Microcosm Study on Mineralogical changes of post Molasses Injection with Savannah River Site (SRS) F-area Sediments

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Site Overview

- SRS reservation located in SC adjacent to the Savannah River (1950s)
- Refined nuclear materials
  - tritium & plutonium-239
- 310 square miles that included:
  - five reactors
  - two chemical separation plants
  - heavy water extraction plant
  - nuclear fuel and target fabrication facility
  - waste management facilities
- Discontinued in 1988
- Remained operational with non-defense related activities

www.storenuclearfuel.com

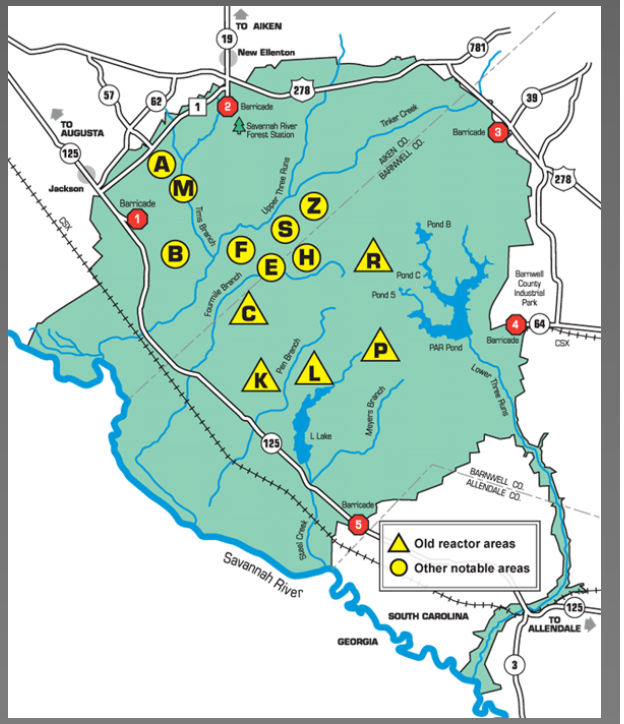


Photo by srs,gov

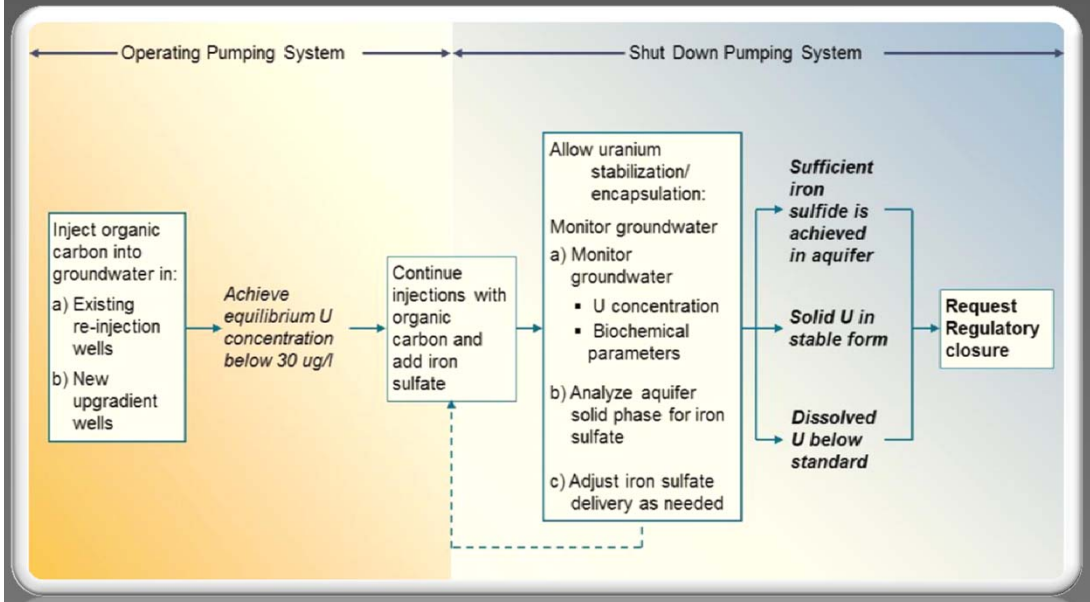
Present Condition

- Owned by the U.S Department of Energy (DOE)
- Placed on EPA's National Priority List (NPL) of contaminated sites (1989)
- The main concern: high-level-waste tanks
  - store highly radioactive liquid waste
  - considered by the DOE and the South Carolina Health and Environmental Control (SCDHEC) as "the greatest human health risk in South Carolina"
- No tank leaks

