Natural Sciences Poster Sessions
Student Works

Fall 2021

Soil Research Project

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Literature Research: Earthworm’s Impact on Soil

My topic is how earthworms interact with soil.

Most people learn from an early age that earthworms are an important part of soil and plant life, but many do not know the actual reasoning and evidence behind it.

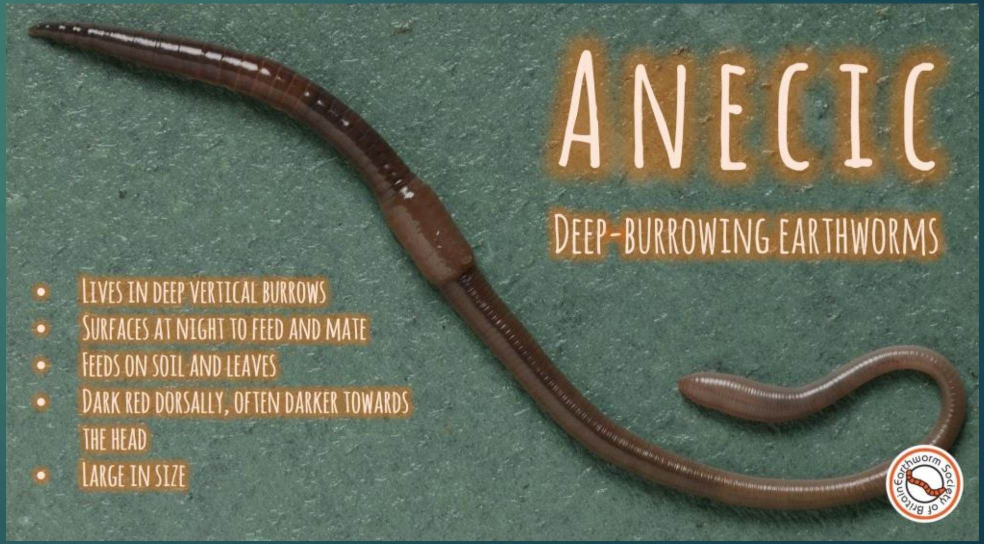
My audience would be interested in this topic because it is interesting to expand knowledge on things already considered well know.

While many earthworms are not endangered, we still need to be carful and protect the animal that is vital to plant growth and soil health.

Important terms

- Endogenic
  - Horizonal burrowing earthworm, feed on soil, pale in color ("Earthworm Ecology").
- Anecic
  - Vertical burrowing earthworm, feed on leaves, darker red in color ("Earthworm Ecology").

Endogeic earthworms (c) Natural History Museum, London. Adapted by Earthworm Society of Britain. (CC BY 4.0) ("Earthworm Ecology)



Anecic earthworms (c) Natural History Museum, London. Adapted by Earthworm Society of Britain. (CC BY 4.0) ("Earthworm Ecology")

Literature Research: Earthworm's Impact on Soil

- Earthworms do much more than dig holes in the ground and turn waste into fertilizer.
- The most important things earthworms do for the soil are transportation, fertilization, and irrigation.
- The most important thing that the worm gives the soil to accomplish all of this is mucus.
- While most of us learned at a young age that earthworms dig their homes in the ground and make tunnels that help with aeration, this is only just a slight glimpse of what they actually do for the soil.

(Guhra, Tom, et al. 1)

Literature Research: Earthworm's Impact on Soil

- The purpose of this study was to determine the effects of earthworm mucus structures and their relationship to the organic material in the surrounding soils.
- The team ran many tests and collected many samples of mucus to determine what it consisted of and how it impacted the soil.
- The samples were collected from crop sites and pasture sites in northwestern Germany.
  - The soils are not native to North America and originate from limestone.
  - However, these studies can be applied universally.

