4-24-2024

An Analysis of Pollution in Liverpool, UK

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April 24, 2024

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Abstract

Within this experiment the different levels of pollution in areas around Liverpool were tested. These areas were Stanley Park, Lunt Meadows, and Woolton Road. At Stanley Park one of two transects had a geochemical analysis as well as magnetic measurements run to investigate source attribution within the urban environment resulting in data showing high variability in soil properties among the transect. With data supporting evidence of diamagnetic, paramagnetic, and ferromagnetic properties in soil along the same transect. At Lunt Meadows, through the use of XRF for soil samples and nitrate and phosphate testing for water samples, it was found that there was an abnormally high amount of iron within the first two centimeters of the soil, a trend also seen in Ca, Mn, and Sr. Additionally, strong positive correlations between presence of the element and depth were found in Al, Si, P, and Ti and negative correlations were present in S and Cl. The nitrate and phosphate water test found high amounts of nitrate and low amounts of phosphate. At Woolton Road, low Xfd% values as well as negligible XRF data indicated insignificant levels of pollution within the soil.

Introduction

With the rising levels of pollution throughout the world, stemming from automobiles, industrialization, landfill sites, and other environmentally dangerous technologies, the need for better understanding the effects on the surrounding environment has never been more paramount. The presence of different heavy metals and natural metals within the soil can lead to a conclusion that there is pollution within the soil, with the amount of pollution increasing as the amount of heavy metals increases as well (Gomaa et al. 2020). Additionally, landfills can lead to higher levels of heavy metals in the surrounding areas due to leachate, thus affecting the health of the surrounding environment (Beinabaj et al. 2023). Therefore, it is particularly important to use instruments like the XRF and magnetic susceptibility to determine these levels of pollution within the soil. By determining the pollution levels in the soil, the origins of the pollution can be found and plans for remediation can be made.

Experimental

Within the experiment there are three different procedures carried out at three different study sites. The experimental section is thus divided into the procedure for collecting the different samples, the different locations, and then methodology behind the machinery used to collect the data. Additionally, it is worth noting that all sampling was done during the summer months.

Stanley Park: Within Stanley Park two transects must be taken that are 200 meters in length with the two transects being separated by twenty meters. After this has been completed, take a soil sample at ten different locations across the transect, labelling them with Letters A-J to represent their "cluster". Once back in the laboratory, divide each cluster into ten different subclusters, illustrating the difference using letters once again (Aa, Ab, Ac, etc.). Separate the subclusters into groups of approximately 15 g each. Once this has been completed, allow the samples to air-dry overnight, making sure all the moisture is out of the soil sample. Following the completion of the allotted time, take the samples in subcluster "a" (i.e. Aa, Ba, Ca, etc.) and further separate them into five different groups: 100 °C, 200 °C, 400 °C, 600 °C, and 800 °C. Record the mass of these groups and then place them into the oven at their respective temperatures (indicated by their group), allowing them to sit for four hours. Mass the groups again after being dried in the oven. Once this has been completed, gather all the samples from all the different clusters and prepare them to be run through the magnetic susceptivity instrument. A Bartington MS3 meter combined with an MS2 sensor was used for the magnetic susceptibility of this project. To do this, obtain “pots” that are suitable to be placed inside of the instrument as well as Saran wrap to surround the dirt inside of the pot. In preparing each sample, follow this procedure: obtain saran wrap suitable for wrapping around the soil sample, weigh the saran wrap, weigh the amount of soil used (8-10 g is suitable), then place the sample wrapped with the saran wrap inside of the pot. Do this for all clusters and subclusters. Once this has been completed, set up the magnetic susceptibility instrument using the Barton software with the following settings: select file new, individual study, Ms2b, then hit next. Select multi susceptibility meter, then hit “next” two times. Boxes should appear with checkmarks next to them, make sure that: “Check raw measurements,” “Identifier," “Sample variable," and “comment” are selected. Hit next, then change the measure period to five-seconds. Hit next again, select fixed exponential, then change the exponential value to -5 and make sure the units of measurement are in “SI”. Once this has been completed, set up the magnetic susceptibility instrument in a manner that is connected to the laptop and away from any devices, outlets that are turned on, and avoidable metal objects (such as the stools in the laboratory). Before running any of the prepared samples, make sure that the instrument is calibrated correctly, using the provided sample sitting inside of the instrument to determine the calibration. If the calibration matches what is stated on the pod, the samples are ready to be run through the instrument. In testing the sample, run an air sample first, then run the sample, repeat the sample so that there are a total of three scans for the prepared sample, then run another air sample after. There should be a total of five scans done for each sample, two air and three of the sample itself. Repeat this process for all samples that need to be run through the magnetic susceptibility instrument. Do this for the Lf and Hf settings and then put the results, mass, and name of the sample inside of an Excel document. To calculate the Xfd%, use the following equations.

$$XLf = (Lf/(mass/1000))/100$$

$$XHf = (Hf/mass/1000))/100$$

$$Xfd\% = ((XLf - XHf)/XLf)*100\%$$

Figure 1: Equations for determining Xfd%

For the Lf and Hf values, make sure the units are in $10^{-3}m^3$ and that the mass is in grams. From this, the results can be interpreted as anything at 5% or higher for the Xfd% value is indicative of fine magnetite particles (super paramagnetic domains) within the sample and thus pollution.

Lunt Meadows: In collecting samples for Lunt Meadows, collect one core sample, ideally .5-1 meter in depth, near the former landfill site. Additionally, collect a water sample near the landfill site and another water sample near the reed bed. Once the core is back in the lab, separate the core into each centimeter (i.e., if the core is 50 cm the core will be separated into 50 groups). Once the core has been split into its respective centimeters below the surface, prepare the samples to be run through the XRF. To do this, the soil must first be dried. Allow the samples to be air-dried for several days (two to three days is sufficient) until the moisture is out of the soil. After this has been completed, obtain the four micron “saran wrap” like material, the XRF sample containment pots, and a mortar and pestle. Prepare the XRF chambers by placing the four-micron saran wrap on top of the pot, placing the outside ring on the pot, then flipping the pot over and locking the ring into place. Make sure that the saran wrap has no abrasions, little to no wrinkles, and is smooth once completed for the best results. In preparing the soil samples, first place them separately into the mortar and pestle and grind them up until the soil sample appears homogenous in nature. Following this, place as much of the sample as possible in its respective pot then obtain a piece of black sponge and place it inside with the soil sample in order that the sample is being pushed against the saran wrap and the black sponge acts as a plug for escaping soil. Place the lid on and brush off any excess dirt that may have accumulated on the edges of the pot. The samples are now ready to be run through the XRF. In setting up the XRF, make sure that there is a certified lecturer to oversee the use of the instrument. Set up the XRF so that the scan times are as follows: 20/20/20/60 seconds. Once the XRF is ready to be used, place the sample inside of the machine with the lid facing up, double checking for no dirt on the outside of the pot. While the instrument is running, it is vital that the user is a reasonable (1 meter or more) distance away from the instrument. After all samples have been run through the instrument (a Niton™ XL2 GOLDD XRF Analyzer was used in this experiment), record the results. In preparing the water samples, nothing specific needs to be done and the water samples are ready for immediate testing. If testing is done at a later date, refrigerate the samples. Use Pallintest kits to measure the nitrates and phosphates in the water and perform a conductivity test on the sample as well. Record the results.

Woolton Road: In collecting samples for Woolton Road, find a place along the road that has a clearing of grass and trees that is large enough to take several transects. Take one transect parallel and close to the road, and two transects that are perpendicular to the road. If possible, take one of the perpendicular transects in a non-mowed area of grass (the two other transects should be in areas of mowed grass). Once the transects have been found, take soil samples at 2-meter intervals among the transects. After returning to the lab, separate the soil samples into the different transects and distance among the transects. Allow the soil samples to air-dry overnight or for several days until the moisture is gone from the samples. Once this has been done, prepare the samples to be run through the magnetic susceptibility instrument as directed previously. Once all the samples are prepared, run them through the magnetic susceptibility instrument, following the same procedure used in Stanley Park. Record the results. After this has been completed, choose one of the Transects (preferably the non-mowed transect) and prepare the samples from the transect for the XRF in the same way as done for Lunt Meadows. Following this, run the sample through the XRF as mentioned in Lunt Meadows. Record the results.

Once all the data has been collected from the different parks, analyze the data, and create different graphs to illustrate the results.

Results and Discussion

The Pollution in Urban Areas across Liverpool Project tested three different areas. Therefore, the results and discussion will be separated by location. An overview for the pollution project is taking different cores, soil transect samples, and water samples across Stanley Park, Woolton Road, and Lunt Meadows to determine the relative amounts of pollution in the area using Magnetic susceptibility and X-Ray Fluorescence Analysis (XRF).

Stanley Park: The Stanley Park research project was started by Leon O'Callaghan in terms of getting the soil samples. Therefore, there was no involvement personally until the lab phase. In collecting the samples, two transects were made stretching 200 meters in length with samples collected at 10 different locations with the two transact lines being 20 meters apart (O'Callaghan et al. 2023).

Figure 2: Locations pictured in O'Callaghan's Learning Report

However, for the research done only Transect 2 was assessed which included 2A, 2B, 2C, 2D, 2E, 2F, 2G, 2H, 2I, and 2J. In terms of distance from the road, the locations are as follows: Cluster 2A was collected 84 meters from the road, Cluster 2B 91 meters, Cluster 2C 98 meters, Cluster 2D 103 meters, Cluster 2E 108 meters, Cluster 2F 113 meters, Cluster 2G 118 meters, Cluster 2H 123 meters, and Cluster 2I 129 meters from the road. While there is a cluster 2J that was collected, the distance from the road is not recorded. After collecting the samples, O'Callaghan divided each Cluster into 10 parts, labeling them a-j (i.e. 2Aa, 2Ab, 2Ac, etc.), and separating them into 15 g each wet. The lab phase for this project began at this point in the experiment. After air drying the samples for the project, the subclusters were reweighed and their masses were recorded. The samples that fell within subcluster A (2Aa, 2Ba, 2Ca, etc.) were massed and prepared to be heated in the oven to determine a temperature induced magnetic curve. However, only Clusters 2Ha, 2Ia, and 2Ja were run through the oven. The samples were further separated into five different groups each heated at different temperatures. The groups were heated at 100, 200, 400, 600, and 800 °C respectively. The samples were then massed and placed inside of tiny "pots" to be run through the magnetic susceptibility instrument, thus giving a temperature induced magnetic curve.