Background

- Major concern → proximity to the Savannah River
- *In situ* bioremediation technologies are being researched and implemented in several underground water plumes
  - Cost effective way to deal with the groundwater contamination
- Factors that influence *in situ* remediation:
  - Equilibrium relations between contaminant phases
  - Biological and geochemical processes
  - Characteristics affecting reductive and oxidative conversion parameters
  - Chemical and biological availability

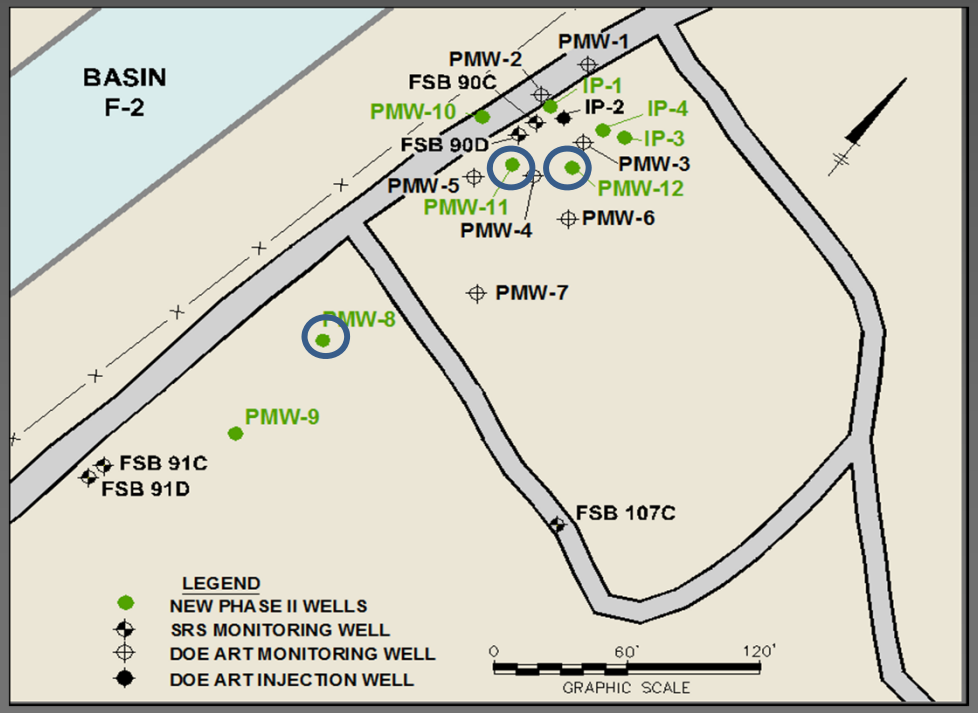
ARCADIS Technology



Picture from ARADIS presentation for DOE July

- Enhanced Anaerobic Reductive Precipitation (EARP)
  - Targets metals and radionuclides
- *In situ* Reactive Zones (IRZs)
- Produced anaerobic conditions through microbial action
- Uranium is a redox-sensitive radionuclide