(Guhra, Tom, et al. 2)

Literature Research: Earthworm's Impact on Soil

- This Primary research Article studied the effects of earthworm mucus casts on soil and how it interacts with plants, water, nutrients, microorganisms, and the soil itself.
- They accomplished this by studying the mucus of two different species of earthworms.
- These casts are used for many things:
  - They help the worms as explained on the right side.
  - They transport water, nutrients, and microorganisms.
  - They are used as pathways for roots, especially in crop areas like fields and gardens where earthworms are prominent.

(Guhra, Tom, et al. 1-2)

Literature Research: Earthworm's Impact on Soil

- When earthworms tunnel through the soil they secrete a mucus from their skin.
  - This lubricates the tunnels so they can move through with ease.
  - It also keeps the soil from collapsing on top of them.
- The mucus consists of water, carbohydrates, polysaccharides, lipids, and proteins.
- The casts form when the mucus dries with the soil, microorganisms, and organic matter.
  - The casts are so strong that many outlive the worms that created them.

(Guhra, Tom, et al. 1-2)

Literature Research: Earthworm's Impact on Soil

- The team collected two types of worms to start off the series of experiments.
  - The first group of worms were endogenic.
    - They were collected by handpicking the worms out of the top 15 cm of the soil.
  - The second group of worms were anecic.
    - They were collected by mixing the rest of the soil with a mustard solution to find the worms.
  - The species were kept separate during the experiments.
- Before collecting mucus, the worms were cleaned.
  - The worms were kept on wet pulp for 60 hours to void their guts of anything that could potentially skew the results, and to give a fresh start to the experiments.
  - They were also rinsed with pure water to make sure the mucus samples were pure and clean.

(Guhra, Tom, et al. 2)

Literature Research: Earthworm's Impact on Soil

- Mucus Extraction
  - Worms were placed into beakers with pure water and stirred with a glass rod.
    - Stirred for one-minute intervals, every three minutes, for fifteen minutes.
    - Then five minutes straight after the fifteen-minute session was complete.
  - This irritated the skin without causing damage, to advance mucus production.
- The mucus was collected, some frozen, and some freeze dried.
- They found two types of bands:
  - O-H bonds were found to be around 3300 cm^{-1} against surface water.
  - Bands of methylene groups (C-H) were shorter, at 2900 cm^{-1}.
    - Shorter bands were more pronounced than longer bands
- All bands were moderately stretchy.

(Guhra, Tom, et al. 2-3)

Literature Research: Earthworm’s Impact on Soil

- There were many similarities in the mucus of the two species.
- In both samples:
  - The most concentrated organic compound was potassium.
  - Phosphorus was the most absorbed.
  - Sulfur was not well absorbed.
  - Similar proportions of carbohydrates (anomeric C) were found.
- There were also similarities in strength, compounds, symmetry, amino acids, proteins, and amides.

- There were some differences between the mucus of the two species.
- In endogenic
  - Higher concentrations of many elements such as phosphorus, calcium, sulfur, magnesium, silicon, manganese, iron, and aluminum.
- In anecic
  - Higher pH
  - Higher carbon concentration

(Guhra, Tom, et al. 3-4)

(Guhra, Tom, et al. 4)

Table 2

Total organic carbon (TOC) and dissolved organic carbon (DOC) as well as inductively coupled plasma optical emission spectrometry (ICP-OES) measured element concentrations of K, P, Ca, S, Mg, Si, Mn, Fe and Al in the dispersed anecic *L. terrestris* and endogeic *A. caliginosa* mucus references. Uncertainty is given as standard deviation (n = 3).