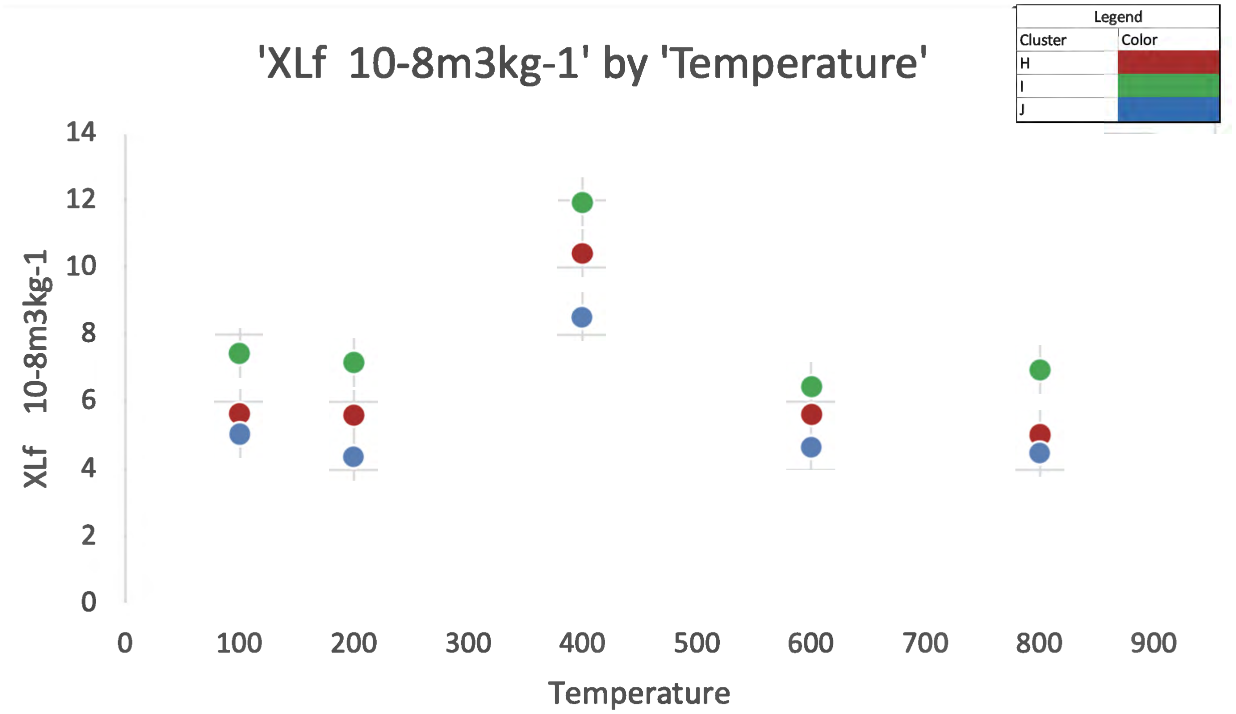


Figure 3: Temperature Induced Magnetic Curve, XLf by Temperature

From the Temperature Induced Magnetic curve graph (Figure 3) it can be observed that generally, the XLf observed from 100 to 200 °C are roughly similar, a spike is observed at 400 °C, followed by a drastic decline at 600 °C, completed by a similar number at 800 °C. The reason for this must be that as the sample is exposed to a certain level of heat, some sort of magnetite within the soil is forming, thus causing the sample to be involved in a dipole moment during the scan inside of the magnetic susceptibility machine and causing a higher XLf.

However, the graph of the curve is not linear in nature due to the spike at 400 °C, leading to the conclusion that only at this temperature was magnetite able to be formed and sustained to exhibit ferromagnetic qualities in the soil. The soil exhibiting ferromagnetic properties additionally supports the idea of more magnetite forming within the soil. The soil at all other temperatures was paramagnetic, exhibiting a weak magnetic susceptibility in response to the external magnetic field that the instrument is producing.

After running samples 2Ha, 2Ia, and 2Ja through the oven and magnetic susceptibility instrument, the rest of the samples ranging from subcluster b-g were prepared and run through the magnetic susceptibility instrument.

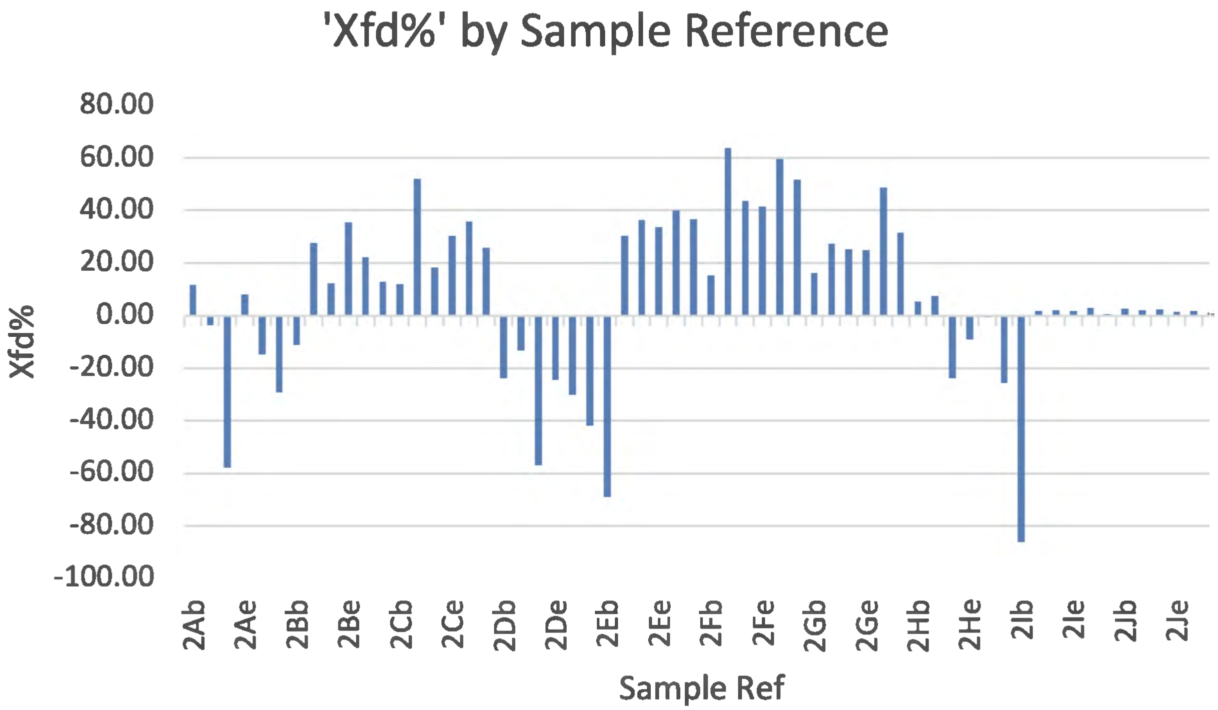


Figure 4: Xfd% by Sample Reference (Name)

The graphs (Figure 4) show a great deal of variability among the data. Additionally, there are quite a large number of negative numbers. Negative Xfd% values generally mean that the soil sample is diamagnetic; however, some of the values, on both the negative and positive side of the spectrum, are far too great to not be scrutinized. When breaking down the data further, the following can be observed (Figure 5).

