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The Legacy of Contamination by Lead Smelters in Missouri

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THE LEGACY OF CONTAMINATION BY LEAD SMELTERS IN MISSOURI

A Master's Thesis

Presented to

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Geology

By

Robert S. Armstrong

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THE LEGACY OF CONTAMINATION BY LEAD SMELTERS IN MISSOURI

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ABSTRACT

Missouri has a rich history of lead mining. In the smelting process lead particles are emitted, which may be toxic to plants and animals. This study focuses on two primary lead smelters, Herculaneum and Glover, in Missouri. Smelting operations have ceased at these two sites, and unlike Herculaneum, Glover has no reported lead concentrations. Findings from air and sediments of these two sites were compared to background conditions and to each other. Thirty-three samples were collected from Herculaneum and Glover (thirty samples and three replicates) and eleven samples (ten samples and one replicate) for background. For Herculaneum sediment, lead levels ranged from 2 to 250 mg/kg, cadmium levels ranged from below detectable limit (<0.5 mg/kg) to 3 mg/kg, and zinc levels ranged from 8 to 322 mg/kg. In Glover sediment, lead levels ranged from 106 to 956 mg/kg, cadmium levels ranged from 0.7 to 4.4 mg/kg, and zinc levels ranged from 36 to 261 mg/kg. For background sediment, lead levels ranged from 48 to 75 mg/kg, all cadmium levels were below detectable limit, and zinc levels ranged from 25 to 36 mg/kg. Correlation of metal values in sediment normalized by iron clearly separated the sites by their degree of contamination as Glover > Herculaneum > Background. In Glover, average monthly lead air concentrations in 2013-2014 ranged from 0.04 to 0.15 $\mu g/m^3$ and in 2018-2019 ranged from 0.01 to 0.04 $\mu g/m^3$. In Herculaneum, average monthly lead air concentrations in 2013-2014 ranged from 0.02 to 0.29 $\mu g/m^3$ and in 2018-2019 ranged from 0.03 to 0.15 $\mu g/m^3$. For both background sites, lead air concentrations in their final year of data ranged from 0.01 to 0.02 $\mu g/m^3$. In air, the contamination was Herculaneum > Glover > Background. Backgrounds for both sediment and air were significantly lower than the values observed for the smelter sites.

Keywords: Smelter, sediment, air pollution, lead, normalization

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To Tom and Angel Kruzen, for giving me a glimpse into what it means to care for our planet. I did not realize the effect that your passion had on me until entering this program. I like to think that my thesis is a continuation of your hard work.

I dedicate this thesis to the late Tom Kruzen and my newborn son, Asher.

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INTRODUCTION

Mining

French settlements played a large role in the early development of lead mining throughout southeast Missouri. The French miners often relied on Native Americans as guides and prospectors to aid in locating lead ore. Much slave labor was also used during this time to hand-dig the lead ore. Barite was a product of mining and was discarded until the demand for *le tuf* increased, which provided a second wind to many of the mines. Mining shafts were introduced to Mine a Breton (now Potosi, Missouri) by Moses Austin, who also introduced the first reverberatory furnace in Missouri at the beginning of the 19^{th} century (Gold, 1979).

Mining in the Old Lead Belt (OLB) occurred from the mid-1700s until the last mine ceased operations in 1972 (Gale, et al., 2004). Industrial mining began in the OLB in 1864 with the St. Joseph Lead Company (SJLC). As mining technology advanced and deeper ores were discovered the SJLC continued to expand. In 1891 a primary lead smelter was built in Herculaneum, MO. When mining began to slow within the OLB efforts were shifted toward mining within the New Lead Belt, or Viburnum Trend (VT).

The VT is located near the southwestern limit of the OLB (as seen in Figure 1) and is within the Mark Twain National Forest (MTNF). The MTNF has many creeks and rivers that drain the area. Because of the many waterways present, metal toxicity in these streams is a serious risk. Elevated heavy metal concentrations have been reported to have an effect on invertebrate and fish communities within these streams (Besser et al., 2009).

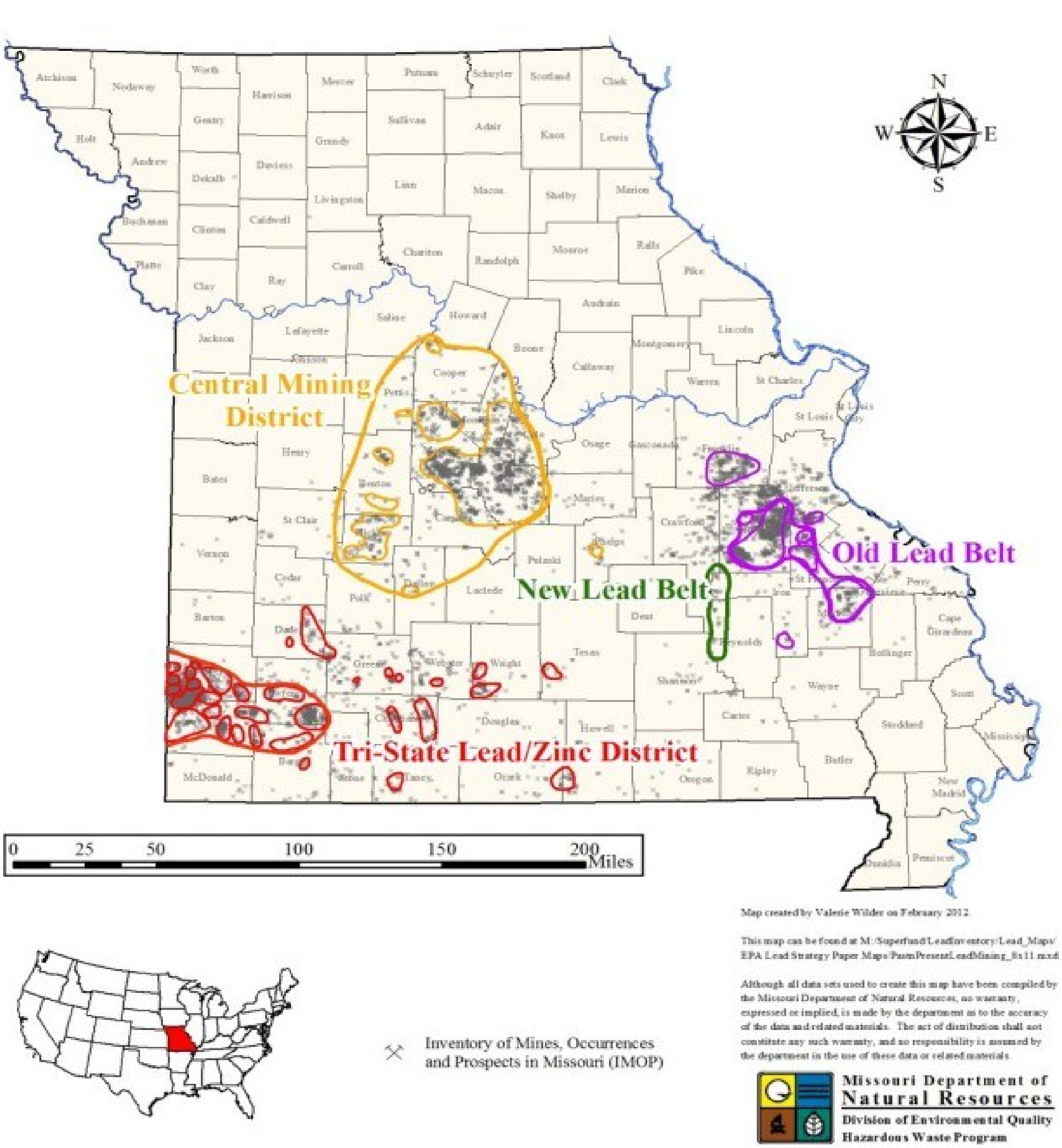

Figure 1. Missouri mining districts map, Missouri Department of Natural Resources.

Smelting

Primary lead smelting is the process of extracting pure lead from ore by crushing an ore into powder and then sintering (heating and compressing) to return the ore to a pure, solid mass

(Gale and Wixson, 1979). With sintering, the goal is to obtain PbO because it is easily yields metallic Pb (de Andrade Lima and Bernardez, 2017) The process for sintering at a primary lead smelter (Figure 2) is to mix ore concentrate, limestone, and sand together and roast to “desulfurize” the concentrate. In this reaction, PbS is converted to PbO and the oxide is then taken to a blast furnace to further isolate the lead. Sulfur released from PbS is converted to SO_2 and passed through a cooling chamber, baghouse filters, and scrubbers with the aid of updraft currents. Particulates that are caught by the filters are then recycled back through the furnace. Additionally, some sites have an acid plant that any captured SO_2 can be converted to sulfuric acid. Once the gases have been cleaned and cooled, they are released through a stack into the air. Gases can bypass this filtration and scrubbing and be released into the stack. As these volatiles will then accumulate in the stack high concentrations of heavy metals can be released if the filtration system is not operating efficiently (Gale and Wixson, 1979). Over many years, this accumulation of dust-borne lead greatly contaminated the greater Herculaneum area.

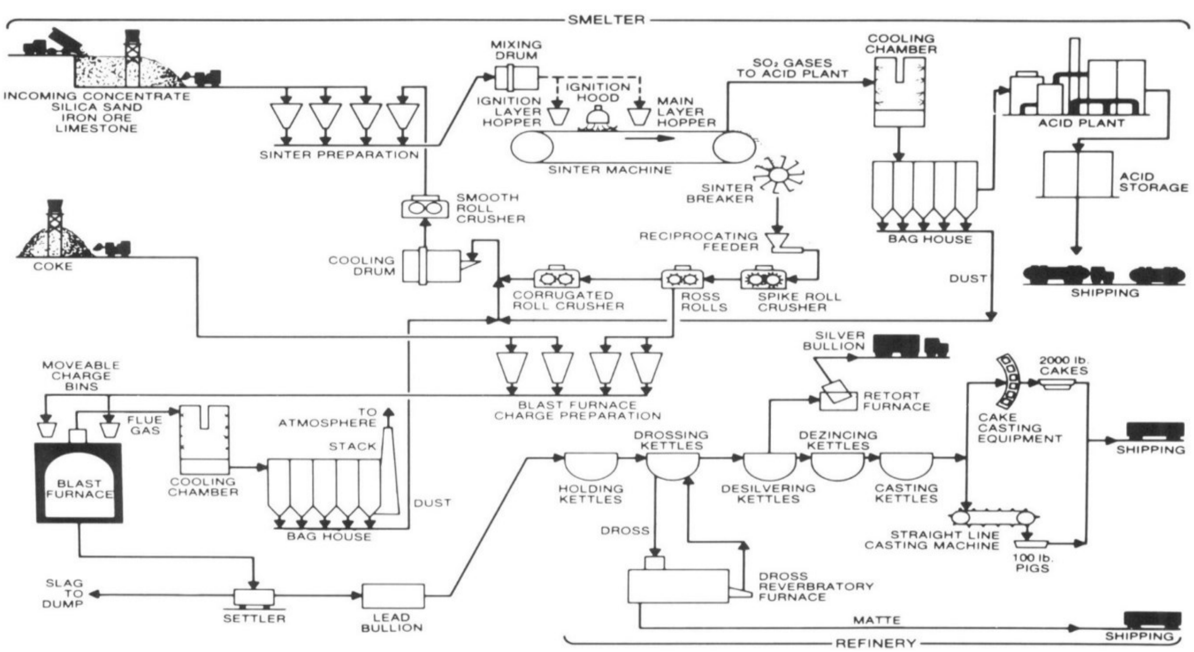

Figure 2. Primary lead smelting process.

The city of Herculaneum developed a master plan in 2006 in coordination with the United States Environmental Protection Agency (EPA) to combat the contamination caused by the lead smelter. This master plan provided that the EPA completed environmental sampling in Herculaneum and found lead levels in yard soils as high as 33,100 mg/kg, in street dusts ranging from 30,000 mg/kg to 300,000 mg/kg, and in air ranging from non-detectable to 85 $\mu g/m^3$. The primary form of remediation completed in Herculaneum consisted of replacement of yard soils for 407 residences and cleaning the interior of 113 homes. In addition to this remediation, a settlement required Doe Run to make an offer to purchase properties within 3/8 mile of the smelter, 142 properties were purchased (Herculaneum Master Plan 2006, 2006).

Background Lead Concentration

Prior to the automotive industry's shift toward unleaded gasoline, lead emissions were common on and along US roadways. PbO*PbSO4 was found to be a major component of primary lead smelting emissions that was not known to be a product of vehicle emissions (Biggins and Harrison, 1980). Most lead that was added to street dust from automobiles weathers into an assortment of differing lead compounds (Harrison et al., 1981). Simply stated, any lead that may be detected will be difficult to identify the source. To limit this, a baseline for lead levels in Missouri was established.