Sample	[mg/l]										
	TOC	DOC	K	P	Ca	S	Mg	Si	Mn	Fe	Al
anecic mucus	23.12 ± 0.05	16.5 ± 1.0	5.65 ± 0.04	1.065 ± 0.005	0.973 ± 0.007	0.83 ± 0.01	0.342 ± 0.003	0.06 ± 0.01	0.0231 ± 0.0001	0.0211 ± 0.0006	LOD
endogeic mucus	15.37 ± 0.07	14.8 ± 0.3	4.77 ± 0.06	0.653 ± 0.004	0.54 ± 0.04	0.551 ± 0.009	0.233 ± 0.009	0.125 ± 0.001	0.0080 ± 0.0001	0.053 ± 0.008	0.011 ± 0.001

This table shows the emissions of various elements in the mucus samples of each species. The ± shows the standard deviation of each sample in a variable of 3 mg/L.

Literature Research: Earthworm's Impact on Soil

- In conclusion to this experiment:
  - Earthworms are essential to soil and plant health.
  - They are needed for irrigation, transportation, fertilization, and much more.
  - Mucus is predictable and consistent based on the soil mineral the worms have access to.
  - Earthworm soil has altered physiochemical properties that non-earthworm soil lacks.
    - These altered properties are beneficial to the growth and development of plants and organisms that use the soil to grow.
- Casts are vital to soil and plant health.
  - Vertical tunnels are used for waterflow so excess mucus is used to make those casts.
  - Horizontal tunnels are used to transport nutrients, organic material, and microorganisms.
    - This is especially important in crop areas to ensure proper irrigation and fertilization.

(Guhra, Tom, et al. 7-9)

Literature Research: Earthworm's Impact on Soil

- To follow up this set of experiments:
  - One suggestion would be to study different species of worms on different types of soil to test if these conclusions remain true across all types.
  - Another suggestion would be to take a set of worms and study them on a different type of soil than they are used to, to test if certain worms have lower mucus outputs in soil that they do not like or are not used to.
- My Background:
  - I always knew that earthworms were an important part of the ecosystem and helped plants to grow in some form.
    - I thought that they added nutrients to the soil that the plants used to thrive.
  - After reading this article I learned that the key component is their mucus, not their waste.
  - This topic connects to my experimental research because one of my samples is from a field so some of my findings might be connected to the earthworms in some way.

Experimental Research

Sample 1- Barn floor

Image taken by Kate Donaldson

- My first soil sample was collected from a barn floor on my property in Colfax, IL.

Sample 2- Rotation Crop- Corn

- My second sample is from a field next to my house that rotates between soybeans and corn and was in the corn rotation.

Image taken by Kate Donaldson

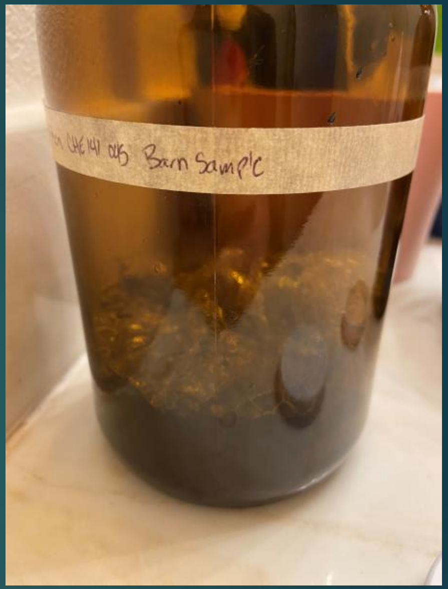
Both soil samples are Saybrook Silt Loam.

The main question I had at the beginning of this project was; what will the difference in concentration and properties of each soil sample?
I thought that the base properties would be similar, but the field sample would have more nutrient concentration than the barn sample. I also thought that the field sample would have more moisture than the barn sample since it is more exposed to the weather.