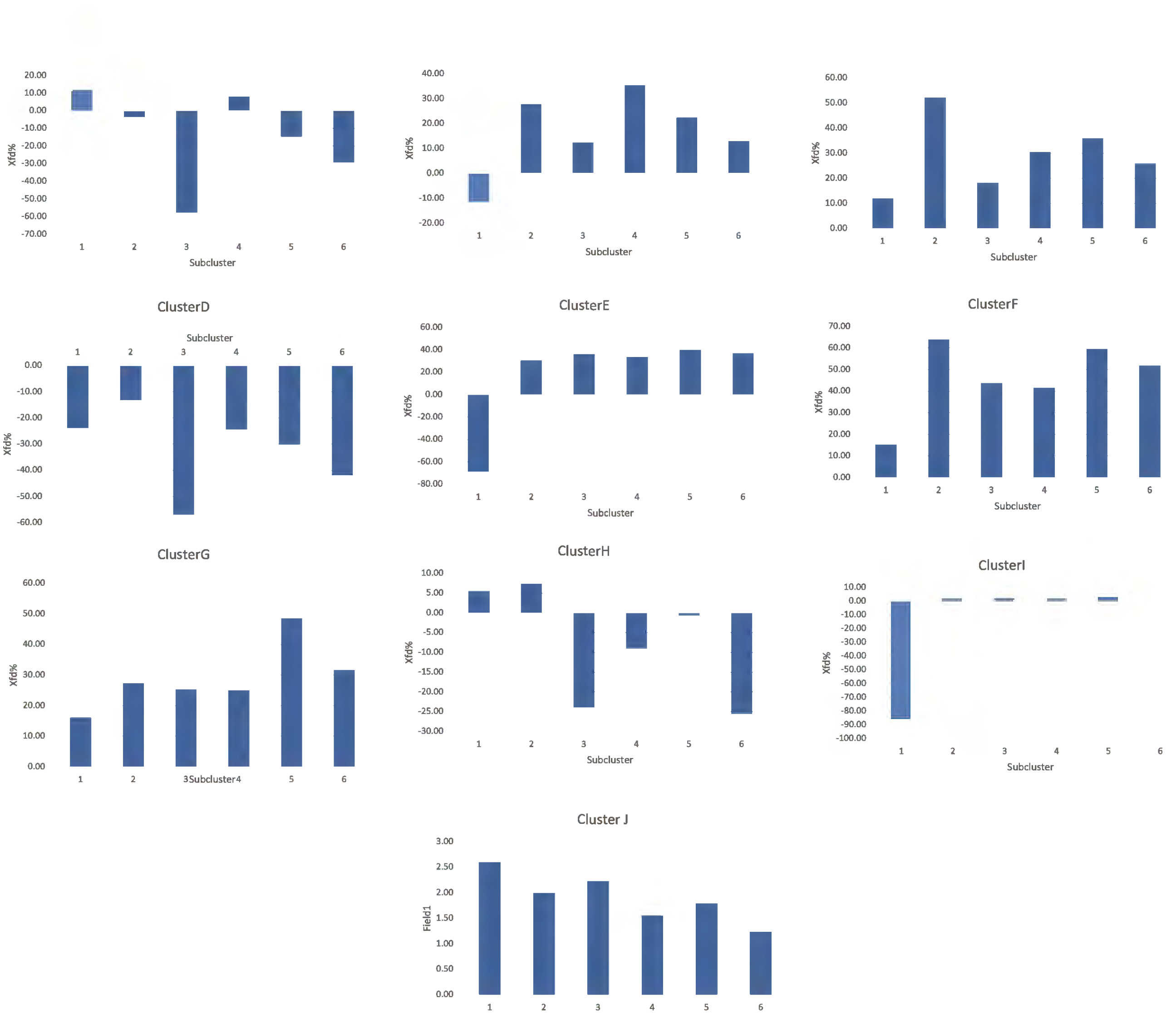


Figure 5: Xfd% by Sample reference

There appears to be very little correlation between most of the data inside of their specific clusters. It is also important to note the means of the data when looking at these graphs. The means for the Xfd% for the clusters are as follows: Cluster A: -14.217, Cluster B: 16.583, Cluster C: 29.063, Cluster D: -31.694, Cluster E: 18.033, Cluster F: 45.940, Cluster G: 28.971, Cluster H: -7.695, Cluster I: -12.856, and Cluster J: 1.902. Generally, anything that is higher than 5% is indicative of pollution inside of the sample due to the high amount of metals in the sample. However, if the number is extremely high then there is most likely an issue as the sample taken is of soil, not metal, which would give such high values. From the graphs and the means, it can be observed that most of the clusters are highly variable, but some show some trends. For example, Cluster J has most of its data within 2.50% and 1.00%, a reasonable amount of Xfd% that is not overly high or low. Cluster J shows a negative linear line. Cluster I has similar results that are close to 0 besides a huge outlier sitting around -86%. This is most likely due to an error in the reading for sample "1" which correlates to subcluster b. Some other clusters like G, E, and C also have relatively small standard deviations within the data; however overall, there is a trend of great variability within the subclusters even though the subclusters were taken at the same spot. Apart from this, if the data were assumed correct, it would suggest a high amount of pollution in certain parts of the transect such as Cluster 2B, 2C, 2E, 2F, and 2G and thus strong ferromagnetic materials, while Clusters 2A, 2D, 2H, and 2I would suggest diamagnetic materials within the soil due to their negative magnetic susceptibility. Finally, Cluster J would be considered the only sample with paramagnetic materials due to the data falling at an average of 1.902%.

In trying to find a trend among the transect, the distance compared to the Xfd% can also be observed. However, due to the large amount of variability within the Xfd%, a graph observing the XLf and XHf by distance is more appropriate.

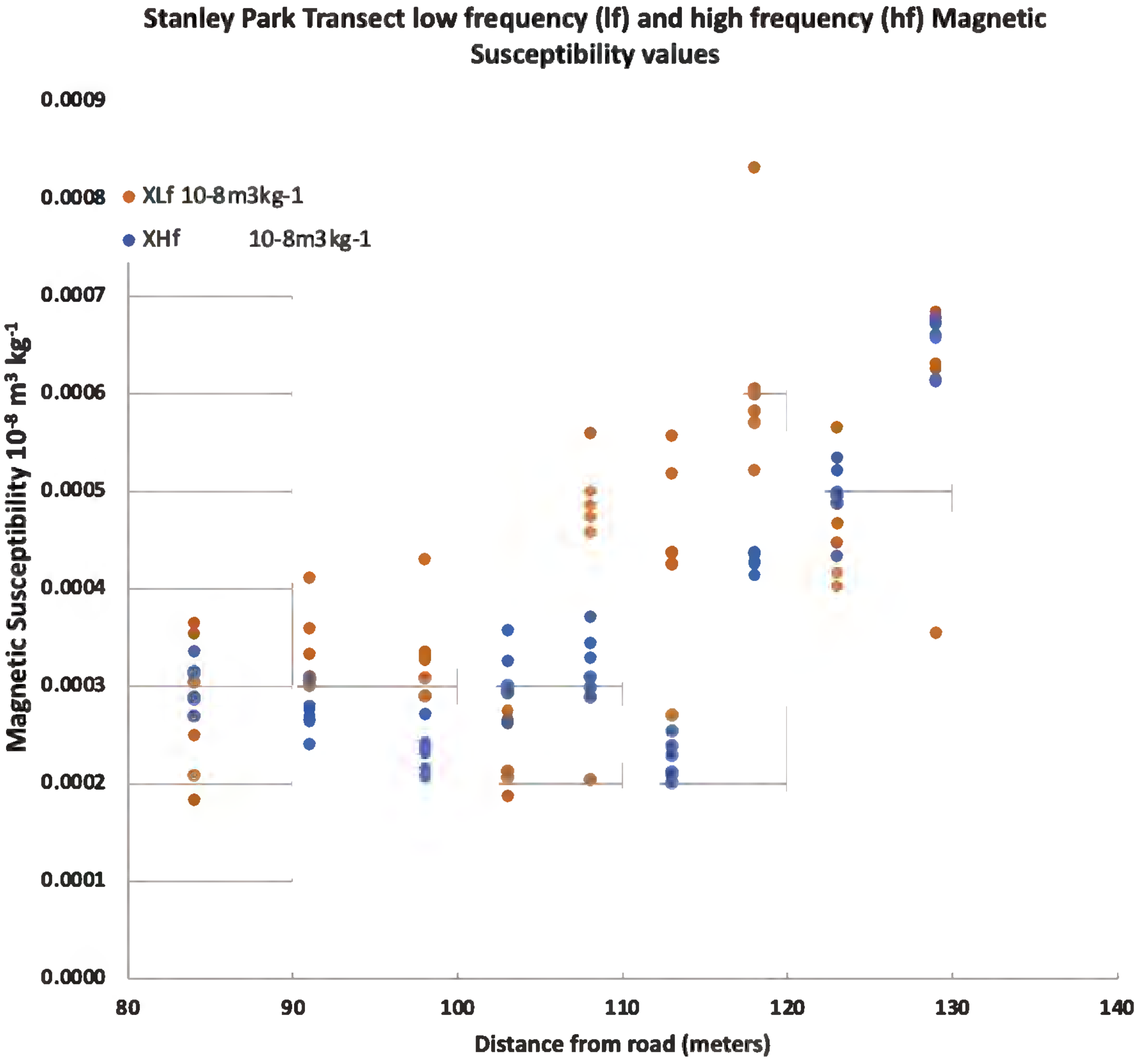


Figure 6: XLf and XHf by Distance from Road (graph made by Dr. Halsall)

The XLf and XHf values are byproducts of the formula mentioned in Figure 1 and are still highly correlated to the Xfd% value. In general, Figure 6 displays that as the distance from the road increases so do the XLf and XHf values. However, because the Xfd% is calculated using the difference between XLf and XHf divided by XLf, it is more important to look at the disparity between the orange and blue dots on the graph within the same distance. By looking at the difference that is shown between the XLf and XHf, the data for the most part is more spread out in nearer distances and becomes more consolidated at farther distances, away from the road. This again would suggest conclusion that the Xfd% is going to be highly variable, which it is. While the pollution in the soil is seemingly extreme in some parts of the transect, due to the large variability in the data, the evidence supporting the presence of pollution within the soil is weak.

Lunt Meadows: Within the project at Lunt meadows the initial goal was to collect a core that was at least 50 cm deep in several locations and to collect several water samples. However, after arriving on the site and spending time there it was very evident that the access to locations used previously to gather samples was restricted due to the overgrowth of the plants there. Furthermore, a lot of the soil was very difficult to take cores from. Therefore, only two cores were taken, both below/near the old landfill site. One core taken was 29 cm in depth and the other core was 27 cm in length. Additionally, two water samples were taken: one where the cores were taken near the old landfill site, and one near the reed bed. Once the samples were taken, they were brought back to the lab. In preparing the core, each centimeter of the 29 cm core was broken up, creating 29 different groups. The groups were labeled by depth, the first centimeters were labelled “0-1 cm” the second “1-2 cm” and so on. Once separated the samples were allowed to dry overnight. The other core was separated into four different groups: 0-3 cm, 3-12 cm, 12-19 cm, and 19-27 cm. These samples were dried in a freeze-drying process and while their masses were recorded before and after, no further testing was done to determine levels of pollution inside of the core. The masses pre-oven drying were 15.3 g, 41.9 g, 65.3 g, and 60.5 g respectively. After being dried in the oven the masses were 4.3823 g, 17.9009 g, 41.2029 g, and 45.9236 g respectively. Therefore, for group 0-3 cm there was a 71.3575% reduction in weight, for group 3-12 cm there was a 57.2771% reduction, for group 12-19 cm there was a 36.9021%

reduction, and for group 19-27 cm there was a 24.0932% reduction. As the mass of the sample increased, the percent reduction of water within the sample decreased. Alternatively, it could also be the percent of water within the sample if it is assumed that the oven dried out all the moisture within the compound. Generally, it is presumed that this is the case, although it may be harder to oven-dry samples of larger masses completely. In terms of the other core sample that is 29 cm in length, after allowing the samples to dry overnight, they were prepared and then run through the XRF. In preparing the samples for the XRF, each sample was crushed in the mortar and pestle to make the mixture of soil homogenous in nature to get better results from the XRF instrument. Additionally, the mortar and pestle were washed and dried between each use to avoid cross contaminating the soil. While the XRF was being used it was under the proper provision of authorized and trained lecturers. For the site, some of the main concerns were of high amounts of iron within the soil as well as other heavy metals. However, due to the largely orange tint of a lot of the water and soil in the area, it was presumed that a large amount of iron (Fe) was most likely in the soil.