Potentially toxic metals (PTM) are present in soil and sediment in low concentrations because rocks are susceptible to weathering (Kasemodel, Papa, et al., 2019). To determine the degree of PTMs in an area untouched by anthropogenic lead a background was selected at a considerable distance from smelter influence. To build this baseline value, in addition to the smelter site samples that will be taken, samples were taken at distances greater than 100 km from

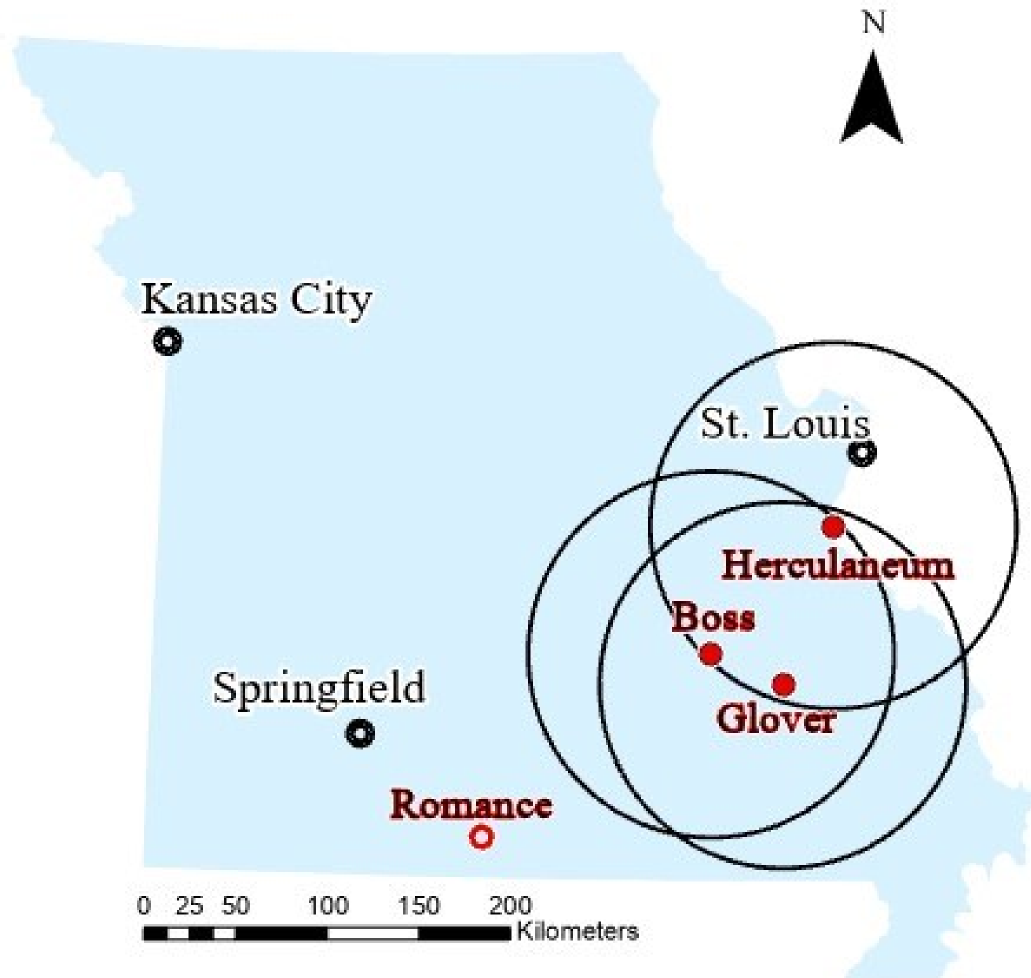

Figure 3. Map of Missouri with buffers of 100 km placed around disqualifying areas for background concentration of lead. Romance is the selected location for background concentrations of lead in Missouri.

each of the sites (Figure 3). Lead has been detected in peat at distances of approximately 100 km from a smelter (Zoltai, 1987). Buffers with a radius of 100 km were used as disqualifying areas for background contamination samples. By creating buffers of one- hundred kilometers from the Herculaneum and Glover smelters, as well as the secondary lead smelter that is in Boss, Missouri, a background contamination location was selected near Romance, Missouri, which will hereon be referred to as background.

Sediment samples have been collected from each site as closely as arbitrary and natural boundaries allow, approximately equidistant from the smelter. Lead levels in soil and vegetation are highest in absolute proximity to lead smelters with a steep decrease as distance from the smelter is increased. (Linzon et al., 1976). Using this as a guide, emission buffers were created in ArcGIS Pro and placed on top of a compiled orthoimage for the Herculaneum (Figure 4) and Glover (Figure 5) sites. Using orthoimagery with these buffers allowed for targeted selection of sediment collection within a set distance from the smelter. The goal was to have all smelter samples obtained from a range of 0.5 km to 1 km away from the smelter.

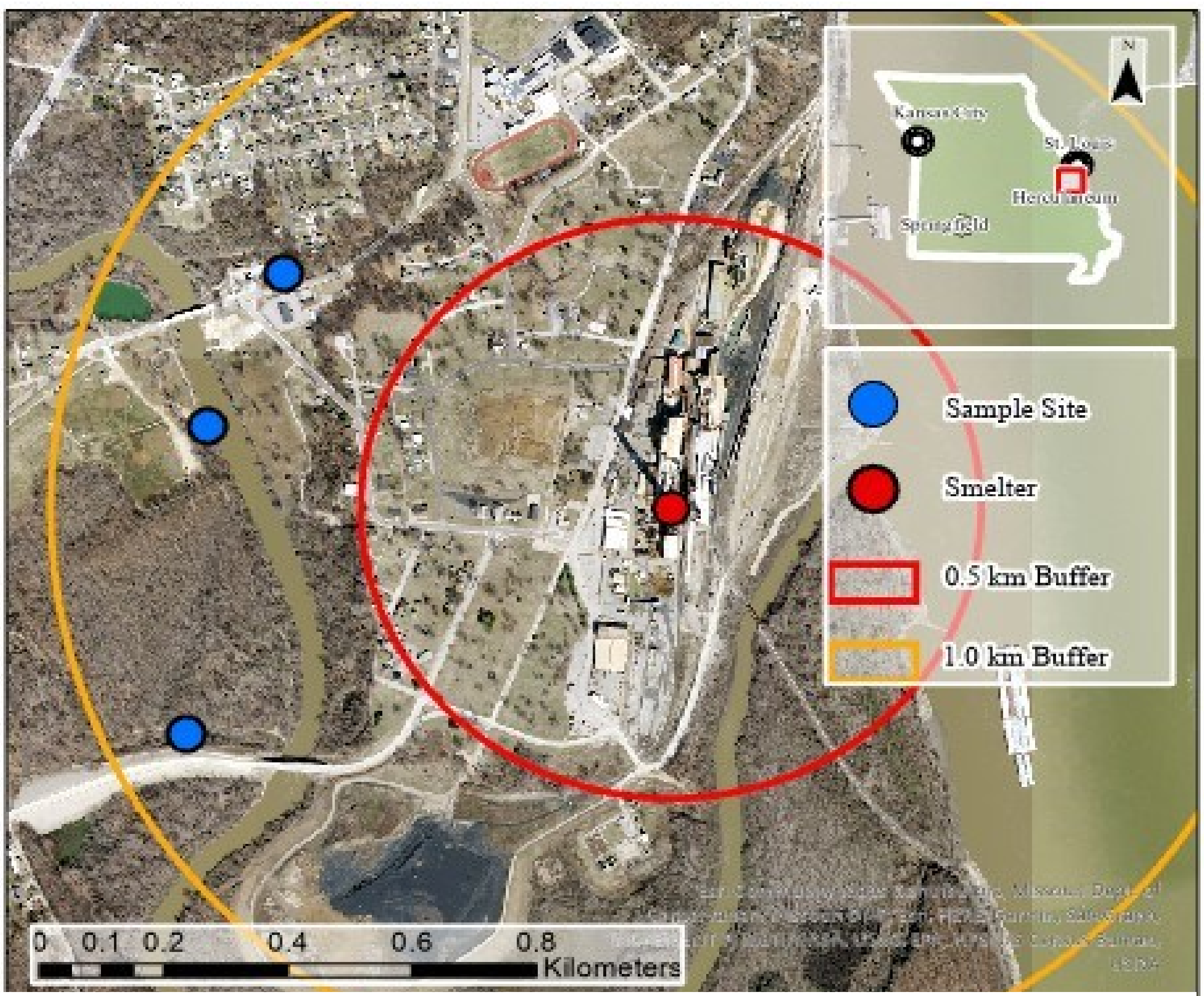

Figure 4. Map of Herculaneum, MO with emission radii placed around smelter. Smelter is indicated by the red point and sample locations are indicated by blue points.

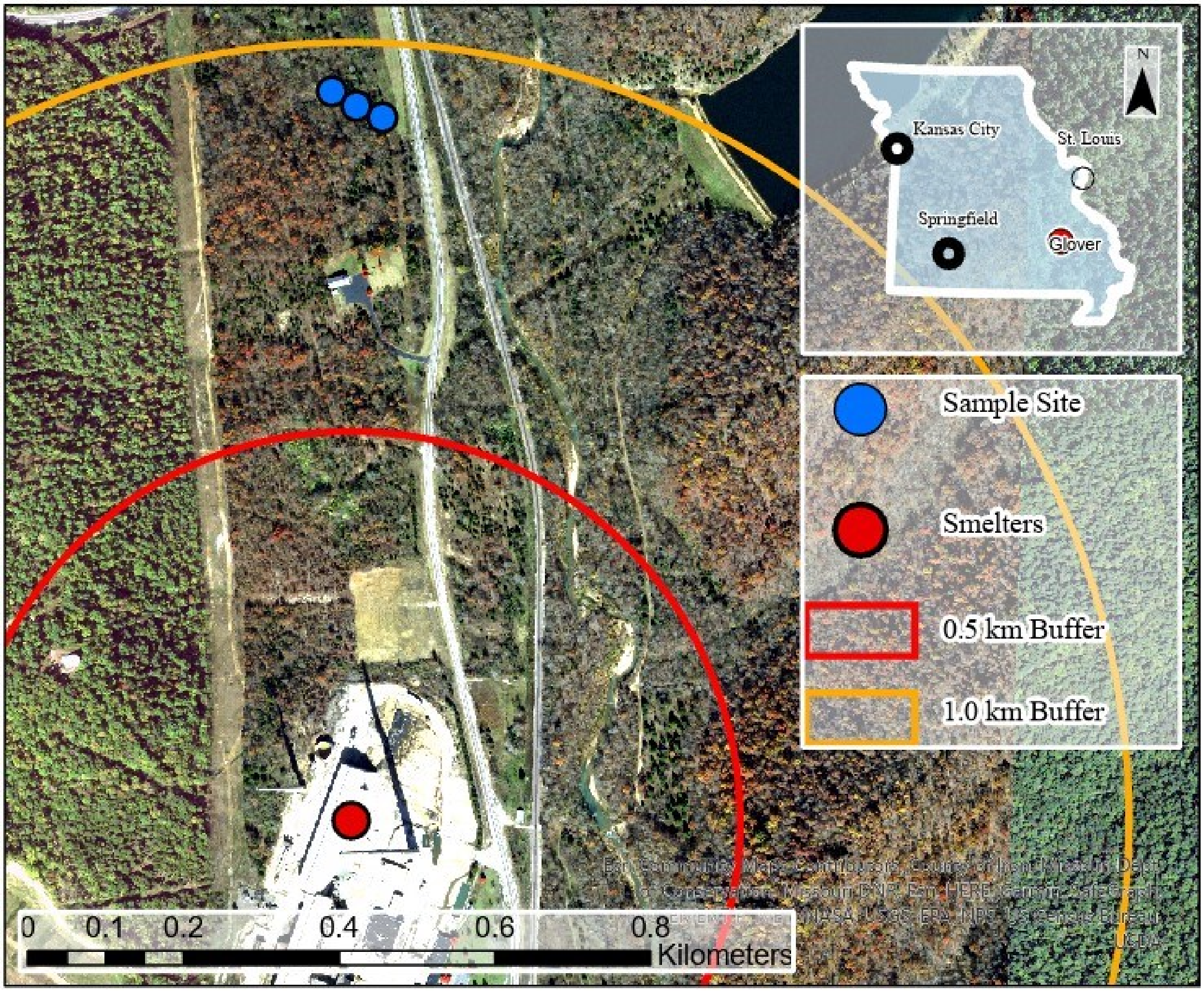

Figure 5. Map of Glover, MO with emission radii placed around smelters. Red point indicates mid-point between two smelters, blue points indicate sample locations.

Lead Mining and Lead Smelting in SE Missouri

In the OLB most of the lead ore is present in the Upper Cambrian Bonneterre Dolomite. Prior to extensive mining in the OLB and Viburnum Trend regions of southeast Missouri there was little geological research conducted. Most research that was completed was done so by companies for the purpose of identifying sources of lead on their own properties instead of large-scale structural and stratigraphic information (Ohle and Brown, 1954). Ohle and Brown (1954) also go on to state that the reason for limited geologic information in southeast Missouri "is due

to the ease of exploration by diamond drilling, for ore reserves could be maintained by simply drilling more holes into known mineralized areas.”.