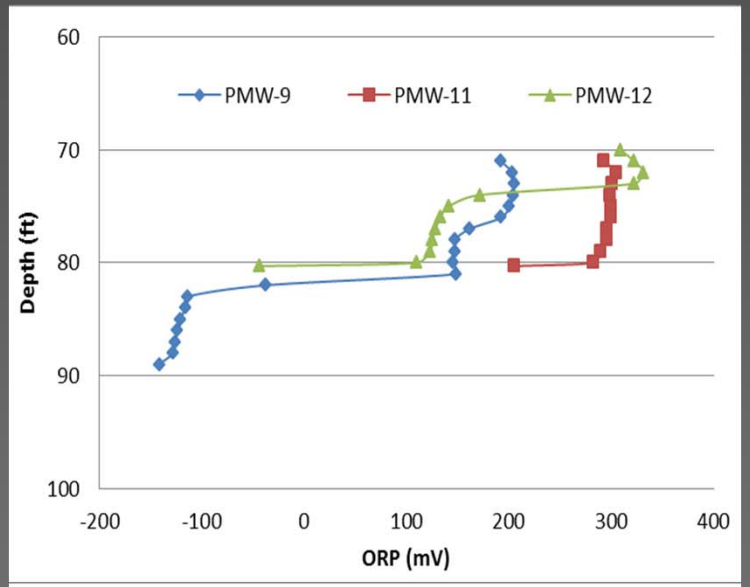
Depth Profile Analysis

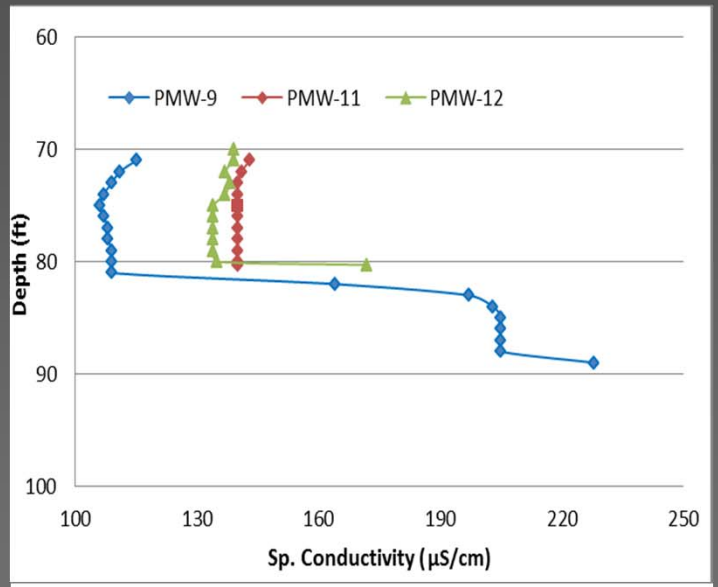


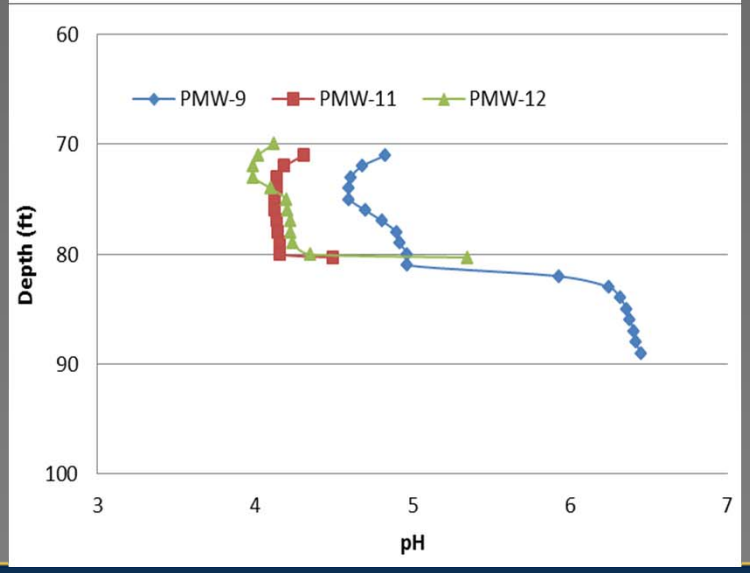
Srs.gov

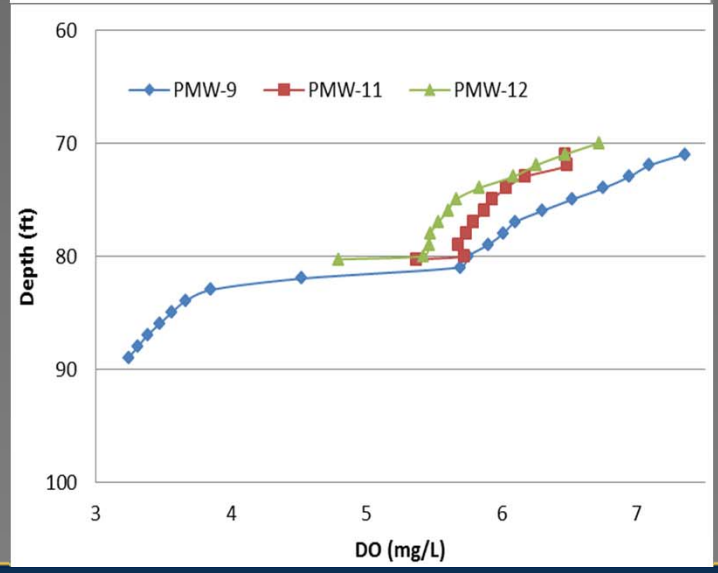
- Contamination source: radiological waste
  - Nuclear reactors
  - Support facilities

Depth Profile Analysis



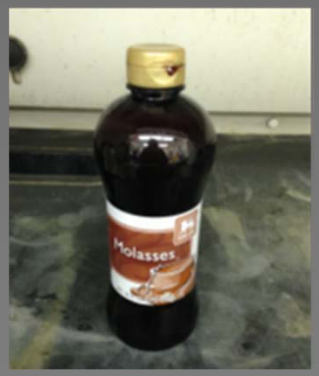




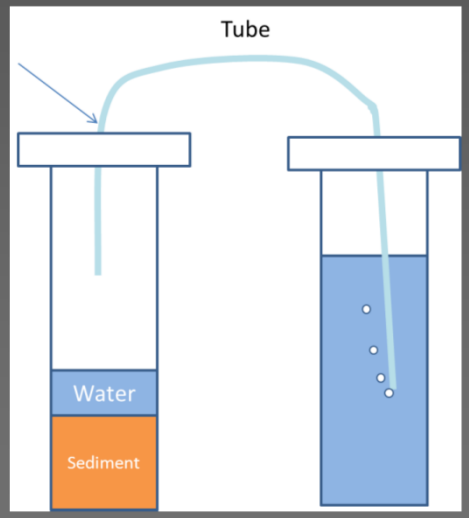


Previous Experiments

- 20 mL of sediment
- 10 mL solution mixture
- DI water
- 0.014 g of $NaNO_3$ (equivalent to 200 mg/L)
- 7 g of molasses (equivalent to 20% by weight of the solution).