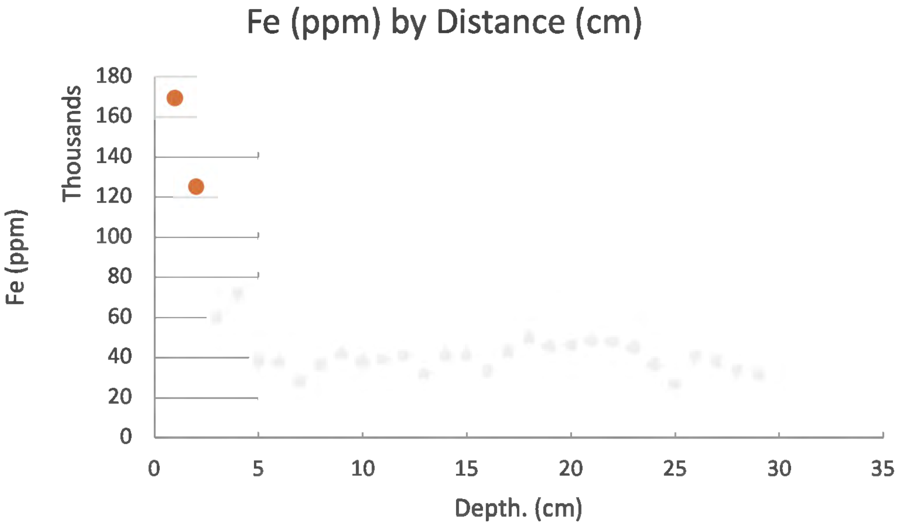


Figure 7: Lunt Meadows iron (ppm) by Depth (cm)

Although the current information of wetland biomes like Lunt Meadows in UK and the standard number of certain metals in the soil such as iron is lacking, it is highly evident that there is a large amount of iron in the first two centimeters of the soil (Figure 7). This is a stark contrast to the seemingly low amount of iron present in the last couple of centimeters and really every centimeter five and after. To determine the significance of the difference between the first two centimeters and the last centimeter of the soil, a test of significance can be run using the mean and standard deviation of the last two centimeters compared to the first two centimeters. The resulting p-value of 0.9987 indicates that there is no significance found within the data. This is because the sample size is only two for each of the means. However, in observing the data comparatively between the lowest and highest points, it can be calculated that the first centimeter is 547.6054% higher than the last centimeter. Several conclusions can be drawn from this: there is most likely little to no leachate occurring in the bottom layers of the soil, and there is most likely either runoff or leachate from the landfill that is causing the current iron levels in the upper tiers of the soil. It is important to also look at the contents of other heavy metals within the soil to further determine whether the leachate of certain materials is taking place as well as the disparity between the first and last centimeters. Some of the materials that are crucial to observe are lead, copper, nickel, and magnesium. However, many other metals were also tested and will be mentioned at the end of the Lunt Meadows summary.

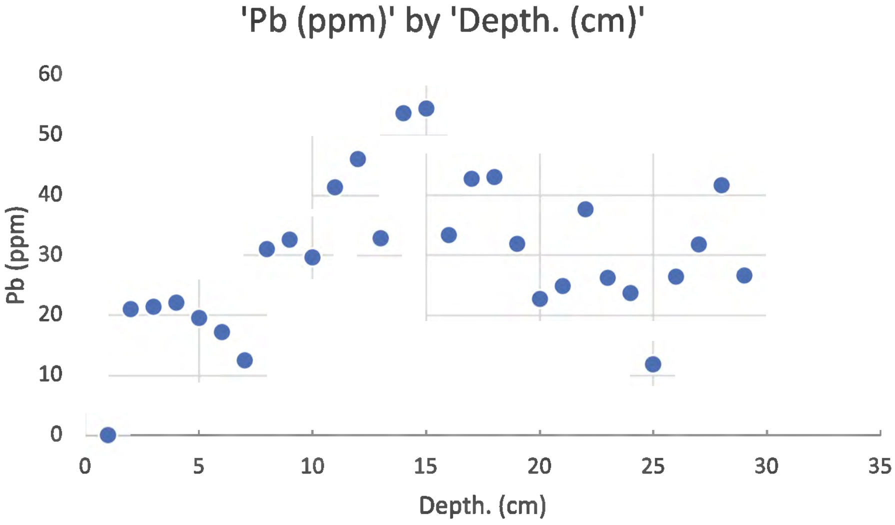


Figure 8: Lunt Meadows lead (ppm) by Depth (cm) Graph

When observing the results for the lead concentrations within the soil, the data is much more sporadic as compared to the results from the iron concentrations. Additionally, the first value is zero due to the amount of lead within the first centimeter being "LOD" meaning that it was in amounts that were too low to detect. The amount of Pb within the core increases to a peak around 15 cm before going back down slightly to around 25 cm where it in turn jumps up again. In contrast to the iron amounts, the highest amounts of lead lie around 15 cm as opposed to the first two centimeters. This suggests lead is leaching into the soil. However, without knowing what an ordinary amount of lead within the soil is, this amount could be normal as well.

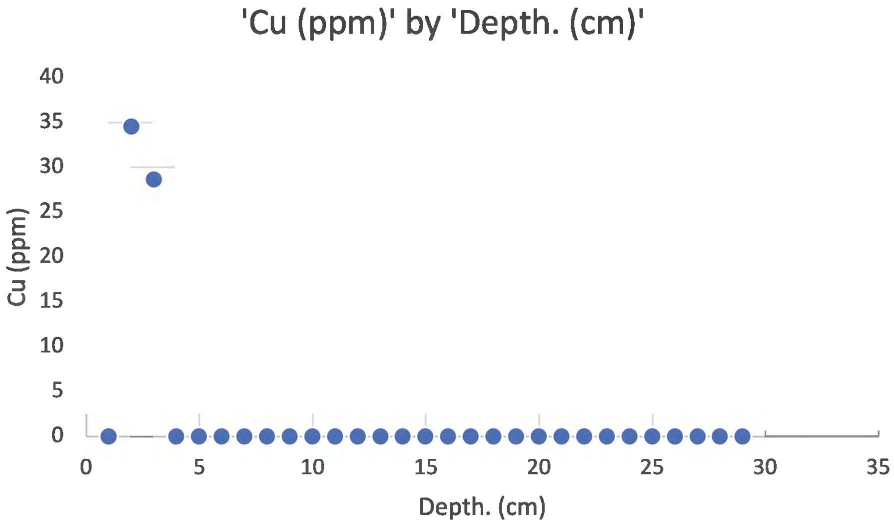


Figure 9: Lunt Meadows copper (ppm) by Depth (cm) Graph

Like the previous graph showing the lead amounts, the values that are listed as “zero” simply imply that the amount of copper within the sample was too low to be measured or be significant. The only significant values of copper are found within the depth of 2 centimeters and 3 centimeters (Figure 9). This aligns with the results found with the iron regarding the metals sitting at the top of the soil. Again, there is no copper at the bottom of the soil suggesting that leaching through the soil is not occurring, at least for copper. However, because of the data being an outlier in centimeters two and three it is also not out of the realm of possibility that contamination of the sample could have occurred.

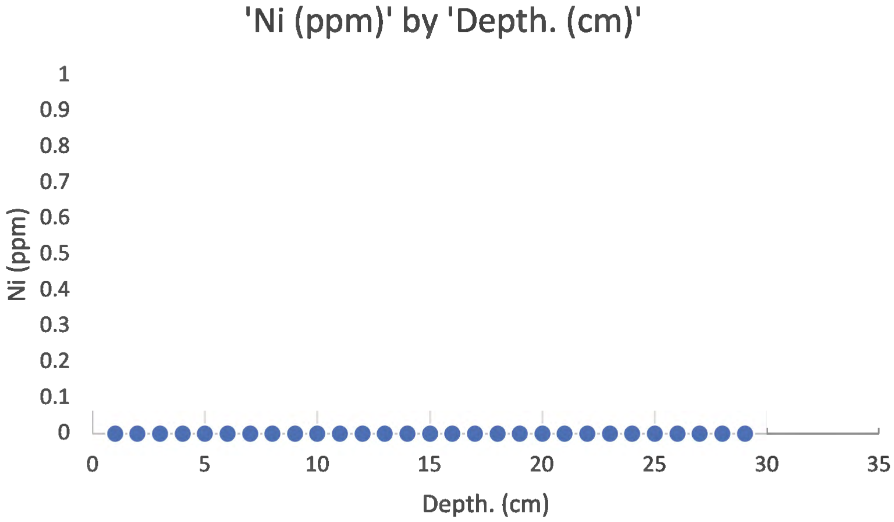


Figure 10: Lunt Meadows nickel (ppm) by Depth (cm) Graph

The results from the XRF for the nickel concentrations inside of the soil suggest that all the values are "LOH" across all the samples. Therefore, it can be concluded that the amount of nickel inside of the soil samples is irrelevant due to the minuscule nature of how much there is.

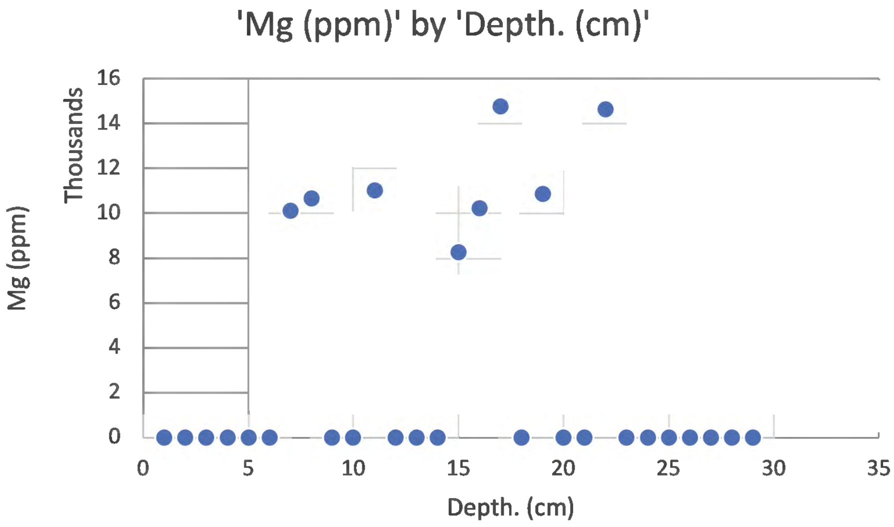


Figure 11: Lunt Meadows Mg (ppm) by Depth (cm) Graph

Again, in the same way as the results for the other graphs, most of the values are LOH. However, there are more values in the middle range of the soil samples that have magnesium than do not. This could suggest a slight bit of leaching is occurring up until 23 centimeters deep, or this may be a regular and healthy amount of magnesium within soil. The rest of the metals and elements tested are listed below (Figure 12 and Figure 13).