Stratigraphy of the area (Figure 6) includes, at the surface, the Potosi Dolomite for a thickness of approximately 365 feet. Underlying the Potosi is the Doe Run Dolomite and Derby Dolomite for approximate thicknesses of 60 feet and 40 feet, respectively. The Davis Shale lies below this and serves as a confining layer to the fluids beneath for a thickness of approximately 165 feet. The Bonneterre Dolomite (the host rock of most of the lead in this region) has a thickness of approximately 375 feet to 400 feet. Underlying the Bonneterre Dolomite is the Lamotte Sandstone for a thickness of approximately 375 feet to 425 feet. Lastly, the basal unit is Precambrian igneous rock (Ohle and Brown, 1954).

As previously mentioned, most of the lead obtained from mining is in the Bonneterre Dolomite. This dolomite was altered from limestone prior to the infiltration of lead. Lead in this region likely originated at depth and migrated up into the Bonneterre Dolomite before crystallizing (Ohle and Brown, 1954).

Ohle and Brown (1954) believed that the source of lead was the Precambrian basement rocks. A later study analyzed isotope ratios of lead to arrive at the conclusion that the lead originated in the Lamotte Sandstone and moved up into the Bonneterre Dolomite (Doe and Delevaux, 1972). The Lamotte Sandstone is less than 100 feet thick in western Missouri and thickens to 400 feet to 500 feet in Eastern Missouri (Ojakangas, 1963).

The most common form of carbonate deposits of lead are sulfide deposits. Deposits such as the OLB and NLB are both characteristic of compressional events, similar to the deposit in the Tri-State Mining District (TSMD) of western Missouri (Gutiérrez et al., 2016). Compression caused by the Appalachian-Ouachita orogeny in Arkansas drove geothermally-heated saline

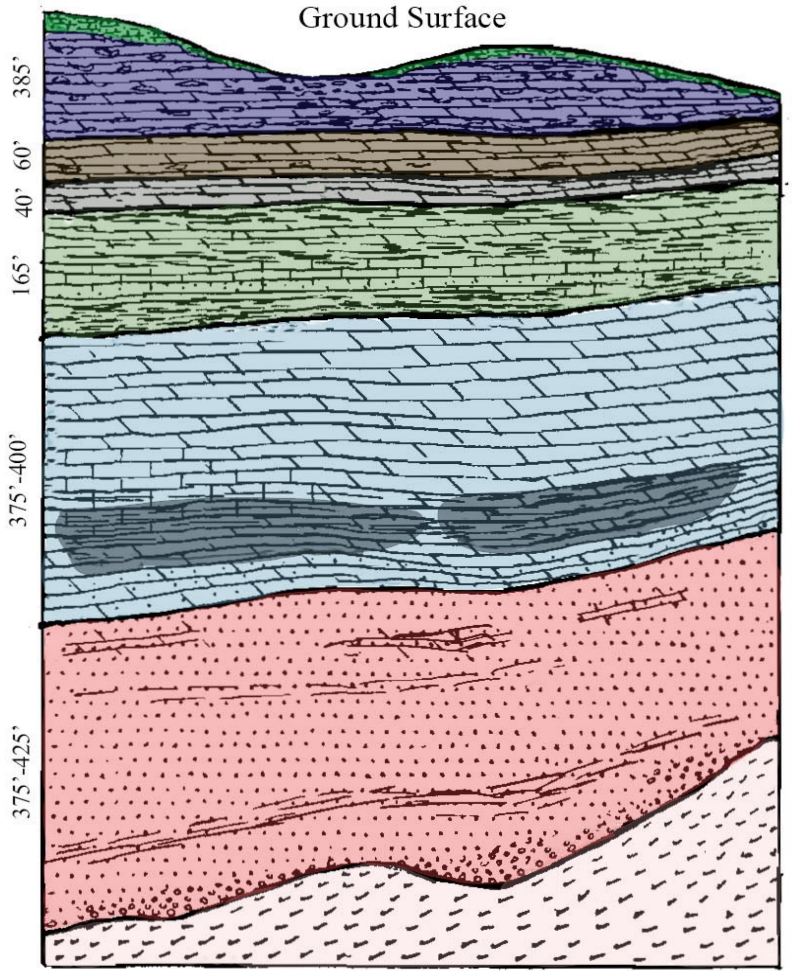

Figure 6. Modified image of stratigraphy of eastern Missouri originally created by Ohle and Brown (1954).

fluids north into the foreland, which contains the OLB, NLB, and TSMD (Bradley and Leach, 2003; Clendenin and Duane, 1990; Leach and Rowan, 1986). These areas in Missouri contain chemically receptive Paleozoic-aged carbonates (Gutiérrez et al., 2019). In the OLB and NLB these carbonates are the Bonneterre Dolomite.

This area has a history of mining and there were large smelters active. After years of lead emission, the area may be contaminated. There were four objectives to this study. The first

objective was to measure the lead content in sediment in Herculaneum and Glover. Secondly, air lead concentrations were examined for these sites. Data for sediment and air was compared between these two sites as well as to background concentration sites. Lastly, the obtained data was compared to established guidelines for contamination.

It is hypothesized that near a smelter the lead concentrations in air and sediment will be higher and that these levels will be above recommended guidelines. The EPA designated guidelines for a violation are a lead concentration are a value greater than 0.15 µg of lead per cubic meter (0.15 $\mu g/m^3$) of air, greater than 15 µg/L for drinking water, and greater than 400 mg/kg in soil in play areas (Ericson et al. 2019; EPA, 2020). The probable effect concentration for lead in streams is 150 mg/kg (Besser et al., 2009).

METHODS

Smelter Selection

The primary site in Herculaneum (Figure 7) was chosen as a reference site to study due to more studies being conducted on the environmental impact of this smelter and the fact that this is the last active primary lead smelter in the US. This smelter is the property of Doe Run Company (DRC). The Glover smelter (Figure 8) was chosen because it is in southeastern Missouri as and

Figure 7. Primary lead smelter in Herculaneum, MO.

unlike Herculaneum, there are no studies conducted on its environmental impact. The smelter was confirmed as being an operating smelter in southeast Missouri by reviewing the history of the DRC on their website.

Figure 8. Primary lead smelter in Glover, MO.

Location Maps

Using imagery obtained from the EarthExplorer online database (United States Geological Survey, 2020.) orthoimagery was uploaded into ArcMap to create detailed maps of each of the smelter sites. Herculaneum had many map files and resolutions available. The images that were selected had spatial resolutions of 0.5 meters. Six of these images were compiled into one large, high-resolution image surrounding the Herculaneum smelter (Figure 9).

Using a similar method for the Glover image (Figure 10), two large images with a spatial resolution of 1m were combined for one larger image of Glover surrounding the smelters. As the resolution of the Glover map is larger, so too is the area surrounding the smelter. Once these maps were compiled a feature class point was placed on the smelters and buffers were created around the smelters to represent radii of 500 meters and 1km. Having these detailed maps included assisted in selecting very specific locations for sediment and air samples surrounding each site.

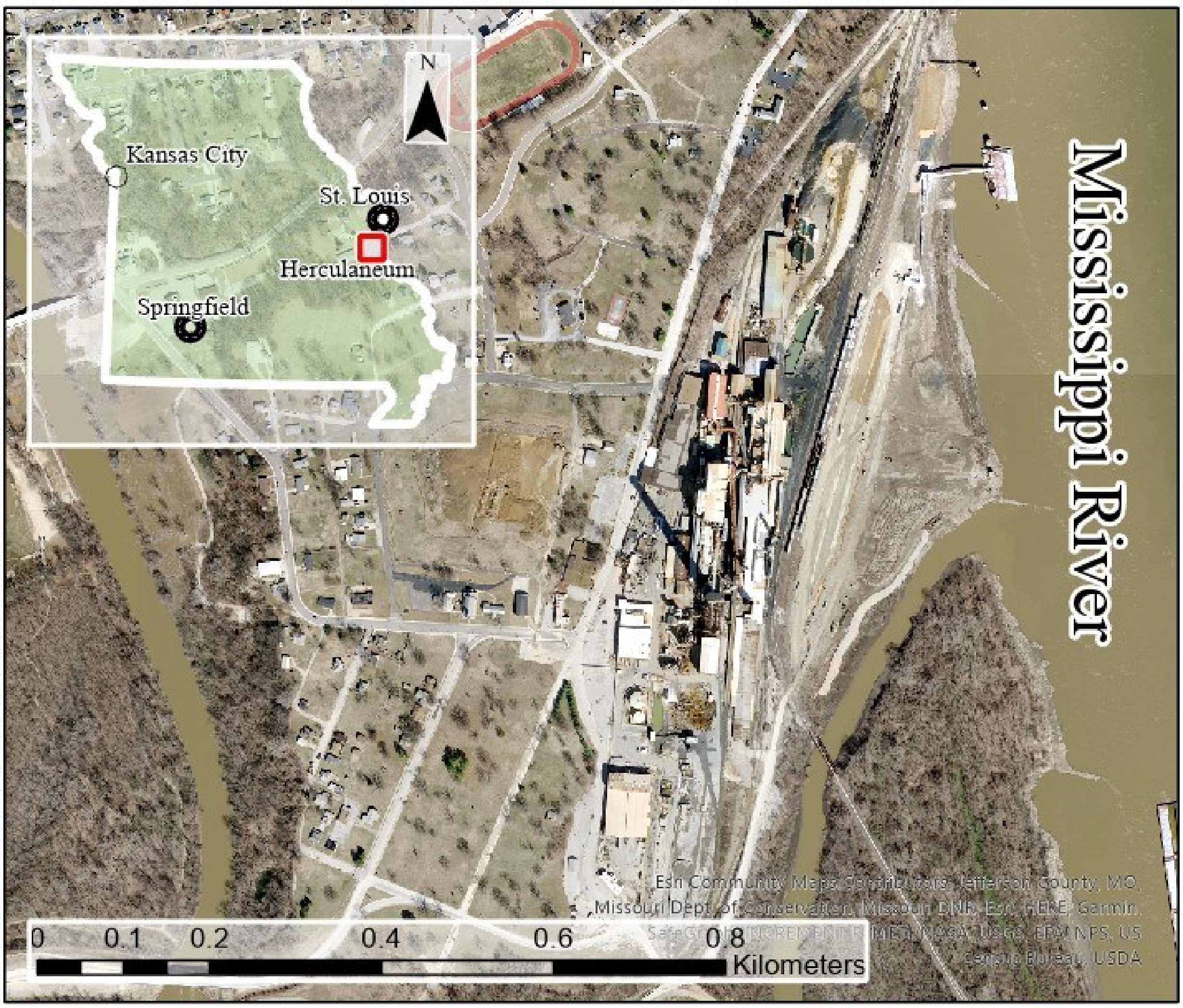

Figure 9. Compiled orthoimage of Herculaneum, MO.

Air Sampling

Missouri provided an updated site where current air quality data for the state of Missouri is archived. Accessing this database provided a targeted search of both the Herculaneum and Glover air quality (Environmental Protection Agency, 2019).

