipitation/bioremediation, zero valent iron, trench fill, ion exchange, advanced oxidation, recirculating well technology, and others like adsorptive filtration. These alternatives will be evaluated for process efficiency, ease of operation, minimal site disturbance, and environmental considerations. Iron can be treated in soil by different methods depend on the type of iron and the source. If bacteria are the main reason for the elevated iron, disinfection can be effective. If the source is related to mobility of ferrous iron due to physical-chemical factors, then chelation, pH control and aeration can be used. The groundwater circulation well technology is an in-situ method to immobilize iron regardless of the source as long as the iron contamination plume is limited in area and the thickness of the plume is less than 15 meters, in most cases. This technology will be further investigated in this study.

  Task 3. Conduct laboratory experiments on selected treatment technologies for managing iron dissolution. The Laboratories for Engineered Environmental Solutions (Lab.EES) is equipped with the capability to conduct laboratory-scale subsurface testing using aquaria (rectangular glass containers) to simulate the reducing conditions underneath a landfill and evaluate in-situ management controls for attenuating the mobility of iron in the subsurface. In the previous project, "*Management of subsurface reductive dissolution underneath landfills,*" the groundwater circulation well technology was the focus of preliminary investigations. The conditions for the testing were refined, and testing for several weeks of treatment was conducted. However, a major problem arose with the protocol for quantifying the concentration of iron in the well. After consulting with colleagues from the University of Florida, it was determined that the ferrous iron test needs to be modified and a total iron test using ICP-MS should be run for iron speciation in our samples. So we plan to use this protocol in task 3.

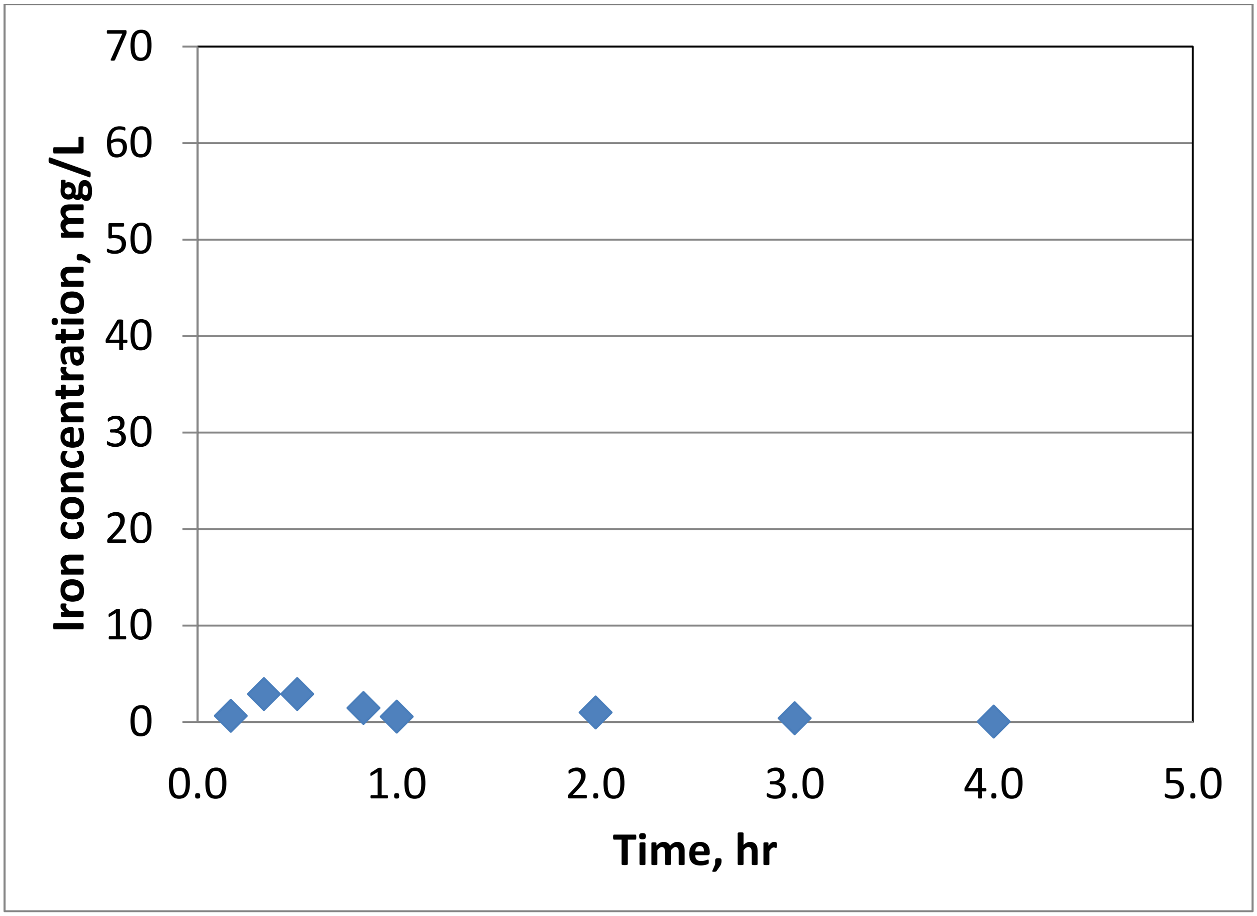
Currently, feasibility tests are being conducted using the contaminated soils and groundwater samples collected in year one to develop the appropriate treatment conditions for scale-up, including parameters such as: aeration conditions, mixing, radius of influence, depth, drawdown, hydraulic grade line, hydraulic conductivity, porosity, and process removal efficiency at the end of the treatment time of several weeks. The effects of soil variations will be investigated by comparison with Boca Raton soils and by collecting samples from various locations at the Polk County landfill at different times of the year. It has been found that both of the soils have an aggressive capability to absorb spiked iron concentrations in excess of 100 mg/L. Therefore, the test containers were saturated with high levels of iron until an equilibrium level could be achieved in the groundwater. So far, equilibrium conditions have been achieved in soils collected on 11/09/2011 from SE and SW of the Lakeland landfill and the others have not yet. An example of a sample that has not achieved equilibrium is shown in the figure for the SE Lakeland sample taken on 05/11/2011 (sample 3), which shows an unstable decrease during the spiked iron loading process.