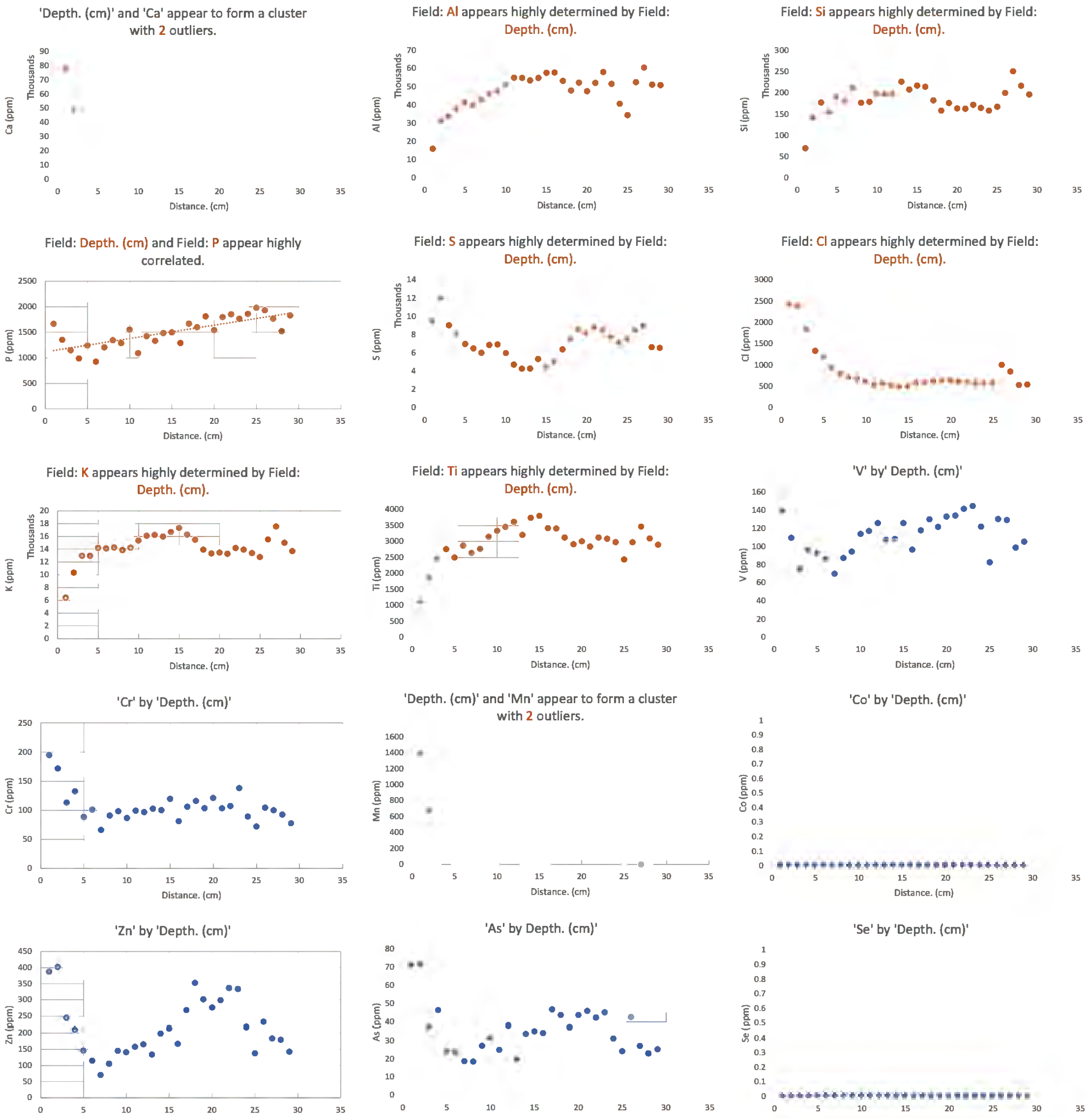
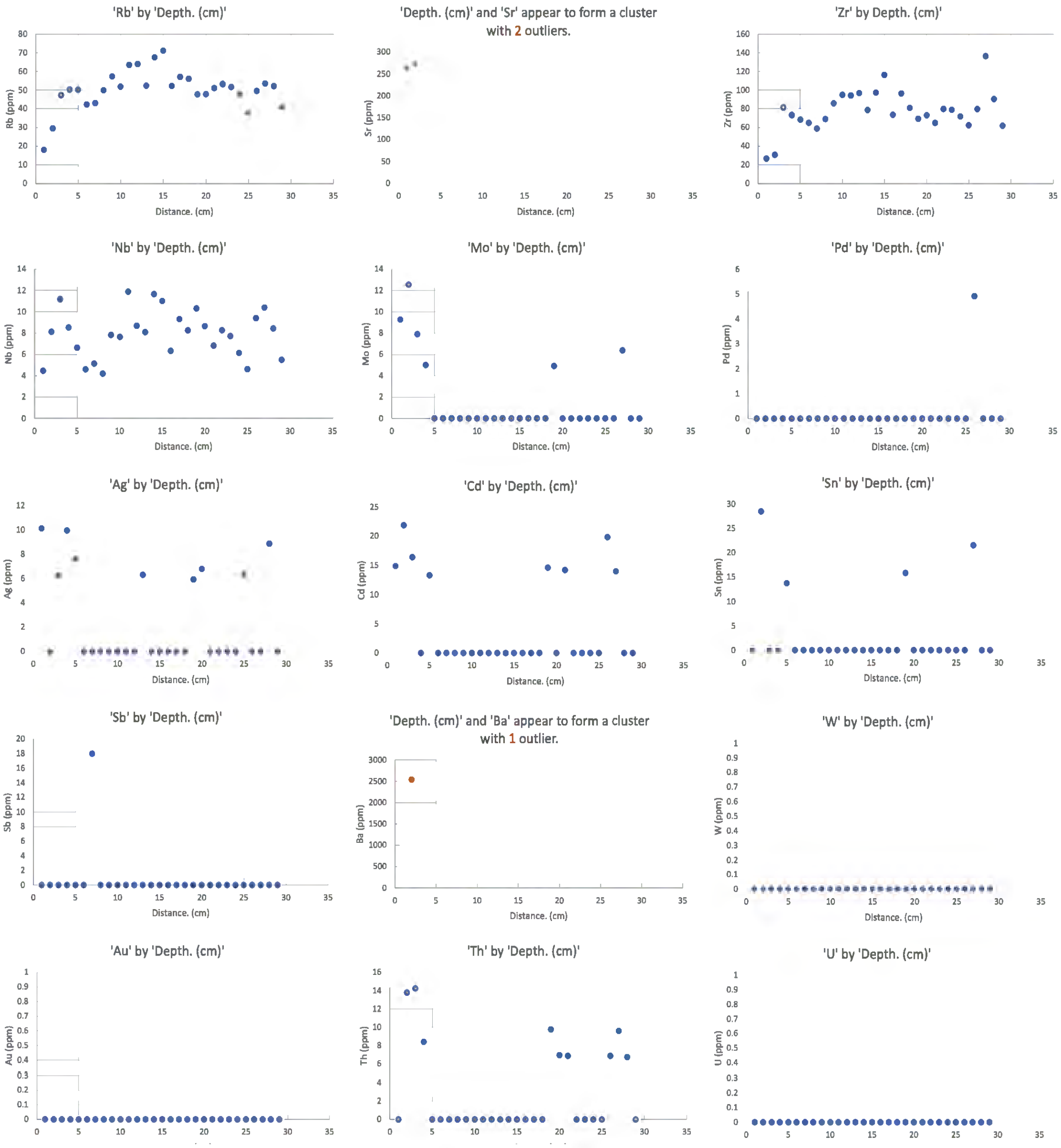


Figure 12: Elements Ca, Al, Si, P, S, Cl, K, Ti, V, Cr, Mn, Co, Zn, As, and Se


'Rb' by 'Depth. (cm)'

'Depth. (cm)' and 'Sr' appear to form a cluster with 2 outliers.

'Zr' by Depth. (cm)'

'Nb' by 'Depth. (cm)'

'Mo' by 'Depth. (cm)'

'Pd' by 'Depth. (cm)'

'Ag' by 'Depth. (cm)'

'Cd' by 'Depth. (cm)'

'Sn' by 'Depth. (cm)'

'Sb' by 'Depth. (cm)'

'Depth. (cm)' and 'Ba' appear to form a cluster with 1 outlier.

'W' by 'Depth. (cm)'

'Au' by 'Depth. (cm)'

'Th' by 'Depth. (cm)'

'U' by 'Depth. (cm)'

Figure 13: Elements Rb, Sr, Zr, Nb, Mo, Pd, Ag, Cd, Sn, Sb, Ba, W, Au, Th, and U

In the above graphs, the orange dots in the graphs followed by grey dots are indicative of outliers being present in the data set. For graphs with only orange dots, there is a strong correlation between the depth and the presence of the element. For graphs with only blue dots, there is a weak or no correlation between the depth and the presence of the element. For elements

Ca, Mn, Sr, and Ba there are outliers within the first one or two centimeters where the outlier indicates large quantities of the element in comparison to the rest of the data. It can be inferred that these elements sit on top of the soil and are not leaching to the bottom of the soil, like the iron. Additionally, there is a positive correlation, with the element becoming more present as the depth of the soil increases in the elements Al, Si, P, and Ti whereas there is a negative correlation for elements S and Cl. The reason for the different strong correlations is undetermined. While not many conclusions can be drawn due to a lack of information on whether certain quantities of the elements presented are indicative of pollution within the soil or not, other information can be concluded by observing the different outliers and strong correlations within the data set. In addition to the information found from the XRF, further information was found from the water samples by doing a nitrate and phosphate test on the water samples.

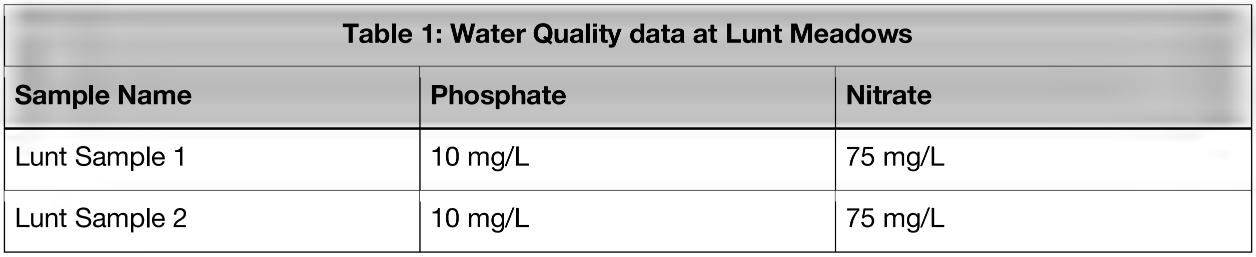


Table 1: Water Quality data at Lunt Meadows

Sample Name	Phosphate	Nitrate
Lunt Sample 1	10 mg/L	75 mg/L
Lunt Sample 2	10 mg/L	75 mg/L

From the samples taken, Sample 1 was obtained near the landfill site, right next to where the core was taken. Sample 2 was taken near the Reed beds. In both water samples, the results were the same. While the methods for finding out specific amounts of phosphate and nitrate within the sample are not used, the test run gives a general amount based on color of the water after adding certain mixtures. From this, it was found that the phosphate was in the lowest amount on the test card, while the nitrate was in the highest amount on the test card. This gives reasonable certainty that there is an abnormal amount of nitrate in the water at Lunt Meadows which is not a good indicator of the overall health of the environment there and is additionally telling of the possible pollutants in the area, as well as possible runoff from the landfill site.