During initial research into Herculaneum an “Environmental” link was found on the website for the city of Herculaneum. This was navigated to locate an outdated page for the EPA that had archived air quality data. A personal communication with a representative of the EPA in

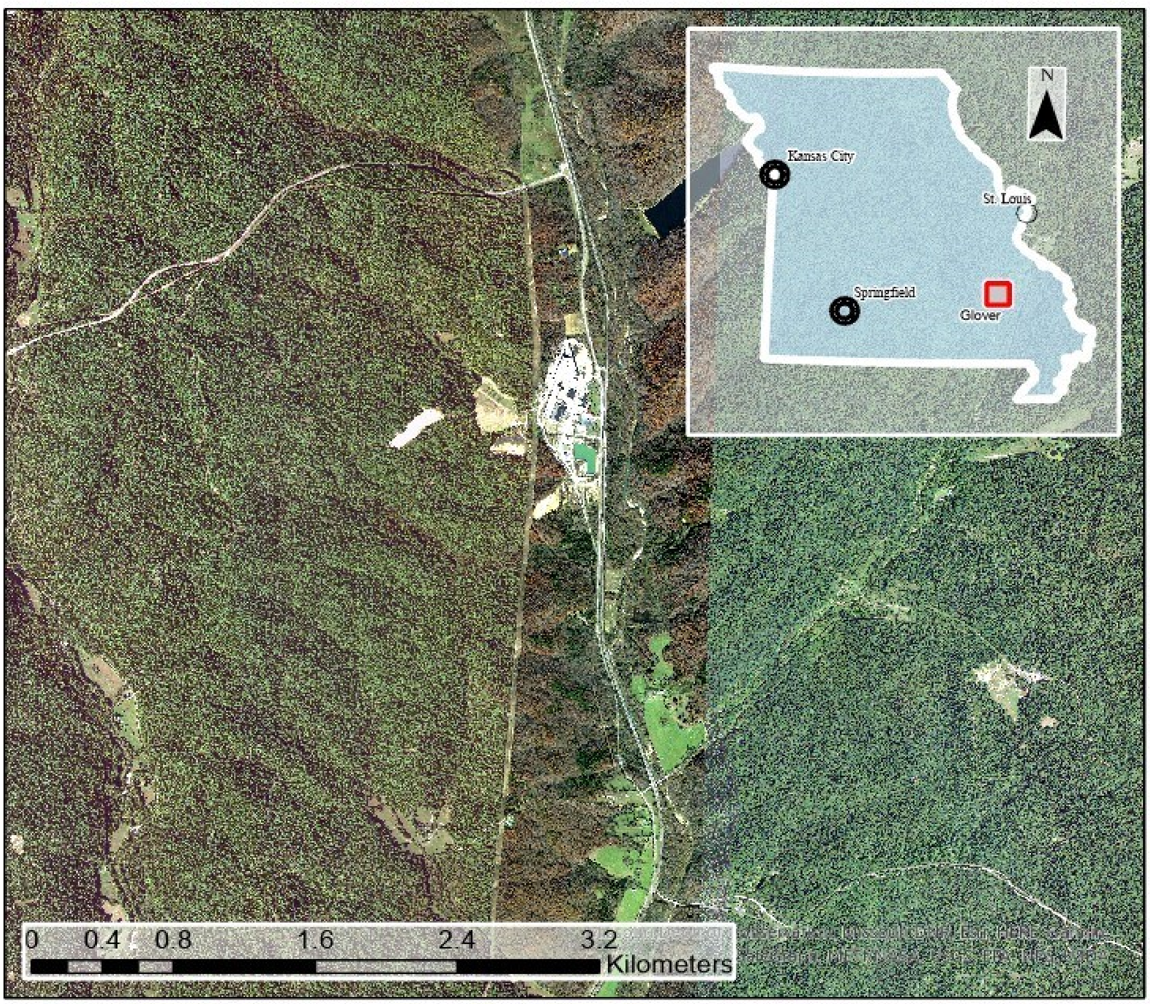

Figure 10. Compiled orthoimage of Glover, MO.

As this database is an ArcGIS web application individual layers could be applied to a map of Missouri to locate stations that monitored lead data. This application also indicated which stations were no longer active. The United States Environmental Protection Agency (EPA) states "If the air quality in a geographic area meets or is cleaner than the national standard, it is called an attainment area (designated 'unclassifiable/attainment'); areas that do not meet the national standard are called nonattainment areas.". To measure the air quality in a site, the EPA uses what are called air quality monitoring stations. This data is compiled in a database sponsored by the Missouri Department of Natural Resources and was used within this study (Tables 1, 2, 3, and 4).

Three air quality monitoring stations in Herculaneum were chosen. Herculaneum has more active air stations but was limited to three sites because this data will be compared to data from Glover, MO which only had data for three air quality stations during the selected time frame. The criteria for selection of stations as follows: firstly, the station needed to have one full year data available from May 2013 through April 2014 and May 2018 through April 2019. The three locations selected in Herculaneum were Church Street (Figure 11), Mott Street (Figure 12), and North Cross (Figure 13). The Glover stations selected were Church (Figure 14), Post Office (Figure 15), and Big Creek (Figure 16). The Glover Church station was deactivated at the end of April 2019 so that timeframe was applied to all the smelter site data for consistency. Secondly,

Table 1. Monthly lead air concentration averages of arithmetic mean micrograms per cubic meter recorded from Glover air quality monitoring stations for May 2013 through April 2014.

Date	Mean	Date	Mean	Date	Mean
May-13	0.13	September-13	0.05	January-14	0.09
June-13	0.09	October-13	0.15	February-14	0.06
July-13	0.10	November-13	0.08	March-14	0.05
August-13	0.04	December-13	0.11	April-14	0.05

Table 2. Monthly lead air concentration averages of arithmetic mean micrograms per cubic meter recorded from Glover air quality monitoring stations for May 2018 through April 2019.

Date	Mean	Date	Mean	Date	Mean
May-18	0.01	September-18	0.01	January-19	0.01
June-18	0.01	October-18	0.01	February-19	0.02
July-18	0.01	November-18	0.01	March-19	0.02
August-18	0.02	December-18	0.01	April-19	0.04

the stations needed to be approximately equidistant from their local smelter. Consolidated air quality data for Glover and Herculaneum for the years of 2013-2014 and 2018-2019 are displayed in tables 3 and 4. Full data tables for Glover 2013-2014 and 2018-2019 and for Herculaneum 2013-2014 and 2018-2019 are provided in Appendices A-L.

Figure 11. Church Street air quality monitoring station in Herculaneum.

Figure 12. Mott Street air quality monitoring station in Herculaneum.

Figure 13. North Cross air quality monitoring station in Herculaneum.

Figure 14. Church air quality monitoring station (removed) in Glover.

Figure 15. Post Office air quality monitoring site (station could not be located) in Glover.

Table 3. Monthly lead air concentration averages of arithmetic mean micrograms per cubic meter recorded from Herculaneum air quality monitoring stations for May 2013 through April 2014.

Date	Mean	Date	Mean	Date	Mean
May-13	0.12	September-13	0.12	January-14	0.02
June-13	0.18	October-13	0.13	February-14	0.18
July-13	0.17	November-13	0.21	March-14	0.15
August-13	0.23	December-13	0.29	April-14	0.19

Figure 16. Big Creek air quality monitoring station (removed) in Glover.

Table 4. Monthly lead air concentration averages of arithmetic mean micrograms per cubic meter recorded from Herculaneum air quality monitoring stations for May 2018 through April 2019.

Date	Mean	Date	Mean	Date	Mean
May-18	0.03	September-18	0.05	January-19	0.08
June-18	0.15	October-18	0.01	February-19	0.06
July-18	0.07	November-18	0.10	March-19	0.04
August-18	0.06	December-18	0.01	April-19	0.11

As a contrast to the air quality in Herculaneum and Glover data from two additional monitoring stations were compiled. To identify a background value of lead air concentration, the two nearest sites that had air quality data beyond the range of influence of the smelting sites were in Chanute, Kansas and Nilwood, Illinois. One year of data was included for the final year both air quality stations were in operation and is displayed in Tables 5 and 6. All sites in Missouri that

have air quality monitoring stations are located near known smelters or within lead mining districts. Chanute and Nilwood both are beyond 100 km from these disqualifying areas.

Table 5. Final year of EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Chanute, KS air quality monitoring station.

Date	Mean	Date	Mean
2/3/1997	0.01	8/8/1997	0.01
3/23/1997	0.02	11/24/1997	0.01

Table 6. Final year of EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Nilwood, IL air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
1/1/2009	0.01	5/1/2009	0.01	9/4/2009	0.01
2/6/2009	0.01	6/6/2009	0.01	10/4/2009	0.01
3/2/2009	0.01	7/6/2009	0.01	11/3/2009	0.01
4/1/2009	0.01	8/5/2009	0.01	12/3/2009	0.01

Sediment Sampling Locations

Lead levels in soil and vegetation are reportedly highest in absolute proximity to lead smelters with a steep decrease as distance from the smelter is increased (Linzon et al. 1976). Additionally, lead concentrations appear to decrease with a shallower slope at the value of 500 meters. Sediment was collected from ephemeral streams. To be within 500 meters of the smelter and have access to an ephemeral stream was difficult due to private property boundaries. For this reason, the sediment collection range was set to 500 meters to one km from the smelters.

To obtain values of what background concentrations of lead in sediment are in Missouri, a background site was selected in Ozark County, Missouri. Sediment collected from background was taken from an ephemeral stream approximately 2 km from the nearest paved road and 500

meters from the nearest gravel road to reduce the likelihood of lead contamination due to automobile exhaust prior to the transition to unleaded gasoline. There is a positive correlation between the number of registered vehicles in an area and concentration of lead in roadside soils (Ahmad, et al. 2019). Street dusts have also been ruled out because in known contamination areas, lead sulfate is the most common lead compound present. Lead sulfate is highly soluble in water which would increase the mobility of lead (Biggins and Harrison, 1980).

To further limit variability, these sample locations should have similar attributes (such as distances from a paved or gravel road, a body of water, known contaminated areas such as tailing ponds, etc.). The samples were collected by using an unused steel gardening spade to obtain sediment at or very near the surface (less than 3 cm depth) (Linzon et al., 1976).

Sediment samples were collected from each site as closely as arbitrary and natural boundaries allowed, approximately equidistant from the smelter. Emission buffers were created in ArcGIS Pro and placed on top of compiled orthoimagery for the Herculaneum and Glover sites. Using orthoimagery with these buffers allowed for targeted selection of sediment collection within a set distance from the smelter. The goal is to have all smelter samples obtained from a range of 0.5 km to 1 km away from the smelter.

Sediment Analysis

Sediment, once collected, was stored in sealed plastic bags (identified by extraction location) to await analysis preparation. Sediment was disaggregated in a mortar and pestle to remove any clasts after being air-dried until samples were completely dry. The primary source of environmental contamination from smelter stacks comes from the finer fractions of dust (Harvey et al., 2016). To target the finer particulates, all sediment was sieved to less than one millimeter

in size to remove clasts. After sieving, all samples were individually placed into small plastic vials and labeled for their corresponding location.

To determine the variability between samples laboratory replicates were included, which is analyzing two sediment subsamples separately. A random number generator was utilized to determine which samples were to have replicates taken and the replicates were obtained from their corresponding homogenized sediment. One replicate was included per ten samples of sediment.

All samples were shipped to ALS Geochemistry in Reno, Nevada for metal (Al, Cd, Fe, Pb, Zn) analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The ICP-AES measures the concentration of specific elements that are present in trace amount. In environmental studies, leaching or extraction procedures are used because they enable the measurement of more varieties or phases of minerals at a level fitting for environmental policy (Rauret et al., 1998).

Normalization consists of a ratio of metal concentrations divided by iron, aluminum, or another nonreactive component. In this study iron and aluminum were selected for normalization of cadmium, lead, and zinc. Normalization is commonly applied to highlight abnormal concentrations. For the purpose of research, normalization to iron or aluminum is common because of the abundance of the two elements in the earth's crust. 50% or more of the concentration variation for lead and zinc can be accounted for with normalization to iron or aluminum (Daskalakis and O'Connor, 1995). This abundance makes iron and aluminum less likely to be influenced by anthropogenic activities (Sakan et al., 2014). Normalization to grain size is also commonly performed in analysis but requires more time and is more difficult than normalizing to iron (Suh and Birch, 2005).

Statistical Analysis

The first step in analyzing sediment data was compiling the results from the geochemical analysis into site-specific spreadsheets for Glover, Herculaneum, and background. The data included in the analysis were sample number, received weight (in kg), aluminum (percent), cadmium (mg/kg), iron (percent), lead (mg/kg), and zinc (mg/kg). Metal content data were normalized with respect to iron and aluminum. Normalization is a common procedure in sediment samples because it minimizes the natural variability of trace metals in sediment.

Normalization also detects and quantifies contributions of anthropogenic metals. Organic matter, sediment size, and other metals can also used to normalize. Of these parameters, iron and aluminum were selected. Iron and aluminum are both effective for normalization (Sakan et al., 2014). These two were compared to determine which would yield better results. Once these normalized values were obtained a correlation matrix was constructed for lead, zinc, and cadmium, as well as their normalized values. Pearson correlation coefficients were calculated for metals and metals normalized to Fe and Al (Ozkan and Buyukisik, 2012; Kasemodel, Sakamoto, et al., 2019). T-tests were performed in Microsoft Excel using Real Statistics. These t-tests examined the significance per element (Al, Fe, Pb, and Zn) per site with a confidence interval of 95% ($\alpha = 0.05$). Glover and background were tested against each other, Herculaneum and background were tested against each other, and Herculaneum and Glover were tested against each other, each with respect to Al, Fe, Pb, and Zn.

A histogram (Figure 17) was also constructed in Microsoft Excel to examine the distribution of values for aluminum, iron, lead, and zinc between the sites. The purpose of the histograms was to see if the data followed a normal curve.