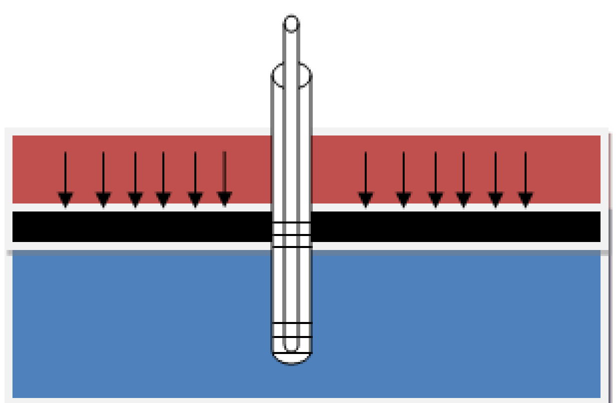
The containers with the SE and SW samples were run as a groundwater circulation well to test the possible immobilization effects of the aeration process. The first sample shows excellent removal in the first hour of treatment, which is a similar to the result obtained for the previous experment run in October 2012, but the effect of soil adsorption for the iron made the results unclear.



The SW sample did not show similar results due to starting at a much lower initial iron concentration level after equilibration (14 mg/L vs. 60 mg/L).



The other samples are continuing the equilibration process. In addition, the Boca soil tests will be repeated. The iron spiking process did not show iron percolation to the entire depth of the soil to increase the overall soil content but instead the added iron stayed on the upper layer leaving an impermeable precipitate layer as shown in the sketch below:



The next step is to guarantee that the iron is equally distributed within the soil. First, the soils in the containers with the spiked iron will be removed and made into a slurry, which will be well-mixed and then loaded back inside the container. That step should make the role of the groundwater circulation well more clear and should guarantee saturation of iron over the entire depth of soil.

To test the radius of influence of the well, a simple monitoring well was devised to be able to measure the effects of the groundwater circulation well at several distances from the main aeration well, as shown in the photos below. The monitoring well is basically a modified 1.0-mL pipet tip installed in the container with a layer of gravel around the tube to prevent clogging.

In June 2013, an additional graduate student, Jenna Bobsein, was hired to assist in the project.

- **TASK 4. Develop final recommendations**. Using the data developed in Tasks 1-3, an assessment will be conducted to evaluate the recommended management approaches to deal with reductive dissolution issues underneath Florida landfills. If the recirculating aeration wells tested in task 3 are found to be successful in ameliorating the iron dissolution issue (with the goal of lowering the iron concentration to below 0.3 mg/L), the process will be evaluated for a preliminary cost analysis and a preliminary model for scale-up will be developed. The preliminary cost analysis will include the capital cost (recirculation well, aggregates, fittings, blowers, connection tubes, installation cost, etc.) and the operating cost (electricity, maintenance, operator fees, etc.). No work has been initiated on this to date.

- **TASK 5. 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 of same. Furthermore, a scholarly publication will be developed, including but not limited to, a poster and a conference paper.

Research planned for the upcoming months:

- Complete the preliminary literature review.
- Complete aquarium-scale preliminary testing.
- Develop design model and cost estimates.