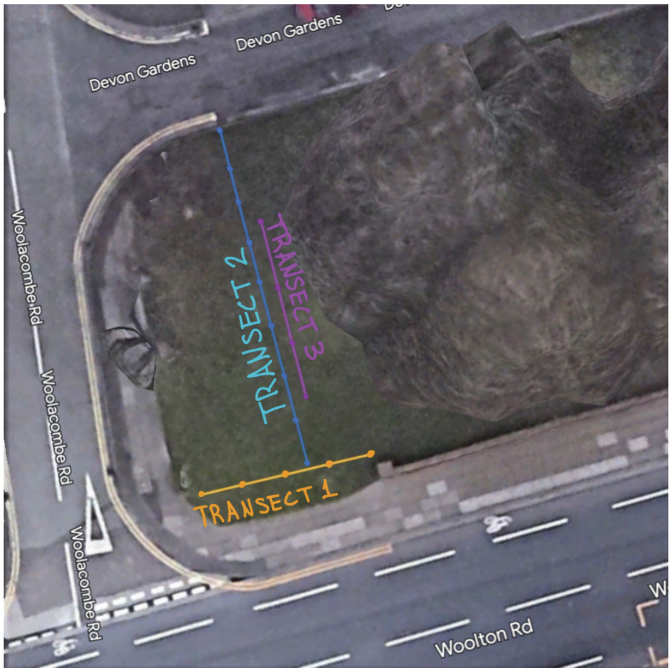


Figure 14: Woolton Road Transects and Location

Woolton Road: Gathering the soil samples for the final project, the goal was to find a stretch of grass near a frequented road that was large enough to take several transects. Additionally, a location close to Liverpool Hope Park University was preferred. Therefore, a spot with a nice area of grass on Woolton Road was found.

When taking the samples from Woolton Road, it was decided that there would be three different transacts made, taking a sample 2 centimeters in depth every 2 meters along the different transects. For transect one, it was made parallel to the road and expected to have the highest amount of pollution among the transects, measuring at 8 meters in length. Transect three was made perpendicular to the road, measuring 16 meters in length, and starting 2 meters from the road. Finally, transect three was made due to the unmowed portion of grass around transect two. Transect three was made two meters to the right of transect two, and measures 6 meters in length. The starting point for transect three is at the 10-meter mark for transect two and runs until the 16-meter mark. Samples were collected and returned to the lab to let dry overnight so that the moisture from the samples would evaporate. Once this was completed, each transect was further divided based on the location among the transect at which it was found. The divisions for transect one are as follows: 0 m, 2 m, 4 m, 6 m, and 8 m. The divisions for transect two are as follows: 2 m, 4 m, 6 m, 8 m, 10 m, 12 m, 14 m, 16 m, and 18 m. Finally, the divisions for transect three are: 10 m, 12 m, 14 m, 16 m. Additionally, four different 2-centimeter samples of soil were taken in the same area at Liverpool Hope University Campus to act as control variables for the experiment; however, when tested it was found that the soil was polluted and could not act as a proper control variable. After the transects were separated based off their location among the transect (i.e. transect 1: 0 m, transect 1: 2 m, etc.), it was decided to sieve the soil to separate the groups based on particle size. This was done because the finer the particle (i.e. the smaller the particle size), the better chance at finding heavy metal pollution in the particles. Originally, it was decided to separate them into all individual layers possible. These layers were 1 mm, 500 um, 250 um, 125 um, 63 um, and <63 um. This process was done for Transect 1, 8 meters (T1 8 m). However, after getting barely any sample for the last two particle sizes, it was decided to conjoin layers to get better results in the magnetic susceptibility instrument. Therefore, each sample after this was sieved and divided into 500-125 um sizes, and <125 um sizes. After sieving all the samples, each sample was prepared and tested for the magnetic susceptibility instrument.

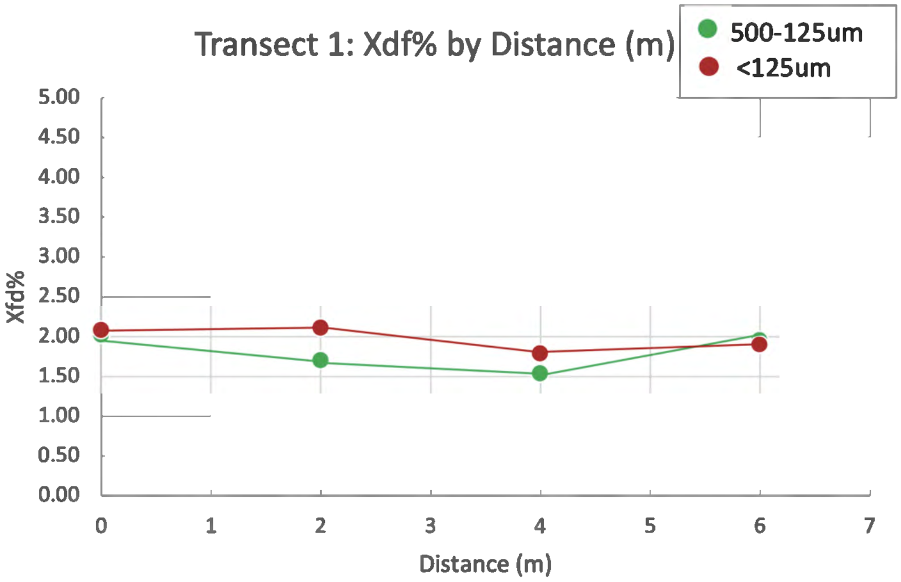


Figure 15: Woolton Road Transect 1 Xfd% by Distance Graph

From the parameters set earlier, it is important to mention once again that when observing graphs displaying data for Xfd%, anything 5% or higher is indicative of pollution within the soil. With the transect being so close to the road, it was anticipated that there would most likely be pollution in the soil due to car emissions. However, in both the <125um and 500-125um samples, the Xfd% barely exceeds 2%. This is opposite of the expected results for Transect 1, as according to this information, there is not much pollution in the soil. More accurately, the soil most likely has diamagnetic and paramagnetic materials due to its low Xfd%.

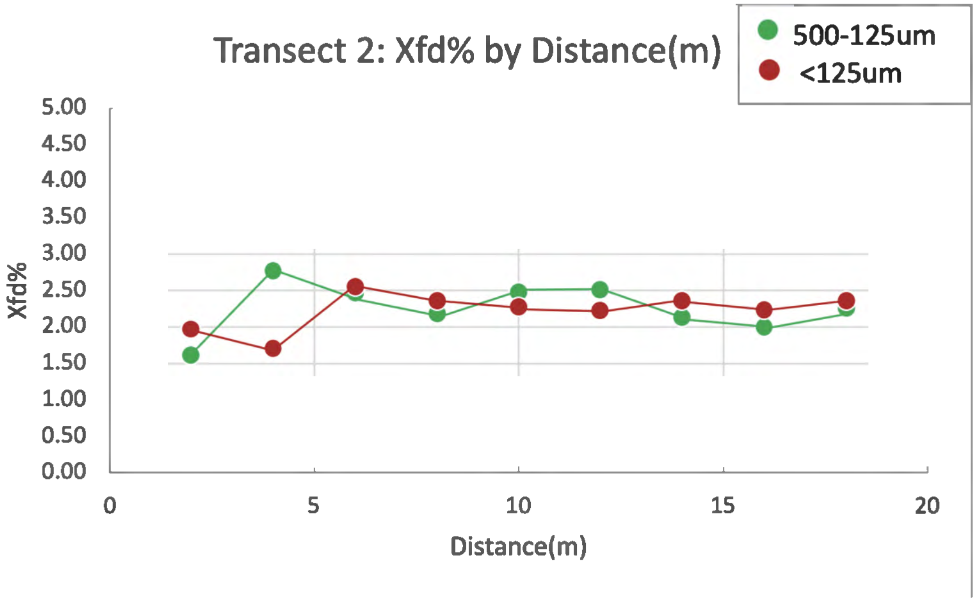


Figure 16: Woolton Road Transect 2 Xfd% by Distance Graph

When trying to make conclusions for Transect 2 (Figure 16), it is immediately apparent that the overall Xfd% is slightly higher overall in Transect 2 then it is in Transect 1. This can be seen as most of the data points exceed 2%, residing around 2.5% for most of the data set. Although this is slightly higher than Transect 2, it is still not a high enough Xfd% to constitute the conclusion that there is pollution in the soil. The pollution in the soil, if any at all, is negligible according to the Xfd%.

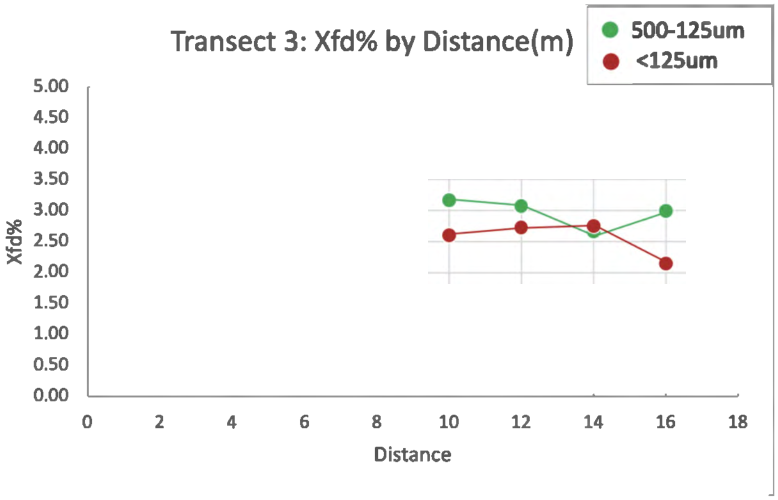


Figure 17: Woolton Road Transect 3 Xfd% by Distance

For Transect 3, it is important to keep in mind that unlike Transect 1 and 2, Transect 3 was taken in an area where the grass was not mowed. This was done with the hypothesis that the Xfd% would be higher in the non-mowed grass when compared to the mowed grass. When looking at the results, this does appear to be true. Overall, all but one of the data points lie above 2.5%, leading the average to be higher than Transect 1 and Transect 2. However, again, the Xfd% is not high enough to draw the conclusion that there is a significant amount of pollution in the soil. However, to get more results for the Project, Transect three was further tested upon. In testing Transect 3 further, the 500-125um and <125um groups were added together, mashed in a mortar and pestle, and then prepared for to be run using the XRF. Once the preparation was completed, the XRF instrument was used to gain further information on Transect 3 regarding the amount of heavy metals and other elements that may be present inside of the Transect.