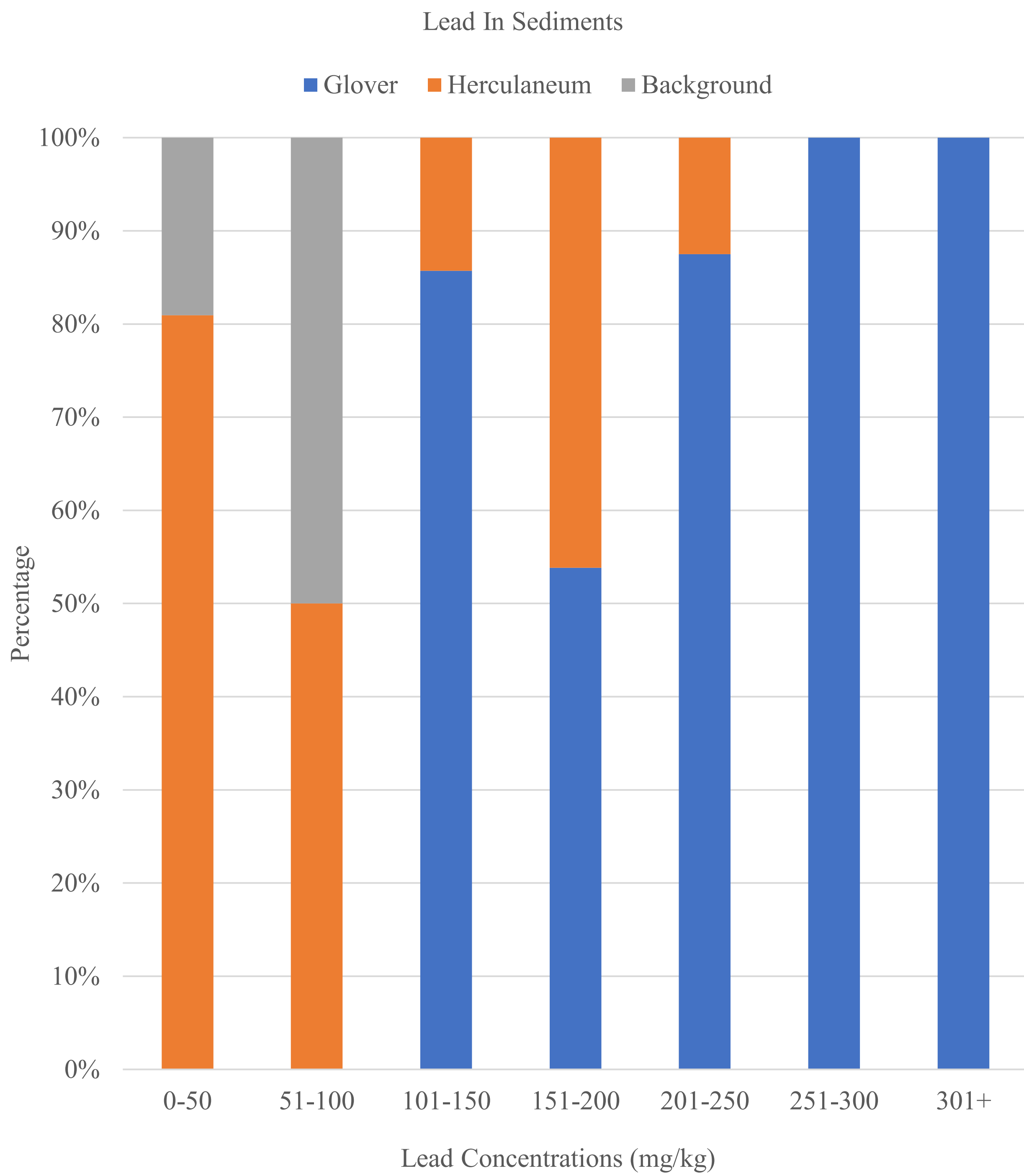

Figure 17. Histogram of lead levels in sediment for Glover, Herculaneum, and Background.

RESULTS

Sediment

Of the 11 samples taken for background sediment concentration 10 were between 48 mg/kg and 62 mg/kg with a sample that was evidently higher than the rest with 75 mg/kg. For statistical purposes, this was considered an outlier from background values and was removed from additional analyses because including the outlier skewed the distribution. After removing the outlier, the distribution then generally followed a normal curve. This is very close and shows this site was a good selection for background contamination of lead (Table 7).

Table 7. Raw sediment data from background (Romance). Bolded samples indicate replicate.

Sample	Al (%)	Cd (BD[1])	Fe (%)	Pb (mg/kg)	Zn (mg/kg)
N1	0.51	<0.5	1.25	54	30
N2	0.54	<0.5	1.53	75	36
N3	**0.48**	**<0.5**	**1.18**	**49**	**28**
N4	**0.48**	**<0.5**	**1.13**	**48**	**27**
N5	0.38	<0.5	1.09	54	25
N6	0.38	<0.5	1.12	53	28
N7	0.44	<0.5	1.61	62	29
N8	0.44	<0.5	1.66	68	36
N9	0.43	<0.5	1.03	49	27
N10	0.49	<0.5	1.12	56	28
N11	0.48	<0.5	1.07	50	27

[1] Below detectable limit.

Herculaneum had a much broader range of values than the background site. The 33 samples ranged from a minimum of 2 mg/kg and a maximum of 250 mg/kg. Samples extracted from collection site H1 averaged 742.83 meters away from the smelter, samples extracted from collection site H2 averaged 760.46 meters away, and samples from H3 averaged 874.35 meters

away from the smelter, for a collective average of 792.55 meters. The median concentration in Herculaneum is approximately the same as the background median concentration but there is a greater range of values and the average value was higher in Herculaneum than the background levels.

Glover has higher values than background for median, average, minimum, and maximum lead. These values were 186 mg/kg, 214 mg/kg, 103 mg/kg, and 956 mg/kg, respectively. Samples extracted in Glover had an average distance of 965.52 meters from S1 and 884.46 meters from S2, for a collective average of 924.99 meters.

There is a clear difference between values in Herculaneum and Glover with respect to the median and average metal concentrations (Pb, Zn, and Cd). However, both Herculaneum and Glover had a very large range of values. In Glover the highest average concentrations of lead were located at G2 (samples G12 through G23) with a value of 302.3 mg/kg. G2 is located between the UTM Zone 15S coordinates of 704,053 E-704,041 E and 4,151,927 N-4,151,948 N. The next highest values were located at G1 (samples G1 through G11) with a value of 178.1 mg/kg. G1 is located between the UTM Zone 15S coordinates of 704,083 E-704,063 E and 4,151,909 N-4,151,927 N. Lastly, G3 (samples G24 through G33) had an average value of 150.0 mg/kg. G3 is located between the UTM Zone 15S coordinates of 704,047 E-704,024 E and 4,151,951N-4,151,959 N. Relative to G1 and G3, G2 samples were collected from a small island in the center of the active ephemeral stream that had less canopy cover (Table 8).

In Herculaneum the highest average concentrations of lead were located at H2 (samples H2.1 through H2.11) with a value of 146.4 mg/kg. H2 is located between the UTM Zone 15S coordinates of 728,779 E-728,786 E and 4,238,096 N-4,238,096 N. The next highest values were located at H3 (samples H3.1 through H3.11) with a value of 64.4 mg/kg. H3 is located between

Table 8. Raw sediment data from Glover, Missouri. Bolded samples indicate replicate.

Sample	Al (%)	Cd (mg/kg)	Fe (%)	Pb (mg/kg)	Zn (mg/kg)
G1_1	0.51	1.6	1.20	198	65
G1_2	0.27	0.8	1.18	118	36
G1_3	0.28	0.9	1.41	114	48
G1_4	0.46	1.4	1.18	213	68
G1_5	0.26	0.9	1.67	116	48
G1_6	**0.66**	**1.8**	**1.43**	**280**	**85**
G1_7	**0.60**	**1.8**	**1.41**	**269**	**80**
G1_8	0.61	1.9	1.40	290	78
G1_9	0.29	0.9	1.32	134	41
G1_10	0.24	0.8	1.57	103	41
G1_11	0.23	0.8	1.37	124	109
G1_12	0.30	0.8	1.26	141	150
G1_13	0.30	1.0	1.46	956	79
G1_14	0.26	0.9	1.38	217	255
G1_15	0.30	1.1	1.73	345	53
G1_16	0.30	1.1	1.50	135	59
G1_17	0.24	1.3	1.12	238	49
G1_18	0.25	0.9	1.20	186	54
G1_19	0.25	1.3	1.29	237	261
G1_20	0.37	2.5	1.54	515	145
G1_21	0.27	4.4	1.19	216	195
G1_22	**0.30**	**1.3**	**1.59**	**209**	**49**
G1_23	**0.30**	**1.3**	**1.28**	**232**	**47**
G1_24	0.28	1.4	1.39	162	49
G1_25	0.28	1.0	1.41	190	190
G1_26	0.24	0.9	1.34	116	40
G1_27	0.24	0.9	1.35	144	38
G1_28	0.29	1.4	1.39	188	54
G1_29	**0.23**	**0.7**	**1.22**	**108**	**39**
G1_30	**0.27**	**1.3**	**1.53**	**183**	**51**
G1_31	0.25	1.0	1.24	151	45
G1_32	0.27	1.6	1.50	152	155
G1_33	0.24	0.9	1.45	106	45

the UTM Zone 15S coordinates of 728,651 E-728,587 E and 4,237,518 N-4,237,506 N. Lastly, H1 (samples H1.1 through H1.11) had an average value of 24.5 mg/kg. H1 is located between the UTM Zone 15S coordinates of 728,898 E-728,891 E and 4,238,351 N-4,238,365 N.

Compared to H1 and H3, H2 samples were extracted from the upper limit of an active river bank with no tree cover (Table 9). Cadmium was below the detectable limit (BD) for all background samples and 21 samples from Herculaneum. For this reason, cadmium could not be correlated between sites. Cadmium was above detection limits Lead values were normalized to better see their geochemical behavior. For background (Table 10), Herculaneum (Table 11), and Glover (Table 12), lead normalized to iron had values of -0.02, 0.61, and 0.99, respectively. The correlation more clearly shows the contamination by lead is higher in Glover and less in Herculaneum. Herculaneum correlation values and Glover correlation values both were significant with *p*-values at 0.01. When normalized to iron there was a strong correlation between lead and zinc for background and lead and zinc for Herculaneum with 0.88 and 0.84, respectively.

Lead and zinc in Glover showed no correlation with a value of 0.14. The lower correlation in Glover may be related to much higher lead concentration found in the sediments. Similarly, remediation conducted in Herculaneum is likely the reason there are lower contamination concentrations for metals. In contrast, zinc normalized to iron behaved in a similar manner to lead for the three sites. Even though zinc values were small, normalization brought the differences out.

Iron remains as iron oxide and is highly stable in soils. Aluminum normalization was also calculated but did not yield results as well as with iron normalization (Tables 13, 14, and 15).

Table 9. Raw sediment data from Herculaneum, Missouri. Bolded samples indicate replicate.

Sample	Al (%)	Cd (BD[1])	Fe (%)	Pb (mg/kg)	Zn (mg/kg)
H1.1	0.11	<0.5	0.26	18	21
H1.2	0.14	<0.5	0.30	29	25
H1.3	0.14	<0.5	0.31	49	30
H1.4	0.18	0.7	0.38	90	131
H1.5	0.11	<0.5	0.28	24	21
H1.6	**0.09**	**<0.5**	**0.44**	**10**	**15**
H1.7	**0.10**	**<0.5**	**0.34**	**15**	**17**
H1.8	0.15	<0.5	0.40	16	26
H1.9	0.04	<0.5	0.15	2	8
H1.10	0.05	<0.5	0.16	6	12
H1.11	0.09	<0.5	0.26	10	16
H2_1	0.99	2.6	1.48	200	236
H2_2	0.76	1.4	1.19	125	161
H2_3	1.14	2.6	1.64	199	278
H2_4	0.89	2.0	1.31	144	234
H2_5	0.44	<0.5	0.71	43	82
H2_6	**1.06**	**3.0**	**1.55**	**194**	**322**
H2_7	**0.97**	**2.5**	**1.46**	**184**	**266**
H2_8	1.11	2.9	1.63	200	289
H2_9	0.41	0.6	0.72	91	152
H2_10	0.34	<0.5	0.55	30	60
H2_11	1.06	2.6	1.56	200	292
H3.1	0.35	0.6	0.68	250	50
H3.2	**0.26**	**<0.5**	**0.54**	**76**	**27**
H3.3	**0.33**	**0.6**	**0.61**	**92**	**126**
H3.4	0.19	<0.5	0.47	92	42
H3.5	0.19	<0.5	0.51	80	41
H3.6	0.09	<0.5	0.25	52	29
H3.7	0.06	<0.5	0.20	24	24
H3.8	0.04	<0.5	0.15	8	22
H3.9	0.03	<0.5	0.13	4	18
H3.10	0.05	<0.5	0.16	21	22
H3.11	0.03	<0.5	0.13	9	20

[1] Below detectable limit.

Table 10. Sediment data from background paired and normalized by Fe. *p* values below 0.01 are bolded and indicated statistically significant correlations.

	Cd	Pb	Zn	Cd/Fe	Pb/Fe	Zn/Fe
Cd		-	-	-	-	-
Pb			**0.88**	-	-0.02	-0.48
Zn				-	-0.20	-0.29
Cd/Fe					-	-
Pb/Fe						0.67

Table 11. Sediment data from Herculaneum paired and normalized by Fe. *p* values below 0.01 are bolded and indicate statistically significant correlations.

