SUMMARY: SUSTAINABLE MANAGEMENT OF POLLUTANTS UNDERNEATH LANDFILLS

Daniel E. Meeroff (PI)[1]

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.

[1] Associate Prof., Dept. of Civil, Environmental & Geomatics Engineering, Florida Atlantic University, 777 Glades Road, 36/222, Boca Raton, FL 33431-0091, Phone: (561) 297-3099, FAX: (561) 297-0493, E-Mail: dmeeroff@fau.edu

PROGRESS REPORT
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Project Title: Sustainable Management of Pollutants Underneath Landfills
Principal Investigators: Daniel E. Meeroff, Ph.D.
Affiliation: FAU
Phone number: (561) 297-2658
Project website: http://labees.civil.fau.edu/leachate.html

Progress to Date:

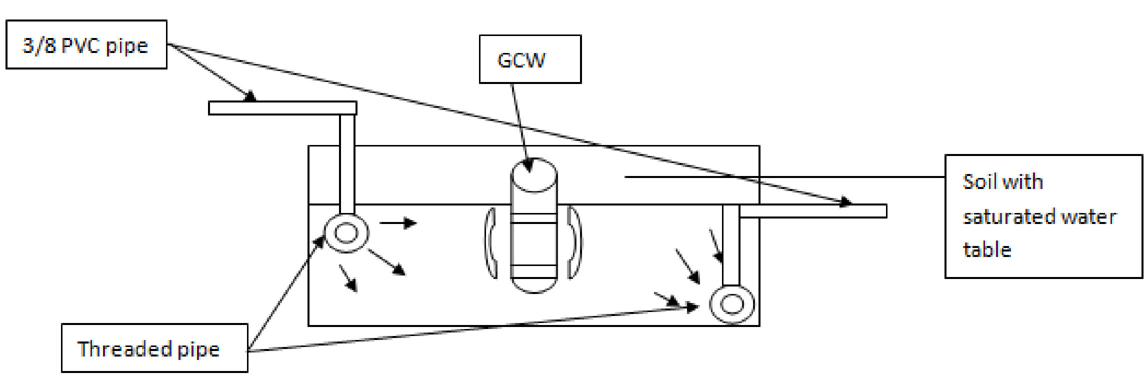
- **Task 1**. **Conduct a literature search of key parameters governing reductive dissolution**. Ahmed Al Basri is near completion of his review of the historical data from landfills experiencing iron dissolution problems as well as the known causes of reductive dissolution such as: biogeochemical, microbial, hydrologic, soil chemistry (pH, Eh, iron sequestration, iron mobility), and leachate pollution. Another student, Jenna Bobsein, is conducting a review of alternative methods for dealing with iron that include air sparging applications as well as pump and treat with surface iron aeration. She analyzed published field data from a North Carolina study to determine operating ranges for hydraulic conductivity, iron removal, distance to the groundwater table, flow rates, pressures, dissolved oxygen concentrations, radius of influence, and well materials and sizes.

  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. Jenna Bobsein is investigating pump and treat methods with surface aeration for removal of iron as a competing process to air sparging, direct push technology, or conventional groundwater circulation wells. The key issue is biofouling.