Microcosm set up



Wrap tape around the tube to prevent any possible air exchange

Previous Experiments

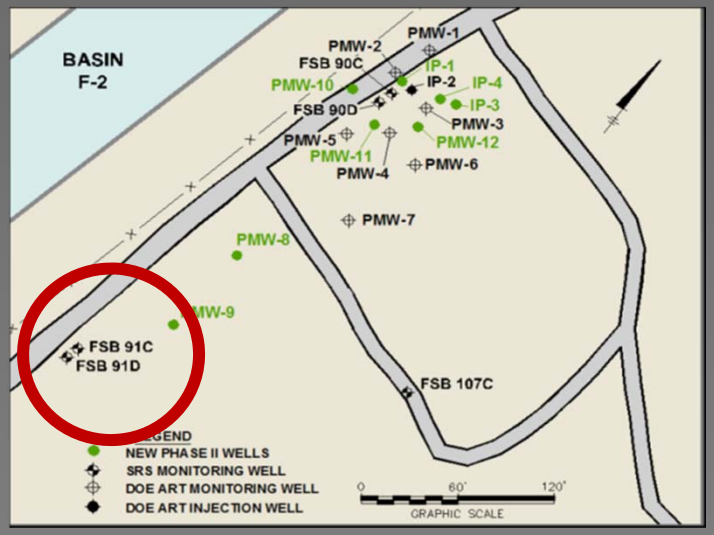
Unsuccessful experiment → Why?

- Slow rate of bacterial growth
- Air inside the tube
- System was not completely sealed off
- Bacteria were not present in the soil

Samples after 4 Weeks

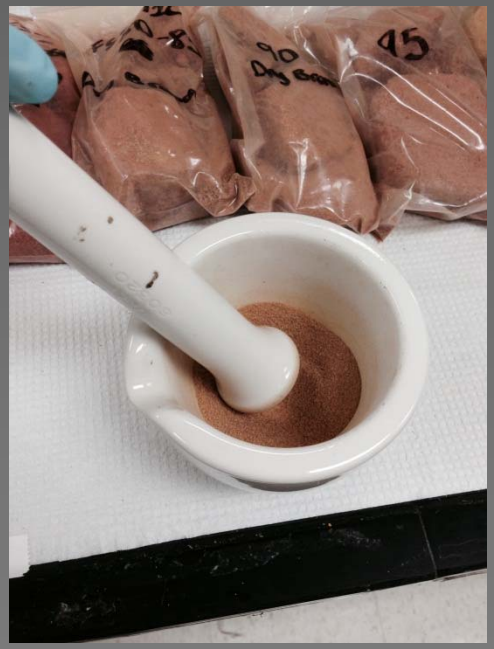
Sample Source

Core samples from FSB 91C



New Experimental Approach

Anaerobic Chamber → Prevents O_2 from entering the system



Experimental Approach Con't

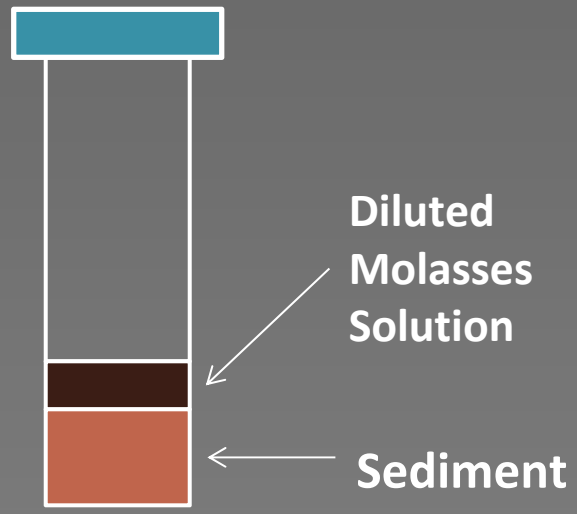
- To enhance bacterial growth, a basal medium was added to the solution

The basal medium (per liter)
1.5 g $NaHCO_3$
0.2 g NH_4Cl
0.1 g $K_2HPO_4 \cdot 3H_2O$
0.055 g KH_2PO_4
0.001 g resazurin as a redox indicator
0.039 g/L $Na_2S \cdot 9H_2O$ as a sulfur source and reductant
0.1 g $MgCl_2 \cdot 6H_2O$