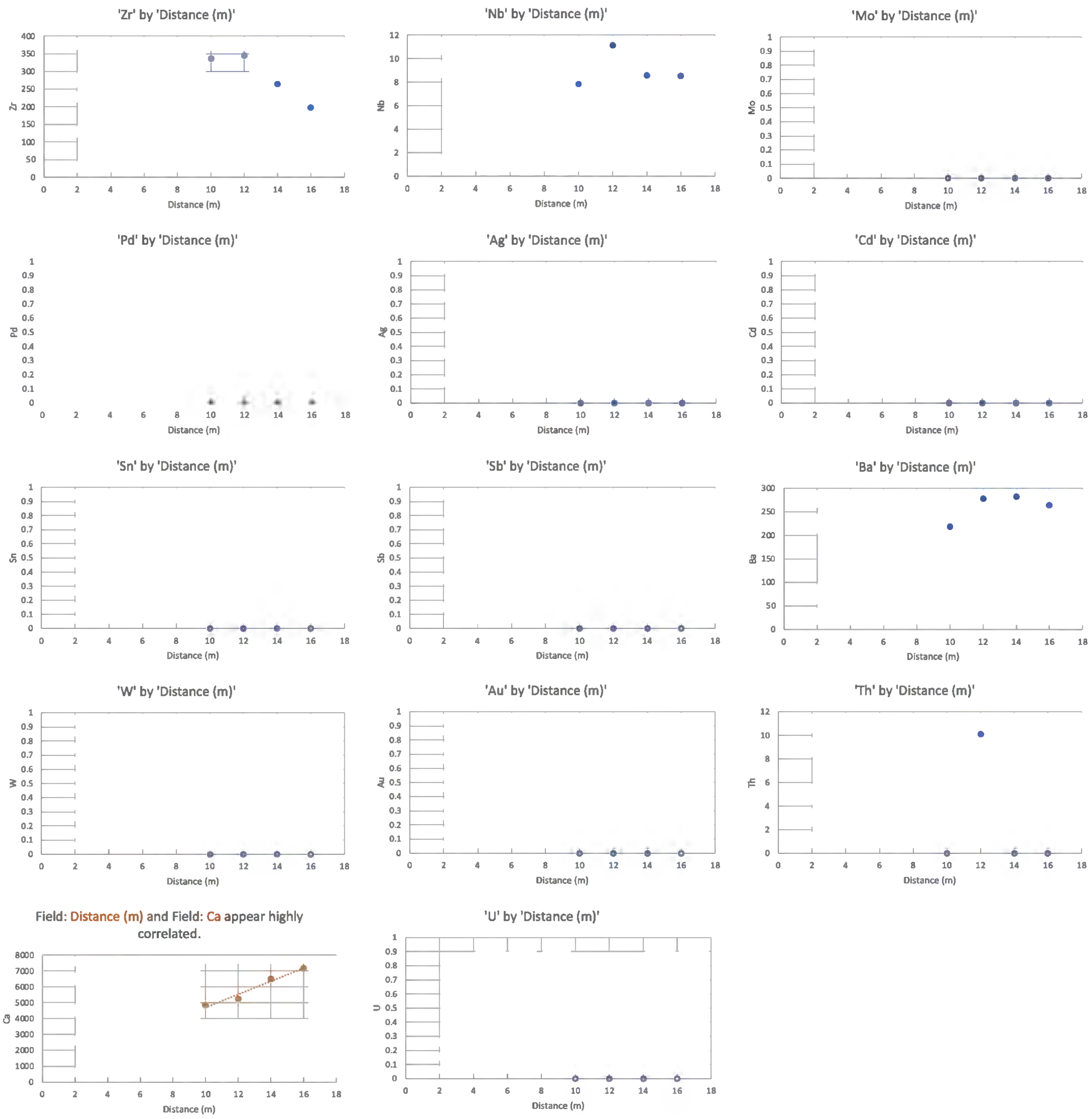


Figure 18: Elements Zr, Nb, Mo, Pd, Ag, Cd, Sn, Sb, Ba, W, Au, Th, Ca, and U for Woolton Road Transect 3

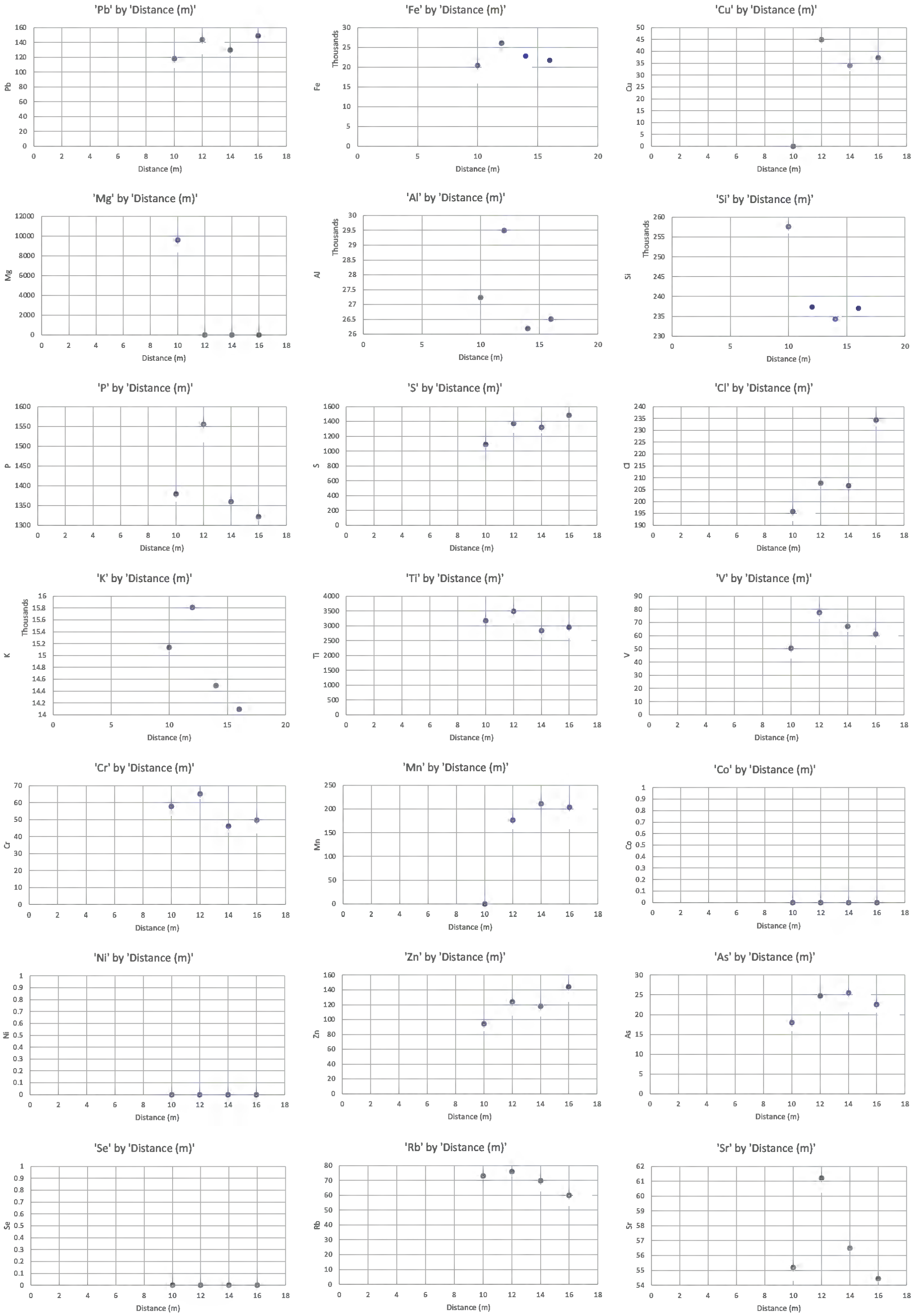


Figure 19: Elements Pb, Fe, Cu, Mg, Al, Si, P, S, Cl, K, Ti, V, Cr, Mn, Co, Ni, Zn, As, Se, Rb, and Sr for Woolton Road Transect 3

Unlike the results found from the XRF on the samples from Lunt Meadows, there is only one strong correlation found within the data for Woolton Road Transect 3. There is a strong positive correlation for levels of calcium within the transect whereas at Lunt Meadows, there was only a high amount of Calcium within the first two centimeters which were outliers. Therefore, it can be concluded that as the Transect was getting further from the road, the levels of calcium within the soil increased. This may also be because of the grass not being mowed and or pesticides within the grass. Additionally, overall, the amount of heavy metals like iron are much lower in the soil here compared to the soil at Lunt Meadows. This may lead to the conclusion that the amount of heavy metals in the soil at Lunt Meadows is above average, indicating pollution within the soil. There are additionally no data sets that feature any outliers at Woolton Road. This is an indication that generally the whole Transect is the same and there is conformity among the samples. This leads away from the hypothesis that as the Transect gets closer to the road, the levels of heavy metals and pollutants will be higher. In the same way the magnetic susceptibility provided conclusions reasoning that there was not a significant level of pollution within the soil, the XRF seems to be providing supporting evidence for that conclusion.

Conclusion

Throughout the Pollution Project the overarching objective was to discover the amounts of pollution in urban areas around Liverpool in the United Kingdom. In doing so, samples were taken at Stanley Park, Lunt Meadows, and Woolton Road.

At Stanley Park, two transects were taken of which one was tested on using magnetic susceptibility and a combination of oven heating and magnetic susceptibility to produce a temperature induced magnetic curve. In doing so, a large range of numbers were found for the

Xfd% from the magnetic susceptibility. This provided a lot of variability within the data and made it difficult to draw any real conclusions. However, based on the data, it can be concluded that in Clusters B, C, E, F, and G, the soil is most likely made up of ferromagnetic materials, suggesting high amounts of pollution in the soil. In contrast, Clusters A, D, H, and I had negative Xfd% values, suggesting the soil had diamagnetic materials and was low in pollution. Finally, Cluster J would be the only sample considered to be made from paramagnetic materials due to the Xfd% being between 0 and 5%. There was an additional graph that was made illustrating the correlation between distance from the road and XLf and XHf values which found that as the distance from the road increased, so did the XLf and XHf values. This does not mean that as the distance from the road increases that Xfd% changes due to Xfd% being based off the difference in XLf and XHf, not the overall values. From the temperature induced magnetic curve done on samples Ha, Ia, and Ja, it was found that the XLf for samples heated at 100, 200, 600, and 800 °C where roughly the same whereas there was a large spike upward in XLf at 400 °C, suggesting the formation of some type of metal in the soil at this temperature.