	Cd	Pb	Zn	Cd/Fe	Pb/Fe	Zn/Fe
Cd		-	-	-	-	-
Pb			**0.84**	-	**0.61**	**0.45**
Zn				-	0.21	**0.65**
Cd/Fe					-	-
Pb/Fe						0.33

Table 12. Sediment data from Glover paired and normalized by Fe. *p* values below 0.01 are bolded and indicate statistically significant correlations.

	Cd	Pb	Zn	Cd/Fe	Pb/Fe	Zn/Fe
Cd		0.21	0.35	**0.98**	0.24	0.38
Pb			0.14	0.15	**0.99**	0.11
Zn				0.34	0.16	**0.99**
Cd/Fe					0.20	0.40
Pb/Fe						0.14

Table 13. Sediment data from background paired and normalized by Al. *p* values below 0.01 are bolded and indicate statistically significant correlations.

	Cd	Pb	Zn	Cd/Al	Pb/Al	Zn/Al
Cd		-	-	**-**	-	-
Pb			**0.88**	-	**0.72**	0.58
Zn				-	0.49	0.58
Cd/Al					-	-
Pb/Al						**0.89**

T-tests for equal variance were conducted for sediment data between background, Glover, and Herculaneum. Between background and Glover (Table 16) the difference in lead concentration was significant with a t-statistic of 3.32 with t-critical values of 1.68 (one-tailed) and 2.02 (two-tailed). Between background and Herculaneum there was not a significant difference in lead concentration (Table 17). Between Glover and Herculaneum there was a significant difference in lead concentration (Table 18). This final comparison had a t-statistic of 4.49 with t-critical values of 1.67 (one-tailed) and 2.00 (two-tailed). All three t-tests were conducted with a confidence interval of 95% ($\alpha = 0.05$).

Table 14. Sediment data from Herculaneum paired and normalized by Al. *p* values below 0.01 are bolded and indicate statistically significant correlations.

	Cd	Pb	Zn	Cd/Al	Pb/Al	Zn/Al
Cd		-	-	-	-	-
Pb			**0.84**	-	0.24	-0.15
Zn				-	-0.16	0.01
Cd/Al					-	-
Pb/Al						0.23

Table 15. Sediment data from Glover paired and normalized by Al. *p* values below 0.01 are bolded and indicate statistically significant correlations.

	Cd	Pb	Zn	Cd/Al	Pb/Al	Zn/Al
Cd		0.21	0.35	**0.86**	0.08	0.23
Pb			0.14	0.06	**0.93**	0.05
Zn				0.38	0.16	**0.96**
Cd/Al					0.12	0.39
Pb/Al						0.16

Table 16. T-test of lead sediment concentrations for Glover versus Background. Test yielded significant difference, rejecting null hypothesis that the samples are the same.

	std err	t-stat	df	p-value	t-crit	sig
One Tail	47.81	3.32	42	9.45E-4	1.68	yes
Two Tail	47.81	3.32	42	1.89E-3	2.02	yes

Table 17. T-test of lead sediment concentrations for Herculaneum versus Background. Test yielded insignificant difference, accepting null hypothesis.

	std err	t-stat	df	p-value	t-crit	sig
One Tail	23.10	0.96	42	0.17	1.68	no
Two Tail	23.10	0.96	42	0.34	2.02	no

Table 18. T-test of lead sediment concentrations for Glover versus Herculaneum. Test yielded significant difference, rejecting null hypothesis.

	std err	t-stat	df	p-value	t-crit	sig
One Tail	30.39	4.49	64	1.54E-05	1.67	yes
Two Tail	30.39	4.49	64	3.09E-05	2.00	yes

Air

In Glover, average monthly values of lead air concentration in 2013-2014 ranged from 0.04 to 0.15 $\mu g/m^3$ and in 2018-2019 ranged from 0.01 to 0.04 $\mu g/m^3$. In Herculaneum, average monthly values of lead air concentration in 2013-2014 ranged from 0.02 to 0.29 $\mu g/m^3$ and in 2018-2019 ranged from 0.03 to 0.15 $\mu g/m^3$. Figures 18, 19, 20, and 21 display all air lead concentrations that were recorded per target year per smelter site (full tables located in Appendices A-L). For both sites, lead air concentration in their final year of data ranged from 0.01 to 0.02 $\mu g/m^3$. In air, the contamination was Herculaneum > Glover > Background.

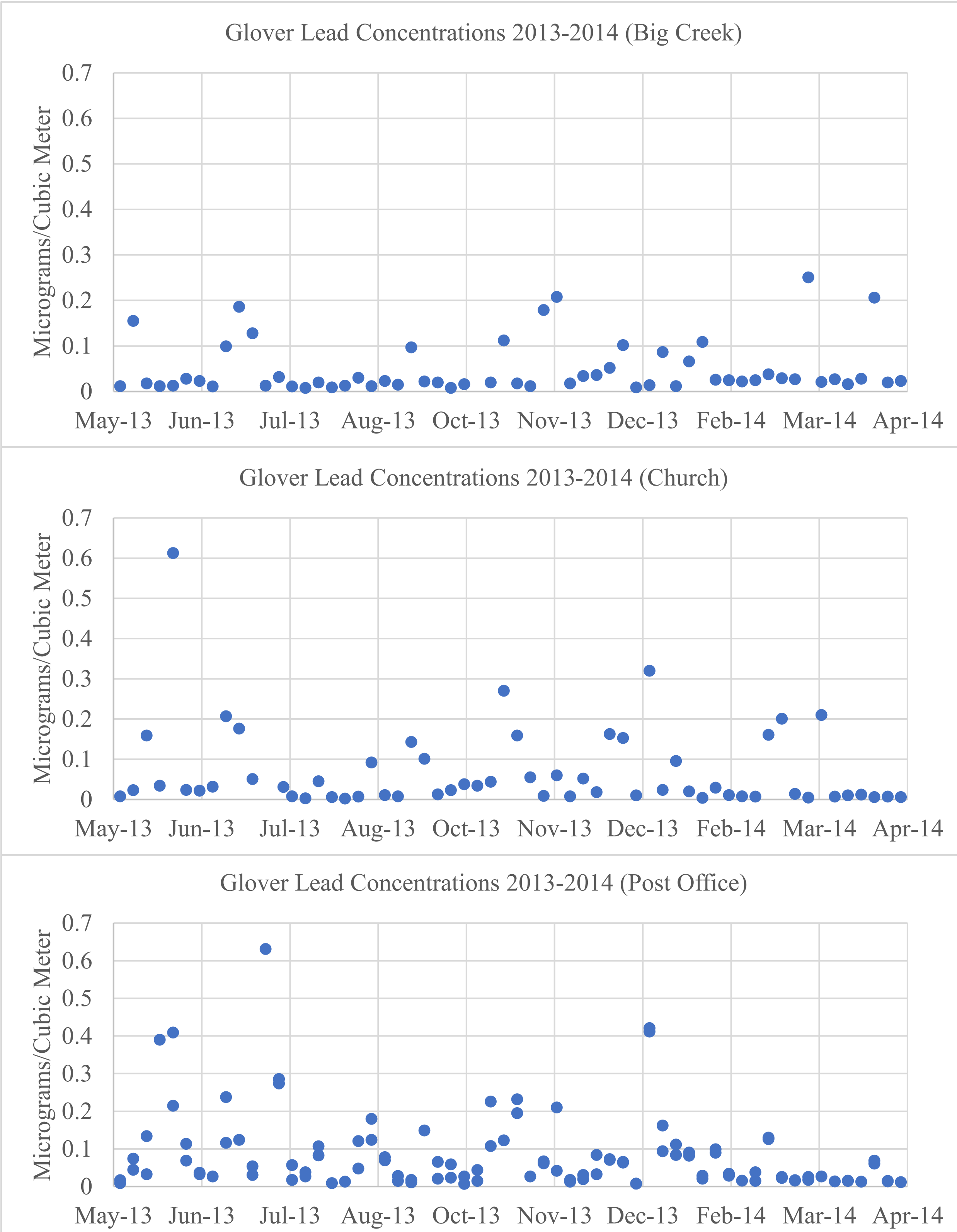

Figure 18. Lead air concentrations in Glover (May 01, 2013 - April 30, 2014) (EPA, 2020).

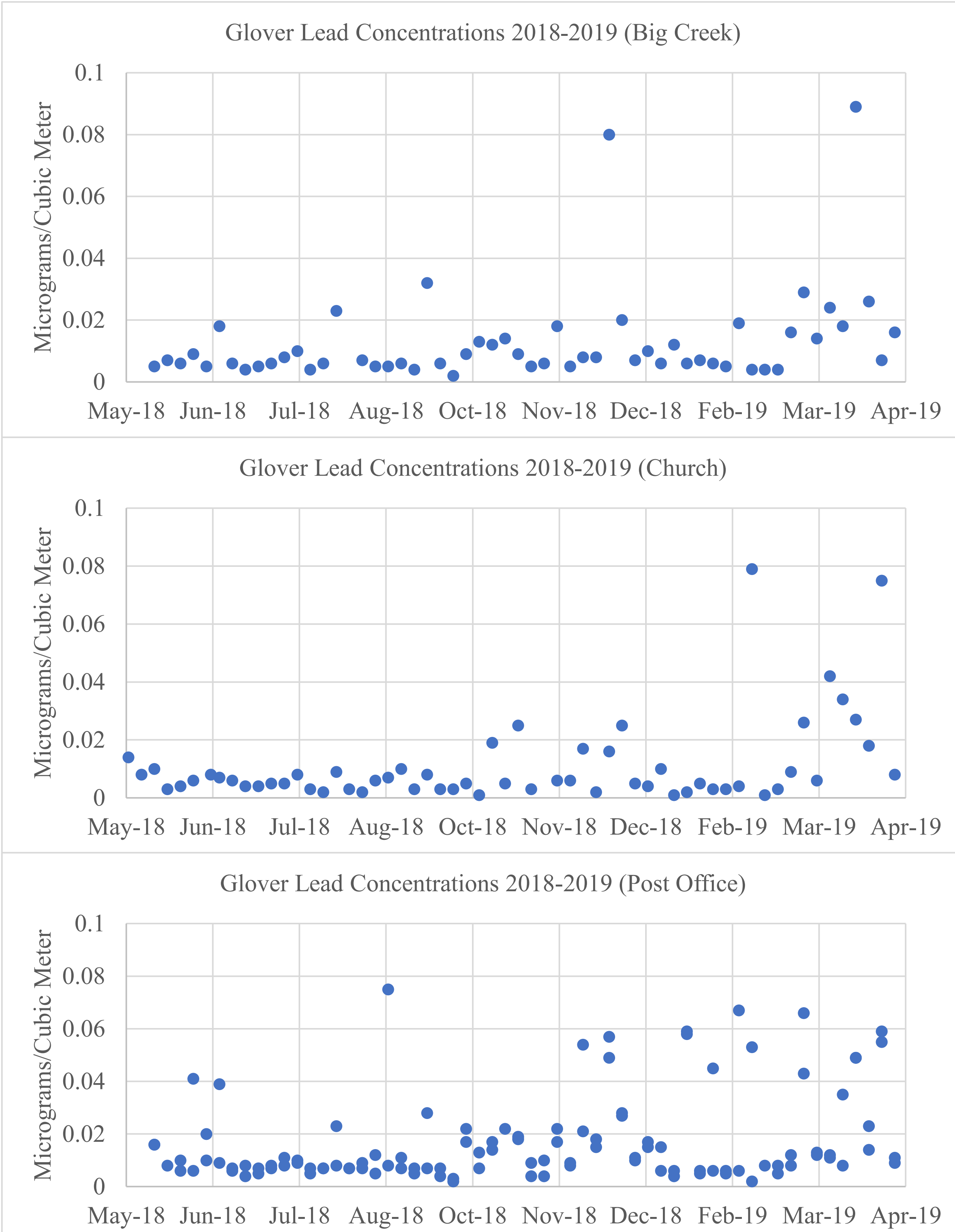

Figure 19. Lead air concentrations in Glover (May 01, 2018 - April 30, 2019) (EPA, 2020).