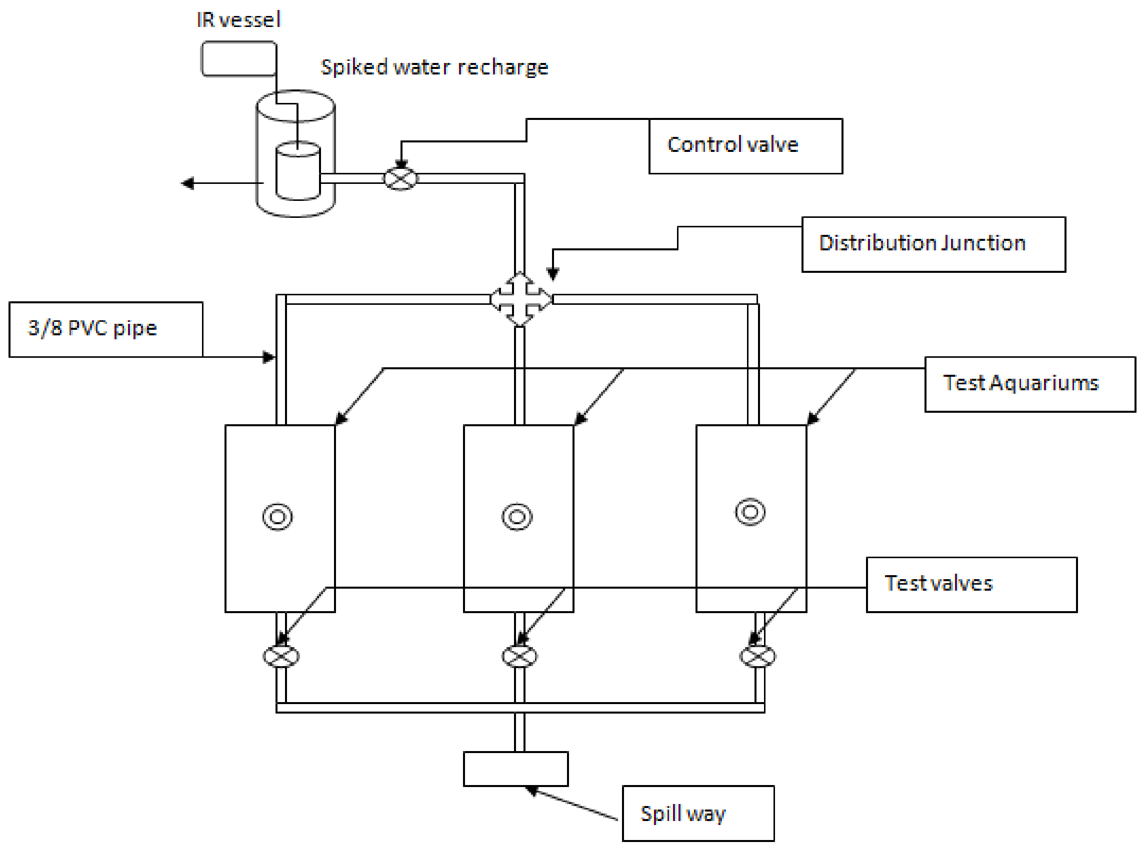
  Task 3. Conduct laboratory experiments on selected treatment technologies for managing iron dissolution. The Laboratories for Engineered Environmental Solutions (Lab.EES) is equipped with the capability to conduct laboratory-scale subsurface testing using aquaria (rectangular glass containers) to simulate 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.

On August 6, 2013, Al Basri presented his preliminary findings to his thesis committee, and it was determined that the formation of an iron oxide layer in the lab aquarium model prevented the percolation of the surface water sample spiked with elevated iron, the suggested plan was to mix the landfill soil with high iron concentration solution instead of continuing to spike the aquaria with more batches of iron solution to reach a stable equilibrium. The committee decided to alter the process to overcome this clogging limitation by introducing the iron via the subsurface in a hydrostatic mode using actual spiked groundwater from the City of Boca Raton municipal water treatment plant raw water wells.

The main target currently is to prove the validity of process out of treating the targeted soils containing different levels of spiked iron. The first set of experiments will utilize sandy soils collected from Boca Raton, FL. There was adjustment in the design of the experiment to create subsurface equilibrium conditions by continuous subsurface feed flow using 2 pipes with slits (the first pipe will feed the aquarium with spiked iron groundwater and the second one will be located downstream to channel the groundwater outflow. Each one of the pipes are surrounded by a fine layer of gravel to act as a filter to protect from pipe/soil clogging due to accumulation of precipitates or biofouling, each one of the pipes are connected to vinyl tube to distribute and collect the groundwater as shown in figure below :



After balancing the flows, the three aquaria are going to be provided from the same source of spiked water with different air flow rates to determine the optimum aeration rate to maximize iron removal and minimize plugging/fouling. The experimental setup is shown as follows:



Currently, Al Basri is completing the construction of the aquarium test at the FAU Lab.EES facility prior to transferring the apparatus to the Boca Raton Water Treatment Plant lab. Some photos of the perforated inflow and outflow pipes are shown as follows:

- **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 continuing literature review.
- Complete aquarium-scale preliminary testing and begin groundwater testing at Boca WTP.
- Design an experiment for the pump and treat with surface aeration process and collect data for comparison to the GCW technology.
- Develop design model and cost estimates.