When analyzing the results from Lunt Meadows, fewer conclusions can be drawn despite the additional data available. The reason many of the conclusions cannot be drawn is because there are no parameters to quantify the data received from running the samples through the XRF. Despite this, different trends in the graphs can be observed to make generalized conclusions and inference about the data. The core taken for the Lunt Meadows project was taken near the landfill site that is no longer in use. In the XRF results for iron, it was found that the top two centimeters of the core sample had results that were outliers when compared to the rest of the data which clustered together. From this, it can be presumed that there is an excessive amount of iron within the first 2 centimeters of the soil which may be caused by leachate from the nearby landfill site. This trend was also seen for the levels of Cu, Ca, and Mn in the soil, having outliers in the first two centimeters. When observing the amount of Pb in the soil, the results were very scattered with the largest amount being centered on 15 cm. Luckily, there was no Ni in the soil which is a good sign. There were some amounts of Mg in the soil in the middle of the core, but the majority of the soil samples had negligible traces of Mg. For the rest of the data compiled by the XRF, there were some elements that had strong correlations while others did not. Al, Si, P, K, and Ti had positive correlations between the amount of elements present and the depth of the soil, therefore, as the depth increased so did the amount of element found in the soil. In contrast, S and Cl had negative correlations. The rest of the data had weak or no correlations in the data with Co, Se, W, and U all having values that were LOH for each centimeter and Sb, Pd having all LOH values besides one outlier. For the water samples taken at the site, there was a water sample taken near the core (location near the landfill site) and another water sample taken near the Reed bed. For both samples, it was found that there was an excessive amount of nitrate (75mg/L <) and little amounts of phosphate (10mg/L>). This concludes that there is most likely a problem with nitrate in the water which could be coming from an unknown source. However, the phosphate levels were as low as the generalized test could measure so it is not worrying.

At the Woolton Road location, the results that were garnered from the use of the magnetic susceptibility instrument as well as the XRF suggest that there is little to no solution in the area. This was found through the Xfd% values of soil samples taken at the Transects. Each sample was taken from the top two centimeters of the soil and were done every 2 meters along the transects. Transect one and two were done in mowed areas of grass while Transect three was done in a non-mowed area of grass. Furthermore, the soil samples taken along the transects were sieved, splitting each sample into two groups based on particle size: 500-125um or <125um.

From this it was found that Transect three had the largest Xfd% values followed by Transect two and then Transect one. Transect three having the largest Xfd% values support the hypothesis that non-mowed areas of grass would feature more pollution than mowed areas of grass. This is still a hypothesis with weak evidence though due to the low sample size of data. However, all the Transects were below 5% which is the universally agreed upon indicator of pollution in the soil. Therefore, The Xfd% values of the Transects are all insignificant in terms of signifying any pollution that may be present in the soil. The soil samples from Transect three combined the different particle sizes and ran them through the XRF to further determine whether there was pollution in the soil. From the XRF, it was found that there was only one strong correlation with Ca being positively correlated with distance. Generally, the levels of all elements were much lower than the levels of elements found within the soil at Lunt Meadows. This supports the idea that the soil at Lunt Meadows most likely is polluted and being contaminated by something.

Through the summation of data from Stanley Park, Lunt Meadows, and Woolton Road, it can be found that all three locations had data that was drastically different from one another. Stanley Park featured results that are slightly suspicious due to the high amount of variability while Woolton Road had consistent and steady data suggesting that there were insignificant amounts of pollution in the soil. In contrast, with the high amounts of crucial elements found within the Soil at Lunt Meadows like iron and high levels of nitrate being found within the soil, there is reasonable evidence to conclude that there is a source of pollution or leaching within Lunt Meadows. This could be from the old landfill site, or this could be from a completely different source that has not been thought about yet. Overall, the Pollution Project yielded results that are telling of the vast differences in soil quality and pollution in areas around Liverpool. Although the locations may not be far apart, the data suggests that they could not be more different in terms of pollution. By investigating the reasons behind said pollution in areas like Lunt Meadows and Stanley Park and even the reasons behind the insignificant amounts of pollution on Woolton Road, more work can be done to better Liverpool.

The Ethics of Pollution from outdoor activities

While looking at research pertaining to pollution and human involvement in its cause, it is important to keep in mind not only what can be done in our daily lives to mitigate this damage towards the environment, but also the ethical responsibility that we have in treating our environment. When it comes to our ethical responsibility to the environment, it is found to be expressed with different degrees of personal involvement. There are four main levels of involvement that can be applied to our responsibility to take care of the environment: an individual level, societal level, corporate level, and global level (Whitcomb 1). Individual levels of responsibility encompass the actions that we can personally make to be more aware of our environmental impact, such as drinking out of reusable water bottles as opposed to plastic ones. The next level of responsibility is societal, which stems from the ability of a collectivistic group of people striving to enact changes that better the environment. The next level is corporate which can be described as the impact that companies have on society. The last level is global, which includes problems and solutions that are global in nature. The focus of the problems discussed will mainly be on an individual level and, in part, a societal level. While it may be hard to mitigate the damages that arise from large contributors to carbon emissions and global warming, like different forms of transportation and electricity, we can still make many changes to how we interact with the environment to lessen our impact. By being more cognizant of how we personally treat our environment when engaging in outdoor activities, we can better take care of our environment.

As the effects of climate change become more pronounced throughout the world and our daily lives, it is increasingly important to take care of our environment in every facet possible. However, this does not always have to be through preventing such pollutants like carbon emissions, heavy metals, or greenhouse gases. On the contrary, there are a plethora of other types of pollution that we can constantly be more conscious of in our daily lives. One of the ways this can be done is by having respect for the outdoors when we participate in outdoor activities. However, before it can be explained why we should take care of the outdoors, it must be agreed upon that we as humans have an ethical responsibility to protect the outdoors to the best of our abilities. Without this foundation, building up other arguments on how people can limit their effects when partaking in outdoor activities becomes baseless as there is no reason to care about the environment if we are not ethically responsible for it. Therefore, the following premises will be built on moderate biocentric and ecocentric ethical principles. These principles, assume there is intrinsic value in the environment as well as the animals that live in it. Therefore, because the environment and animals have intrinsic value, we should do our best as humans to take care of them.

Three outdoor activities will be explored: off-roading, rock-climbing, and hiking. The reason that these different outdoor activities will be of focus is because these activities are frequent choices of outdoor enthusiasts and can damage the environment when pursued incorrectly.

When talking about off-roading one of the main concerns is the physical damage that it can pose to the environment around it. This can be done in many ways, but the main offense happens from going on undesignated trails as off-roading is usually only able to be done on areas/trails that are specifically designed for it. By taking these vehicles off the trails, there is a much higher likelihood of affecting the local environment in a negative way such as killing sensitive vegetation, destroying the landscape, releasing car fumes into unadapted areas, and altering the soundscape (Lindsey B. 1). Therefore, with the ramifications of this outdoor activity in mind, it is crucial that we be cognizant of ways to mitigate this damage.

Rock climbing: While there may not be as much of an apparent impact that rock-climbing has on the environment, it is still highly important to go about this outdoor activity in a way that respects the environment. Because the premise built from caring for the environment is based off an ecocentric view, it is believed that all parts of the environment have intrinsic value and should therefore be respected. Considering this, when analyzing rock-climbing, we find that that the usual threats of pollution are slightly different. Most of the damage that rock-climbing poses to the environment is from the visual pollution that it causes. As most climbers use chalk, it is always apparent where a climber has been as the chalk stays on the rock long after they leave. The issue arises when the rocks that are being climbed on carry social, cultural, or religious significance to people in the area. Additionally, rock-climbing tends to deface the rock after significant repeated use, degrading the original structure and taking away from its natural form. This comes from the use of gear, protection, and bolts on the rock-face that can damage the rock and are frequently left behind. Therefore, on the basis that the environment has intrinsic value, certain measures need to be taken to limit the amount of damage done to the rock face. While there are many different resources that can be used as guidelines to being ecologically friendly while climbing, the gold standard of climbing ethics comes from the American Alpine Club's "Ten Commandments of Sustainable Climbing" made in 1990 (AAC Publications 1). Many of the guidelines written focus on the importance of leaving behind minimal evidence of being in that area. This manifest itself in rules that describe many different fundamental elements: using chalk/gear that matches the tone of the rock, not placing bolts near areas that are prone to breaking, taking responsibility for your trash as well as others trash, having respect of environmental areas of significance (i.e. historically, religiously, etc.), and following local rules and regulations (AAC Publications 1). While this is a generalization of most of the rules, the specifics all fall under one of those general guidelines. By upholding these climbing commandments, one can go about the outdoor sport of climbing in the most ethical way possible and avoid any sort of visual or physical pollution in the area.

Hiking: The final area of outdoor activities that will be analyzed is that of hiking. Hiking is one of the most popular forms of outdoor activities enjoyed by people, with almost 60 million hiking participants in 2022 in the United States (Statista Research Department). Because of the large number of participants that indulge in hiking every year, it is critical that the activity is gone about in an ethically responsible way that respects the environment as well as the wildlife in it. The sources of pollution for hiking can almost act as an amalgamation between off-roading and climbing as many of the sources of pollution are similar. Hiking can feature pollution that damages the environment, leaves trash in the area, leaves visual pollution, and even contributes to sound pollution. Like the ten commandments discussed in the ethics of climbing, there are a similar set of rules for hiking. The standard ethical guideline for hiking also applies across all areas of outdoor activities and is known as “Leave No Trace Ethics”. The fundamental principle of Leave No Trace is as the name implies, to produce minimal to no sign of being in the area. This is like the ethics of climbing which talks about picking up after yourself and others but tends to be more specific towards situations found when Hiking. These specific principles include things like having respect for wildlife and other hikers, being conscious of the surface on which the hiker travels and camps, finding suitable areas to reduce the impact of campfires, partaking in minimal interactions with the environment (i.e., digging, moving objects, taking plants, etc.), and planning for the trip (National Park Services 1). By being more cognizant of ways that we interact with the outdoors, we can leave the outdoors a better place than we found it and make sure that it stays here for years to come.

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