Experimental Research

Barn Sample Experimental Findings

- Soil Texture, pH, and EC lab
  - Texture- Silty Clay Loam ("Natural Resources Conservation Service.").
    - Similar to class
  - pH: 6.88
    - Low end of class
  - Conductivity: 154.6 μS
    - Moderate compared to class
      - Sample only sat for 1 hour 40 min rather than the intended 2 hours
  - Mass of water removed from soil during oven drying: 8.81 g

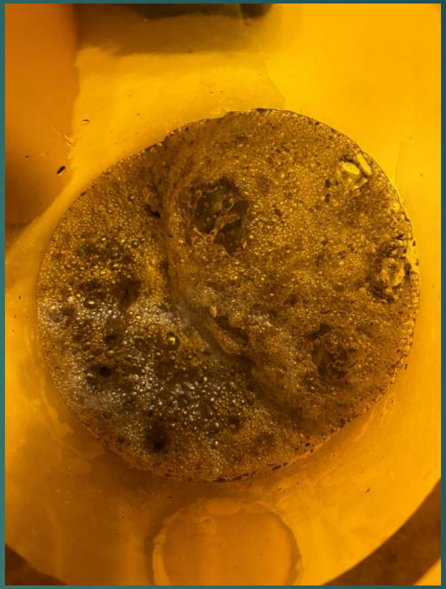


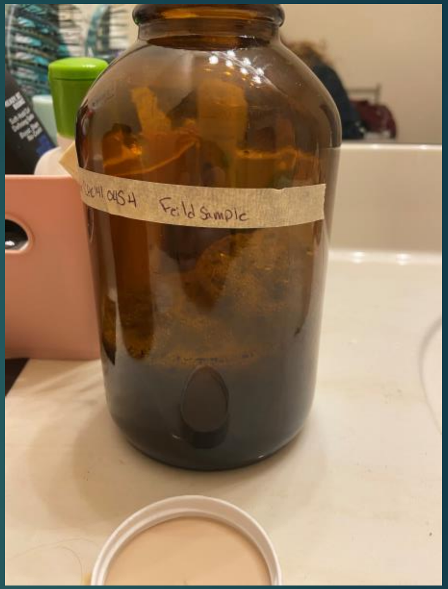
Images taken by Kate Donaldson

Experimental Research

Field Sample Experimental Findings

- Soil Texture, pH, and EC lab
  - Texture- Clay Loam (“Natural Resources Conservation Service.”).
    - Similar to class
  - pH: 6.90
    - Low end of class
  - Conductivity: 191.6 µS
    - Moderate compared to class
      - Sample only sat for 1 hour 46 min rather than the intended 2 hours
  - Mass of water removed from soil during oven drying: 10.4 g





Images taken by Kate Donaldson

Experimental Research

Barn Sample Experimental Findings

- K Analysis Lab
  - K Concentration: 1067.12 lb K/acre
    - Above optimum, very high
      - High end of class

Field Sample Experimental Findings

- K Analysis Lab
  - K Concentration: 1541.1 lb K/acre
    - Above optimum, very high
      - High end of class

Concentrations this high should not affect crop growth, but if more potassium is added it could have a negative affect on crop growth and yields. This is important to take into consideration for the field, but not as important for the barn soil ("Soil Fertility Test Interpretation").