Trace metal solutions recipe (per liter)
0.005 g $FeCl_2 \cdot 4H_2O$
0.005 g $MnCl_2 \cdot 4H_2O$
0.001 g $CoCl_2 \cdot 6H_2O$
0.0006 g H_3BO_3
0.0001 g $ZnCl_2$
0.0001 g $NiCl_2 \cdot 6H_2O$
0.0001 g $Na_2MoO_4 \cdot 2H_2O$
0.002 g $CaCl_2 \cdot 2H_2O$

Experimental Approach Con't

- Composition of the sample:
  - Sediment to fill 10-mL volume
  - 10 mL of diluted molasses solution



Samples placed in the anaerobic chamber

Re Oxidation Period

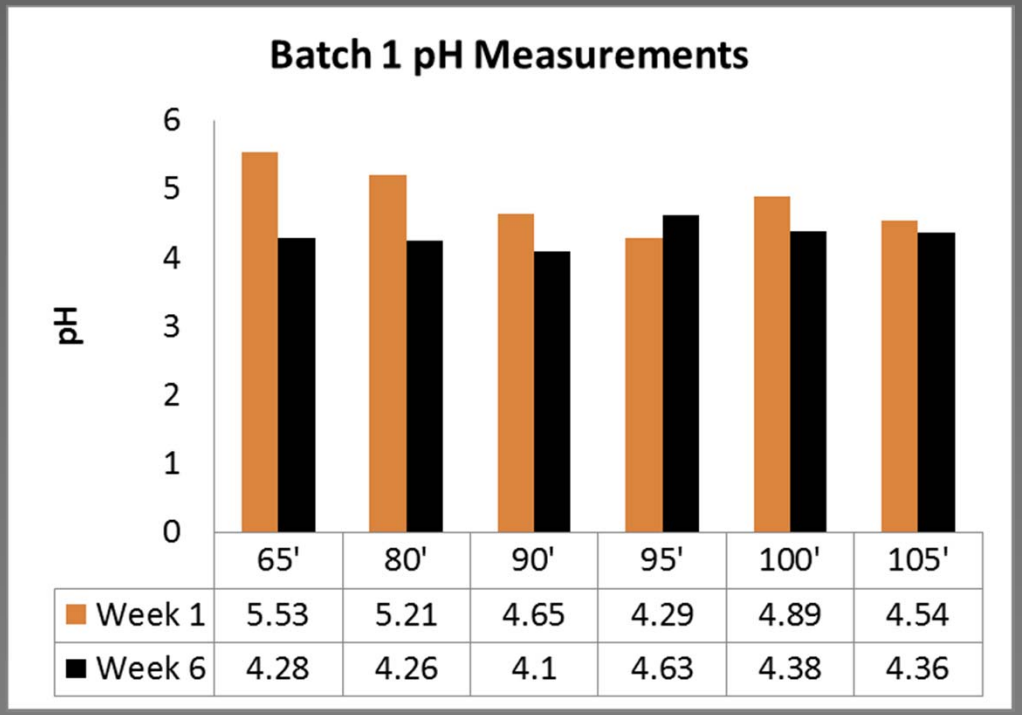
- After six weeks samples will be sacrificed
- Three types of environments:
  - Anaerobic chamber with no oxygen
  - Small chamber containing 2000 ppm oxygen
  - Work bench at atmospheric oxygen levels

Analytical Methods

- Solid Phase → XRD
  - Samples are dried in their respective oxygenated environments (3 weeks)
  - Transported in sealed containers
- Liquid Phase →ICP
  - Liquid is centrifuged
  - Supernatant is filtered (0.45 µm)

pH Results

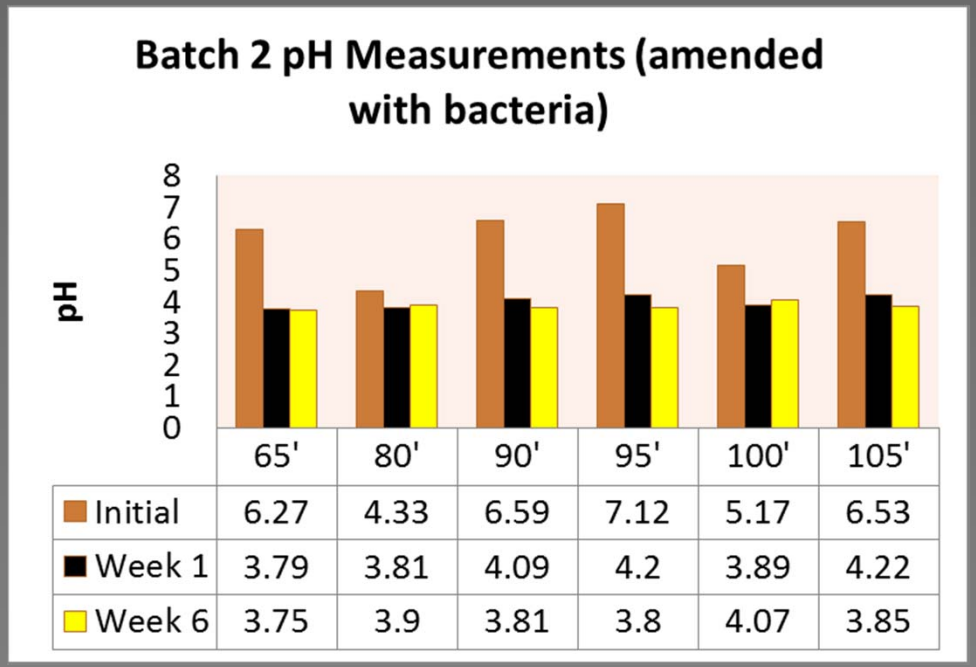
- Batch 1
  - 1 set with duplicates (12 samples)
  - Descending trend in pH for all samples but one (95')