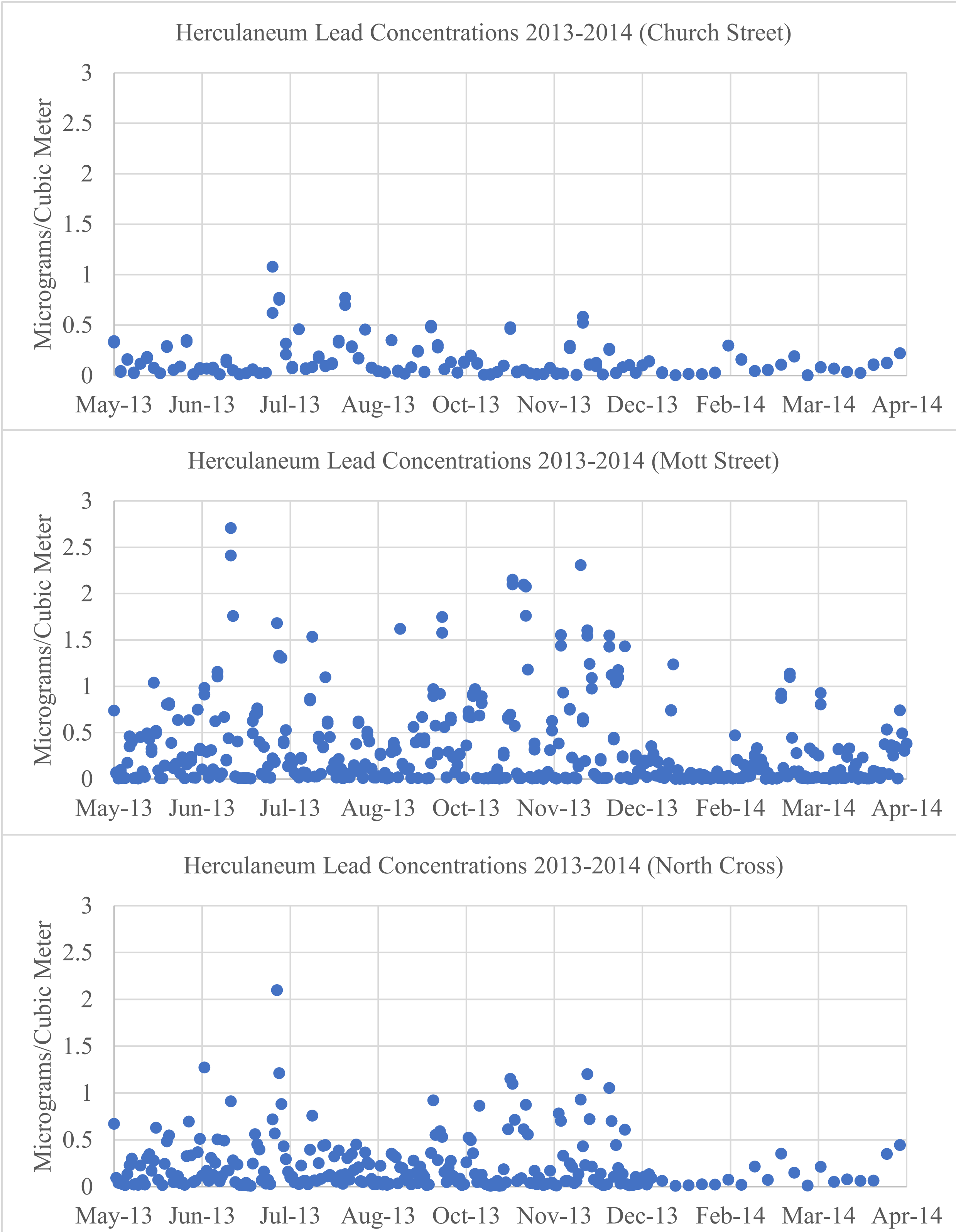

Figure 20. Lead air concentrations in Herculaneum (May 01, 2013- April 30, 2014) (EPA, 2020).

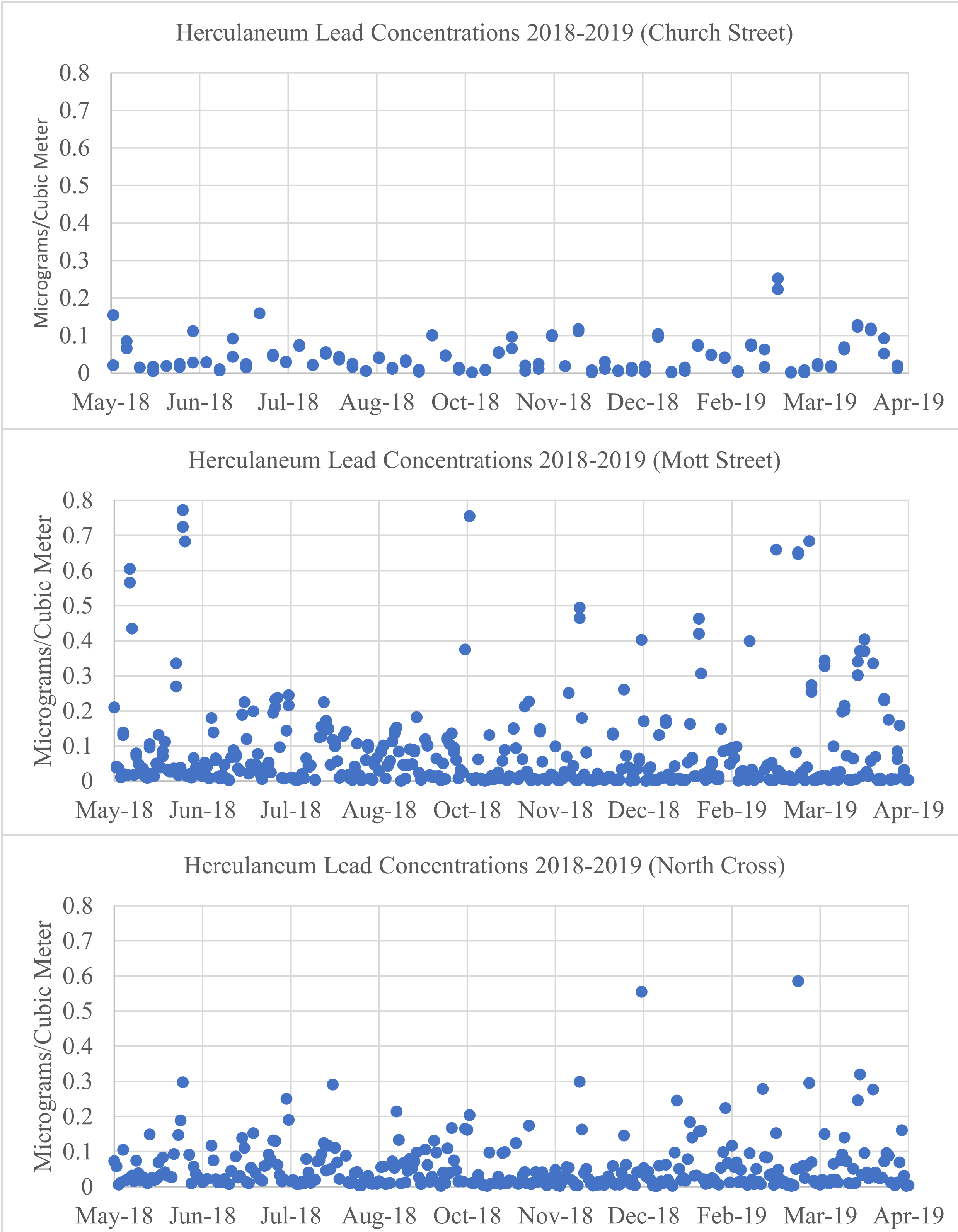

Figure 21. Lead air concentrations in Herculaneum (May 01, 2018- April 30, 2019) (EPA, 2020).

DISCUSSION

Lead in Sediment

The concentrations of lead in Glover and Herculaneum were higher than background. Metal concentrations in sediment in Glover and Herculaneum had a wide range of values for lead and cadmium but not for zinc (lead and cadmium are the most toxic of these three metals). The background site was well chosen because the concentrations were statistically similar.

The heavy metals targeted in this study (lead, cadmium, and zinc) are often associated with sulfide minerals (PbS, CdS, and ZnS). High levels of metalloids are found within sediment that contains sulfide minerals (Anderson and Kravitz, 2010). For this reason, normalization to iron is a better fit and the results of the Fe-normalization support this statement. Normalization to aluminum is better suited to sediment that is derived from granitic host rocks, which have high quantities of aluminum.

Regarding Fe-normalized values, lead contamination in sediment follows Glover > Herculaneum > Background with correlated values of 0.99, 0.61, and -0.02, respectively. Remediation conducted in Herculaneum must be responsible for the decreased contamination values since the smelter reportedly emitted large quantities of lead. Much of the remediation in Herculaneum has been done by removing and replacing the soil surrounding the smelter. In Glover, these areas that have higher concentrations of lead are heavily wooded. Removing soil from a forested area is not a realistic form of remediation. Lead phosphates are the most stable lead compounds because they have large equilibrium constants (Lang and Kaupenjohann, 2003). Some studies have been conducted that applying phosphorus to contaminated areas may change the bioavailability of lead by altering lead into pyromorphite or other metastable lead compounds

(Scheckel and Ryan, 2010). Another study found fluid phosphorus amendments to be more effective than granular amendments and this would make remediation much simpler in heavily-wooded areas (Baker et al. 2014). It should be noted, however, that lead present in soil or sediment can move into vegetation through root systems and then stores in leaves or seeds (Roux and Marra, 2007). As Glover is a heavily wooded area, it can be assumed that the vegetation in the area has elevated concentrations of stored lead.

Lead in Air

As background sites, Chanute and Nilwood were believed to be unaffected by resuspension of lead originally deposited around smelters. Air quality monitoring stations are, generally, only positioned in areas where they are needed due to emissions or another known point source. What that means is that a true background value of lead air concentration cannot be measured at the selected sites monitored by the EPA. While the values measured at these sites was very low, it is not known if those values are true background values of lead air concentration. Chanute and Nilwood are good reference sites, however, because they both had very low values of lead air concentration.

Herculaneum's range of values for lead air concentration were higher than background and Glover. Primary smelting in Herculaneum ceased in 2013, five years after the most recent data for nonattainment areas in Missouri. The most recent data from 2008, the National Ambient Air Quality Standards (NAAQS), yielded a lead nonattainment area surrounding Herculaneum and surrounding a secondary lead smelter operated by DRC near Boss, MO. The Boss smelter likely remains as a nonattainment area because of clean air violations that occurred in 2019. To better evaluate the extent of air pollution surrounding Herculaneum another NAAQS study

should be conducted. Smelting in Glover ceased in 2003 and the 2008 NAAQS study did not yield a nonattainment area. If operations are ceased in Herculaneum, then the air lead concentrations should be modeled to what was displayed in Glover.

Herculaneum, Glover, and background all appear to have no pattern of seasonal variation of lead air concentrations. No month or season appears to be favored for high values or low values of lead air concentrations.

Statistics

Statistical methods used are simple but were found to be highly effective to discriminate between background, Glover, and Herculaneum with respect to lead contamination. The number of sediment samples seemed to have been enough to obtain sound statistical results (11 for background, 33 for Glover, and 33 for Herculaneum). Correlation of metals by themselves and correlation of normalized values provided different results that highlighted the differences between sites, especially for iron normalization. For air the available data are much more numerous, although no statistical methods were applied the data were condensed by month and compared with each other.

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APPENDICES

Appendix A. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Church 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean
5/4/2013	0.008	11/18/2013	0.060
5/10/2013	0.023	11/24/2013	0.008
5/16/2013	0.159	11/30/2013	0.052
5/22/2013	0.034	12/6/2013	0.018
5/28/2013	0.613	12/12/2013	0.163
6/3/2013	0.024	12/18/2013	0.153
6/9/2013	0.022	12/24/2013	0.010
6/15/2013	0.032	12/30/2013	0.320
6/21/2013	0.207	1/5/2014	0.024
6/27/2013	0.176	1/11/2014	0.096
7/3/2013	0.051	1/17/2014	0.020
7/17/2013	0.031	1/23/2014	0.004
7/21/2013	0.008	1/29/2014	0.029
7/27/2013	0.003	2/4/2014	0.011
8/2/2013	0.045	2/10/2014	0.008
8/8/2013	0.006	2/16/2014	0.007
8/14/2013	0.002	2/22/2014	0.161
8/20/2013	0.007	2/28/2014	0.201
8/26/2013	0.092	3/6/2014	0.014
9/1/2013	0.011	3/12/2014	0.005
9/7/2013	0.008	3/18/2014	0.210
9/13/2013	0.143	3/24/2014	0.007
9/19/2013	0.101	3/30/2014	0.010
9/25/2013	0.013	4/5/2014	0.012
10/1/2013	0.023	4/11/2014	0.006
10/7/2013	0.038	4/17/2014	0.007
10/13/2013	0.034	4/23/2014	0.006
10/19/2013	0.044	4/29/2014	0.036
10/25/2013	0.270		
10/31/2013	0.159		
11/6/2013	0.055		
11/12/2013	0.009		