Experimental Research

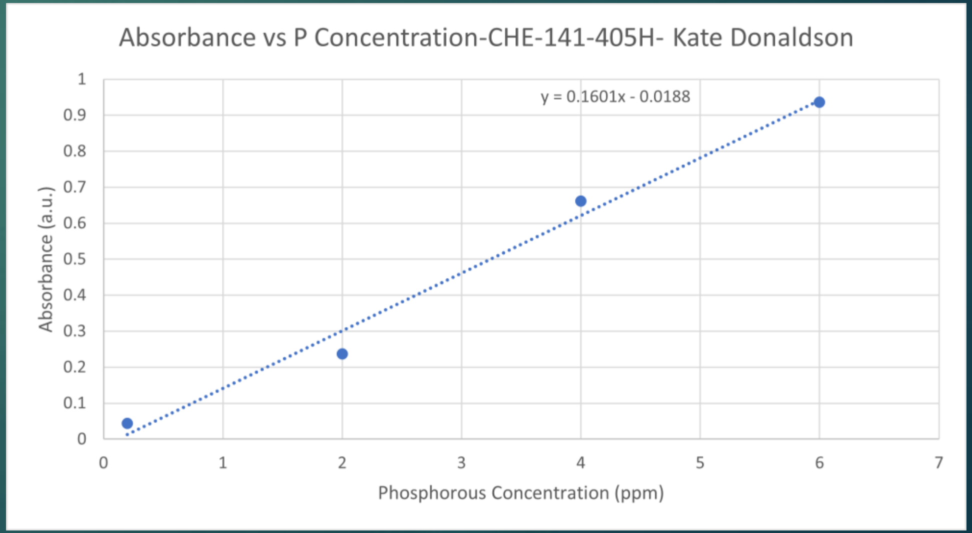
Barn Sample Experimental Findings

- P Analysis Lab
  - P concentration: 277.0 lb P/acre
    - Very high
      - High end of class

Field Sample Experimental Findings

- P Analysis Lab
  - P concentration: 226.6 lb P/acre
    - Very high
      - High end of class

Concentrations this high should not affect crop growth, but if fertilizer with P_2O_5 is added it could have a negative affect on crop growth and yields. This is important to take into consideration for the field, but not as important for the barn soil ("A General Guide for Crop Nutrition and Limestone Recommendations in Iowa").
There is a small amount of error here, as can be seen in the standard curve.



Graph made by Kate Donaldson

Experimental Research

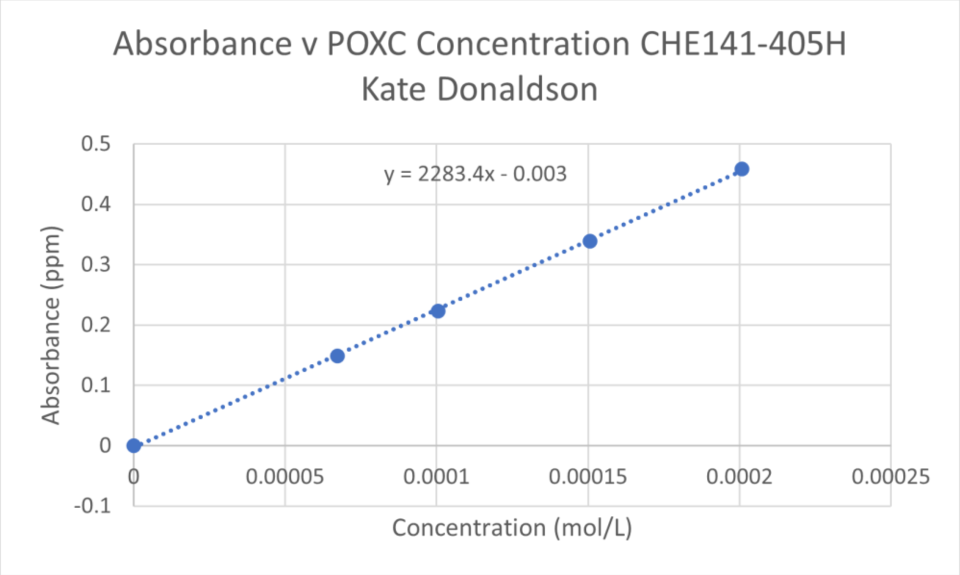
Barn Sample

- POXC Lab
  - Concentration:
    - $4.34x10^4$ mg RC/kg soil
      - High end of class
  - Absorbance:
    - 0.182 abs

Field Sample

- POXC Lab
  - Concentration:
    - $3.74x10^4$ mg RC/ kg soil
      - High end of class
  - Absorbance
    - 0.216 abs

The absorbance values show that the barn sample has a higher POXC concentration, which is shown by the calculations that lead to the concentration.
This is strange compared to the other experiments because usually the field sample has higher concentrations and is overall healthier.
There is no obvious error shown in the standard curve.