	65'	80'	90'	95'	100'	105'
Week 1	5.53	5.21	4.65	4.29	4.89	4.54
Week 6	4.28	4.26	4.1	4.63	4.38	4.36

Task 2.2 – pH Results

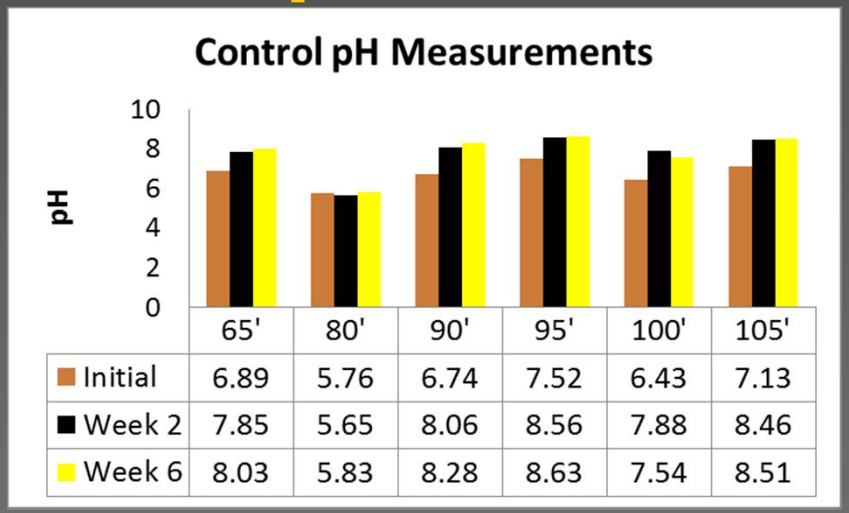
- Batch 2: 1 set with duplicates (12 samples)
- Modifications:
  - Amended with 100 µL bacteria (from anaerobic digester)
  - Each sample was supplemented with additional 0.5 mL of molasses a week after initial addition



	65'	80'	90'	95'	100'	105'
Initial	6.27	4.33	6.59	7.12	5.17	6.53
Week 1	3.79	3.81	4.09	4.2	3.89	4.22
Week 6	3.75	3.9	3.81	3.8	4.07	3.85

pH Results for Control Samples

- Composition of the sample:
  - Sediment to fill 10-mL volume
  - 10 mL of diluted basal medium (no molasses)
- pH of basal Medium = 8.55
- Opposite to Batch sample results
  - Ascending instead of Descending trend in pH
- Contradicts hypothesis that the pH of the samples was dropping due to the reaction of the solution with the acidic soil
- Supports that pH is increasing due to the production of organic acids via the molasses fermentation process