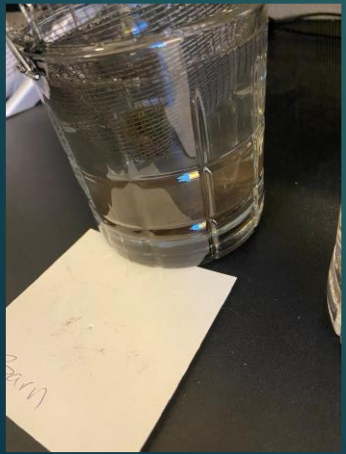


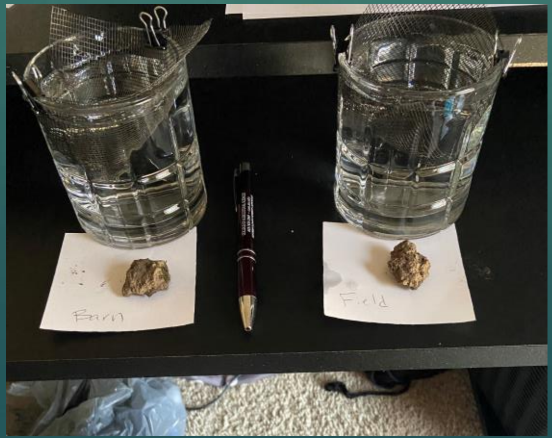
Graph made by Kate Donaldson

Experimental Research

Barn Sample

- Slake Test
  - No bubbles
  - Lots of settling
  - Cloudy water
    - Indicates lower aggregate stability
      - Lower soil health
    - Leads to:
      - Run-off
      - Compacting
      - Erosion
      - Crusting

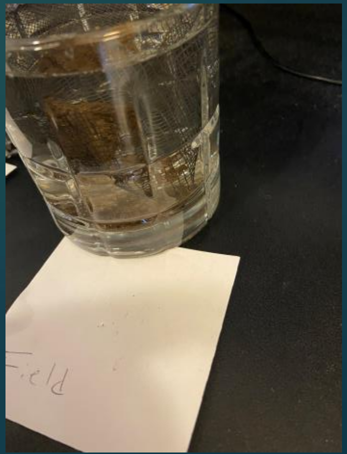




Images by Kate Donaldson

Field Sample

- Slake Test
  - One bubble roughly every two seconds, for the first five minutes
  - Little settling
  - Larger fragments
  - Clear water
    - Indicates higher aggregate stability
      - Higher soil health



Images by Kate Donaldson

Experimental Research

Barn Sample

- Cotton Test
  - 57 days (9/7/21-11/3/21)
    - Intact white cotton round
      - Signs of decomposition
        - Very fragile
        - Slight stretch
        - Thinned out in some areas
        - Brown in color
        - Holes throughout
        - Withered edges
    - Stretched white cotton round
      - Completely decomposed
        - Almost no sign of cotton left
          - May have a few specks left over

Image by Kate Donaldson

Field Sample

- Cotton Test
  - 57 days (9/7/21-11/3/21)
    - Intact white cotton round
      - Signs of decomposition
        - Almost completely intact
        - No stretch
          - Breaks when soil is removed
        - Off white in color
    - Stretched white cotton round
      - Mostly decomposed
        - Small fragments of cotton left

Image by Kate Donaldson

Experimental Research

Barn Sample

- Microbial Activity Titration Lab
  - Average of trials:
    - -16.0 mgCO_2/kg Soil Days
      - Unable to compare to class due to error
      - overshot the HCl in the lab, or the sample registers lower than the control
      - Would need to redo the lab

Field Sample

- Microbial Activity Titration Lab
  - Average of trials
    - 26.7 mg CO_2/kg Soil Days
      - Moderate to class

Experimental Research

Barn Sample Conclusions

- pH indicates less nitrogen was added to the soil directly, but there was some transfer to lower the pH to an acidic level.
- Conductivity also indicates that there was some transfer between the field and barn to add nutrients to the barn soil.
- Lower mass of water indicates that the soil was drier than the field soil.
- Potassium level indicates there was some transfer of K nutrients to the barn soil from the field.
- Phosphorous concentration indicates transfer of excess P from field soil to barn soil.

Field Sample Conclusions

- Lower pH indicates that there is more nitrogen, a fertilizer, added to the field making it more acidic than the field.
- Higher conductivity indicates larger amount of nutrients available in soil.
- Larger mass of water indicates that the soil held more moisture compared to the barn sample.
- Higher potassium concentration indicates more K nutrients added to soil.
- Lower phosphorous concentration indicates healthier soil compared to the barn sample.

Experimental Research

Barn Sample Conclusions

- The slake test indicates that the barn soil could have lower calcium, iron oxides, and organic matter concentrations. It also indicates that it could have higher sodium concentrations, all leading to lower soil health.
- The microbial activity lab findings are unclear for this sample.

Field Sample Conclusions

- The slake test indicates that the field soil has higher aggregate stability, which is related to higher soil health. Lower sodium concentrations and higher calcium, iron oxides, and organic matter.
- The microbial activity findings show that this sample is moderately healthy compared to class findings, but I could not truly compare to the barn soil sample.

Experimental Research

Barn Sample Conclusions

- The POXC test indicates that the barn sample has more organic matter, making it healthier in that aspect than the field sample.

Field Sample Conclusions

- The POXC test shows that the field sample has a slightly lower amount of organic matter in the soil.
  - This could be due to management practices such as field work and the addition of different chemicals for fertilization.

Experimental Research

My findings were in line with my predictions and question. I predicted that the field sample would have more nutrients and moisture than the barn sample. All tests but two showed more nutrients and moisture in the field sample. The only times the barn soil tested higher was in phosphorous concentration and POXC concentration.

Using my literature research project, I can assume that there was some transfer of nutrients from the field to the barn. A good explanation for a higher P concentration in the barn sample would be that the field was spreading out the phosphorous to all nearby soil. Since phosphorous is the most absorbed in the earthworm mucus it is possible that the concentrations are so high in both because of the mucus casts as well as the added fertilizer.

Future Direction

- Collect more sample for the opportunity to redo labs
- Wait full time limit so results are not skewed
- Redo Labs
  - Soil Texture and pH/EC- wait full processing time
  - Microbial Activity Lab- Barn sample
- Repeat labs
  - P and K Analysis- see if results are similar on repeat labs
- Ask farmer what fertilizers were used in the field to test if the high concentrations were from fertilization

Bibliography

"A General Guide for Crop Nutrient and Limestone Recommendations in Iowa" from Iowa State University Extension and Outreach, October 2013

"Earthworm Ecology." *Earthworm Ecology | Earthworm Society of Britain*, https://www.earthwormsoc.org.uk/earthworm-ecology#:~:text=Endogeic%20earthworms%20live%20in%20and%20feed%20on%20the,pale%20colours%2C%20grey%2C%20pale%20pink%2C%20green%20or%20blue.

Guhra, Tom, et al. "Earthworm Mucus Contributes to the Formation of Organo-Mineral Associations in Soil." Soil Biology and Biochemistry, vol. 145, 2020, p. 1-10., doi:10.1016/j.soilbio.2020.107785.

"Natural Resources Conservation Service." *Soil Texture Calculator | NRCS Soils*, USDA, https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167.

"Soil Fertility Test Interpretation - Phosphorus, Potassium, Magnesium, and Calcium." *Soil Fertility Test Interpretation - Phosphorus, Potassium, Magnesium, and Calcium (Rutgers NJAES)*, Rutgers NJAES Cooperative Extension, 13 Oct. 2006, https://njaes.rutgers.edu/pubs/publication.php?pid=fs719.