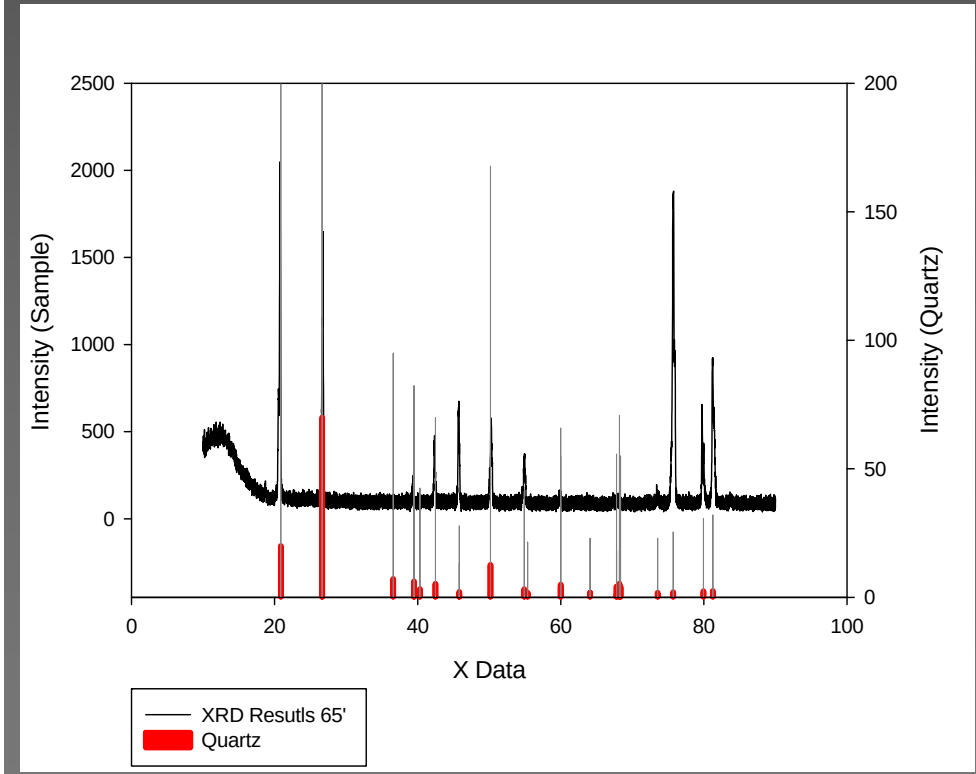


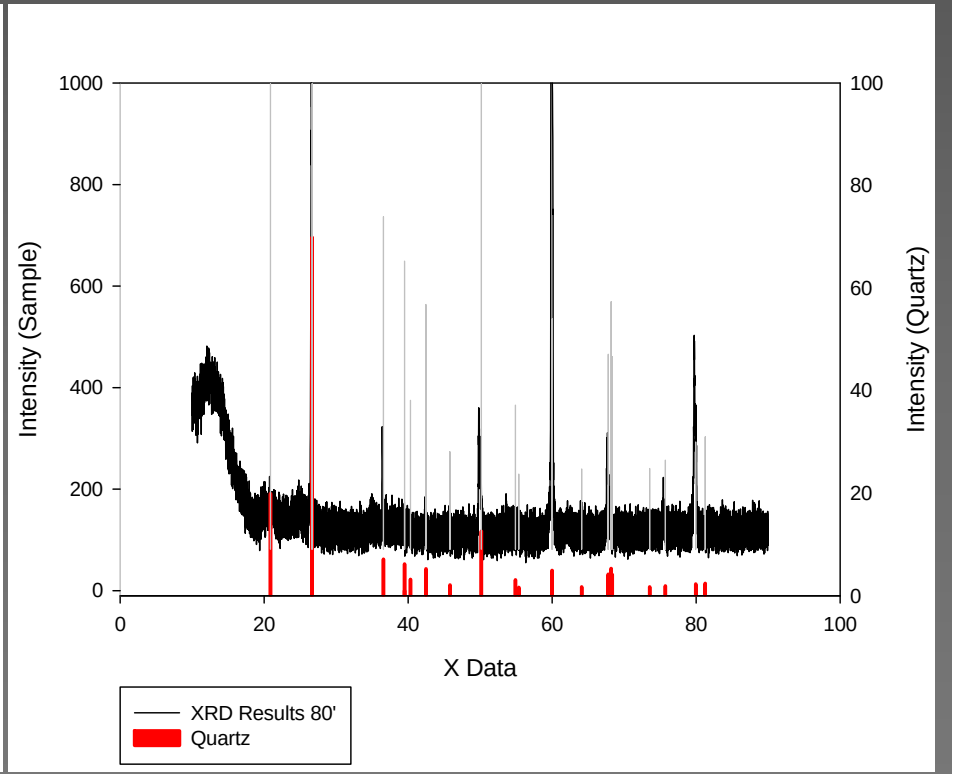
	65'	80'	90'	95'	100'	105'
Initial	6.89	5.76	6.74	7.52	6.43	7.13
Week 2	7.85	5.65	8.06	8.56	7.88	8.46
Week 6	8.03	5.83	8.28	8.63	7.54	8.51

Fungi Growth

Example of fungi growth on some of the samples.

XRD Analysis (Original Samples)





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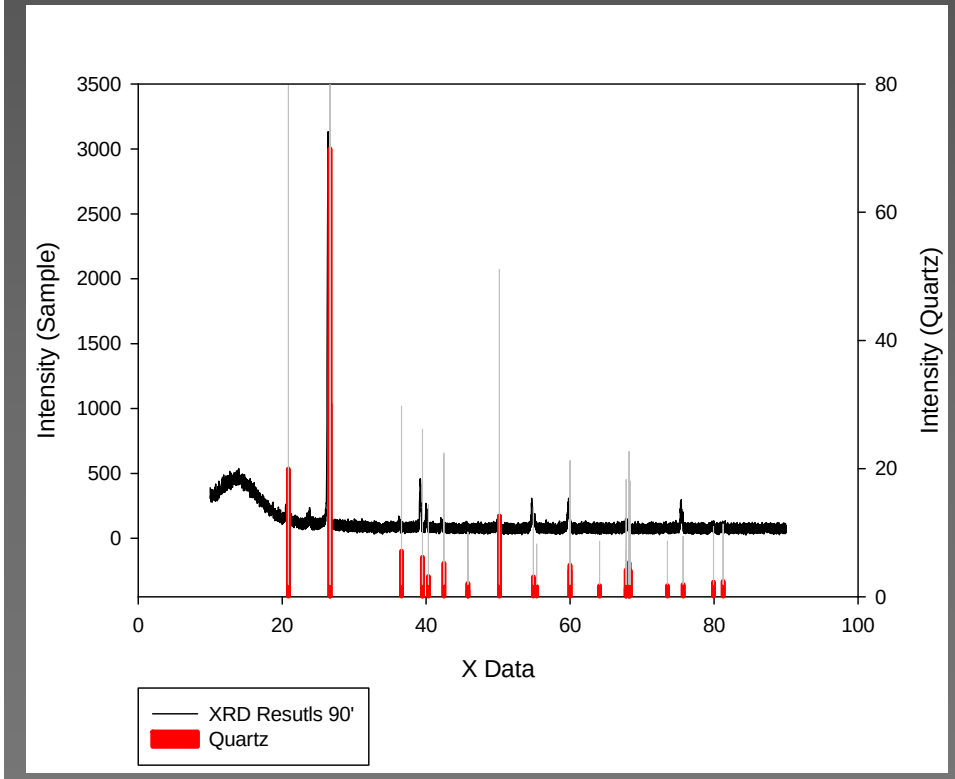

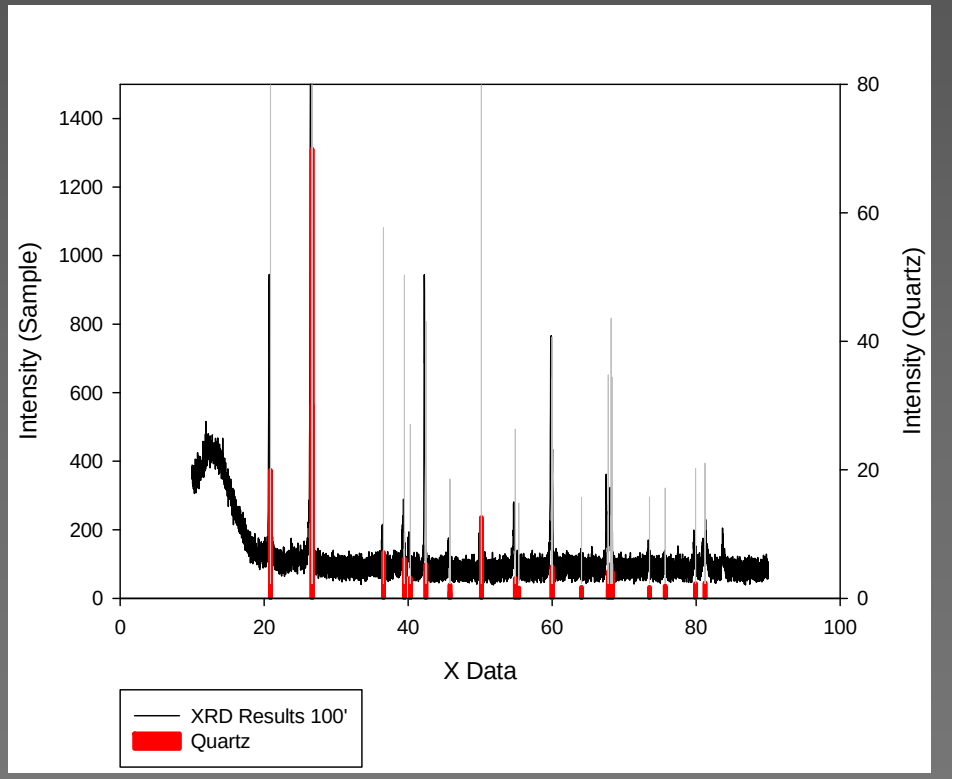

- Most likely match for the results is quartz; 80% of the peaks match and line up at most depths.
- The intensity ratios are sometimes off, could be because those peaks belong to some other mineral also present in the sample but in smaller quantities.

Future Work

- Perform XRD analysis for remaining samples
- Continue with identifications of minerals and analysis of XRD Results
- Receive mineral trap diffusion samples and start analyzing them via SEM/ED and XRD