Appendix B. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Post Office 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/4/2013	0.017	9/1/2013	0.070	12/30/2013	0.412
5/4/2013	0.009	9/7/2013	0.028	12/30/2013	0.421
5/10/2013	0.045	9/7/2013	0.015	1/5/2014	0.094
5/10/2013	0.074	9/13/2013	0.011	1/5/2014	0.162
5/16/2013	0.134	9/13/2013	0.018	1/11/2014	0.084
5/16/2013	0.033	9/19/2013	0.149	1/11/2014	0.112
5/22/2013	0.390	9/25/2013	0.066	1/17/2014	0.091
5/28/2013	0.409	9/25/2013	0.021	1/17/2014	0.082
5/28/2013	0.215	10/1/2013	0.059	1/23/2014	0.021
6/3/2013	0.069	10/1/2013	0.024	1/23/2014	0.029
6/3/2013	0.114	10/7/2013	0.007	1/29/2014	0.090
6/9/2013	0.037	10/7/2013	0.027	1/29/2014	0.099
6/9/2013	0.033	10/13/2013	0.044	2/4/2014	0.034
6/15/2013	0.027	10/13/2013	0.015	2/4/2014	0.029
6/21/2013	0.116	10/19/2013	0.108	2/10/2014	0.016
6/21/2013	0.238	10/19/2013	0.226	2/16/2014	0.015
6/27/2013	0.124	10/25/2013	1.198	2/16/2014	0.038
6/27/2013	0.882	10/25/2013	0.123	2/22/2014	0.130
7/3/2013	0.031	10/31/2013	0.195	2/22/2014	0.126
7/3/2013	0.054	10/31/2013	0.232	2/28/2014	0.026
7/9/2013	0.631	11/6/2013	0.027	2/28/2014	0.023
7/9/2013	7.279	11/12/2013	0.067	3/6/2014	0.017
7/15/2013	0.286	11/12/2013	0.062	3/6/2014	0.016
7/15/2013	0.274	11/18/2013	0.042	3/12/2014	0.018
7/21/2013	0.057	11/18/2013	0.210	3/12/2014	0.026
7/21/2013	0.018	11/24/2013	0.018	3/18/2014	0.027
7/27/2013	0.027	11/24/2013	0.013	3/24/2014	0.014
7/27/2013	0.038	11/30/2013	0.031	3/30/2014	0.015
8/2/2013	0.107	11/30/2013	0.020	3/30/2014	0.016
8/2/2013	0.083	12/6/2013	0.084	4/5/2014	0.013
8/8/2013	0.009	12/6/2013	0.033	4/11/2014	0.061
8/14/2013	0.013	12/12/2013	0.073	4/11/2014	0.069
8/20/2013	0.048	12/12/2013	0.071	4/17/2014	0.014
8/20/2013	0.121	12/18/2013	0.066	4/17/2014	0.015
8/26/2013	0.124	12/18/2013	0.064	4/23/2014	0.012
8/26/2013	0.180	12/24/2013	0.008	4/29/2014	0.096
9/1/2013	0.078	12/24/2013	0.008	4/29/2014	0.104

Appendix C. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Big Creek 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean
5/4/2013	0.012	12/18/2013	0.070
5/10/2013	0.155	12/24/2013	0.028
5/16/2013	0.018	12/30/2013	0.015
5/22/2013	0.012	1/5/2014	0.011
5/28/2013	0.013	1/11/2014	0.018
6/3/2013	0.028	1/17/2014	0.149
6/9/2013	0.023	1/23/2014	0.066
6/15/2013	0.011	1/29/2014	0.021
6/21/2013	0.099	2/4/2014	0.059
6/27/2013	0.186	2/10/2014	0.024
7/3/2013	0.128	2/16/2014	0.007
7/9/2013	0.013	2/22/2014	0.027
7/15/2013	0.032	2/28/2014	0.044
7/21/2013	0.011	3/6/2014	0.015
7/27/2013	0.008	3/12/2014	0.108
8/2/2013	0.020	3/18/2014	0.226
8/8/2013	0.009	3/24/2014	1.198
8/14/2013	0.013	3/30/2014	0.123
8/20/2013	0.030	4/5/2014	0.195
8/26/2013	0.012	4/11/2014	0.232
9/1/2013	0.023	4/17/2014	0.027
9/7/2013	0.015	4/23/2014	0.067
9/13/2013	0.097	4/29/2014	0.062
9/19/2013	0.022		
9/25/2013	0.020		
10/1/2013	0.008		
10/7/2013	0.016		
10/19/2013	0.020		
10/25/2013	0.112		
10/31/2013	0.018		
11/6/2013	0.012		
11/12/2013	0.179		
11/18/2013	0.208		
11/24/2013	0.018		
11/30/2013	0.034		
12/6/2013	0.036		
12/12/2013	0.052		

Appendix D. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Big Creek 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean
5/14/2018	0.005	12/28/2018	0.010
5/20/2018	0.007	1/3/2019	0.006
5/26/2018	0.006	1/9/2019	0.012
6/1/2018	0.009	1/15/2019	0.006
6/7/2018	0.005	1/21/2019	0.007
6/13/2018	0.018	1/27/2019	0.006
6/19/2018	0.006	2/2/2019	0.005
6/25/2018	0.004	2/8/2019	0.019
7/1/2018	0.005	2/14/2019	0.004
7/7/2018	0.006	2/20/2019	0.004
7/13/2018	0.008	2/26/2019	0.004
7/19/2018	0.010	3/4/2019	0.016
7/25/2018	0.004	3/10/2019	0.029
7/31/2018	0.006	3/16/2019	0.014
8/6/2018	0.023	3/22/2019	0.024
8/18/2018	0.007	3/28/2019	0.018
8/24/2018	0.005	4/3/2019	0.089
8/30/2018	0.005	4/9/2019	0.026
9/5/2018	0.006	4/15/2019	0.007
9/11/2018	0.004	4/21/2019	0.016
9/17/2018	0.032	4/27/2019	0.007
9/23/2018	0.006		
9/29/2018	0.002		
10/5/2018	0.009		
10/11/2018	0.013		
10/17/2018	0.012		
10/23/2018	0.014		
10/29/2018	0.009		
11/4/2018	0.005		
11/10/2018	0.006		
11/16/2018	0.018		
11/22/2018	0.005		
11/28/2018	0.008		
12/4/2018	0.008		
12/10/2018	0.080		
12/16/2018	0.020		
12/22/2018	0.007		

Appendix E. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Church 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean
5/2/2018	0.014	12/16/2018	0.025
5/8/2018	0.008	12/22/2018	0.005
5/14/2018	0.010	12/28/2018	0.004
5/20/2018	0.003	1/3/2019	0.010
5/26/2018	0.004	1/9/2019	0.001
6/1/2018	0.006	1/15/2019	0.002
6/9/2018	0.008	1/21/2019	0.005
6/13/2018	0.007	1/27/2019	0.003
6/19/2018	0.006	2/2/2019	0.003
6/25/2018	0.004	2/8/2019	0.004
7/1/2018	0.004	2/14/2019	0.079
7/7/2018	0.005	2/20/2019	0.001
7/13/2018	0.005	2/26/2019	0.003
7/19/2018	0.008	3/4/2019	0.009
7/25/2018	0.003	3/10/2019	0.026
7/31/2018	0.002	3/16/2019	0.006
8/6/2018	0.009	3/22/2019	0.042
8/12/2018	0.003	3/28/2019	0.034
8/18/2018	0.002	4/3/2019	0.027
8/24/2018	0.006	4/9/2019	0.018
8/30/2018	0.007	4/15/2019	0.075
9/5/2018	0.010	4/21/2019	0.008
9/11/2018	0.003	4/27/2019	0.017
9/17/2018	0.008		
9/23/2018	0.003		
9/29/2018	0.003		
10/5/2018	0.005		
10/11/2018	0.001		
10/17/2018	0.019		
10/23/2018	0.005		
10/29/2018	0.025		
11/4/2018	0.003		
11/16/2018	0.006		
11/22/2018	0.006		
11/28/2018	0.017		
12/4/2018	0.002		
12/10/2018	0.016		

Appendix F. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Glover Post Office 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/14/2018	0.016	9/5/2018	0.011	1/3/2019	0.006
5/14/2018	0.016	9/11/2018	0.007	1/3/2019	0.015
5/20/2018	0.008	9/11/2018	0.005	1/9/2019	0.004
5/26/2018	0.006	9/17/2018	0.007	1/9/2019	0.006
5/26/2018	0.010	9/17/2018	0.028	1/15/2019	0.058
6/1/2018	0.006	9/23/2018	0.007	1/15/2019	0.059
6/1/2018	0.041	9/23/2018	0.004	1/21/2019	0.006
6/7/2018	0.020	9/29/2018	0.002	1/21/2019	0.005
6/7/2018	0.010	9/29/2018	0.003	1/27/2019	0.006
6/13/2018	0.009	10/5/2018	0.022	1/27/2019	0.045
6/13/2018	0.039	10/5/2018	0.017	2/2/2019	0.005
6/19/2018	0.007	10/11/2018	0.007	2/2/2019	0.006
6/19/2018	0.006	10/11/2018	0.013	2/8/2019	0.067
6/25/2018	0.004	10/17/2018	0.014	2/8/2019	0.006
6/25/2018	0.008	10/17/2018	0.017	2/14/2019	0.053
7/1/2018	0.005	10/23/2018	0.022	2/14/2019	0.002
7/1/2018	0.007	10/29/2018	0.019	2/20/2019	0.008
7/7/2018	0.008	10/29/2018	0.018	2/26/2019	0.008
7/7/2018	0.007	11/4/2018	0.009	2/26/2019	0.005
7/13/2018	0.011	11/4/2018	0.004	3/4/2019	0.012
7/13/2018	0.008	11/10/2018	0.010	3/4/2019	0.008
7/19/2018	0.010	11/10/2018	0.004	3/10/2019	0.066
7/19/2018	0.009	11/16/2018	0.022	3/10/2019	0.043
7/25/2018	0.005	11/16/2018	0.017	3/16/2019	0.013
7/25/2018	0.007	11/22/2018	0.008	3/16/2019	0.012
7/31/2018	0.007	11/22/2018	0.009	3/22/2019	0.011
7/31/2018	0.007	11/28/2018	0.021	3/22/2019	0.012
8/6/2018	0.023	11/28/2018	0.054	3/28/2019	0.008
8/6/2018	0.008	12/4/2018	0.015	3/28/2019	0.035
8/12/2018	0.007	12/4/2018	0.018	4/3/2019	0.049
8/12/2018	0.007	12/10/2018	0.049	4/9/2019	0.014
8/18/2018	0.009	12/10/2018	0.057	4/9/2019	0.023
8/18/2018	0.007	12/16/2018	0.027	4/15/2019	0.059
8/24/2018	0.012	12/16/2018	0.028	4/15/2019	0.055
8/24/2018	0.005	12/22/2018	0.010	4/21/2019	0.009
8/30/2018	0.008	12/22/2018	0.011	4/21/2019	0.011
8/30/2018	0.075	12/28/2018	0.015	4/27/2019	0.078
9/5/2018	0.007	12/28/2018	0.017	4/27/2019	0.027

Appendix G-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Church Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/1/2013	0.341	6/27/2013	0.015	8/23/2013	0.456
5/1/2013	0.328	6/27/2013	0.012	8/23/2013	0.454
5/4/2013	0.035	6/30/2013	0.024	8/26/2013	0.079
5/4/2013	0.045	6/30/2013	0.023	8/26/2013	0.077
5/7/2013	0.156	7/3/2013	0.062	8/29/2013	0.044
5/7/2013	0.164	7/3/2013	0.054	8/29/2013	0.043
5/10/2013	0.032	7/6/2013	0.023	9/1/2013	0.033
5/10/2013	0.024	7/6/2013	0.024	9/1/2013	0.029
5/13/2013	0.116	7/9/2013	0.028	9/4/2013	0.349
5/13/2013	0.120	7/9/2013	0.029	9/4/2013	0.352
5/16/2013	0.185	7/12/2013	0.620	9/7/2013	0.039
5/16/2013	0.172	7/12/2013	1.078	9/7/2013	0.050
5/19/2013	0.075	7/15/2013	0.752	9/10/2013	0.018
5/19/2013	0.078	7/15/2013	0.770	9/10/2013	0.019
5/22/2013	0.025	7/18/2013	0.211	9/13/2013	0.083
5/25/2013	0.293	7/18/2013	0.317	9/13/2013	0.083
5/25/2013	0.284	7/21/2013	0.087	9/16/2013	0.236
5/28/2013	0.058	7/21/2013	0.074	9/16/2013	0.246
5/28/2013	0.055	7/24/2013	0.459	9/19/2013	0.034
5/31/2013	0.089	7/27/2013	0.073	9/19/2013	0.038
5/31/2013	0.090	7/27/2013	0.062	9/22/2013	0.494
6/3/2013	0.353	7/30/2013	0.085	9/22/2013	0.477
6/3/2013	0.335	7/30/2013	0.085	9/25/2013	0.304
6/6/2013	0.012	8/2/2013	0.175	9/25/2013	0.279
6/6/2013	0.014	8/2/2013	0.191	9/28/2013	0.063
6/9/2013	0.062	8/5/2013	0.098	9/28/2013	0.062
6/9/2013	0.075	8/5/2013	0.093	10/1/2013	0.132
6/12/2013	0.070	8/8/2013	0.124	10/1/2013	0.134
6/12/2013	0.067	8/8/2013	0.114	10/4/2013	0.028
6/15/2013	0.079	8/11/2013	0.347	10/4/2013	0.030
6/15/2013	0.057	8/11/2013	0.327	10/7/2013	0.138
6/18/2013	0.012	8/14/2013	0.699	10/7/2013	0.127
6/18/2013	0.014	8/14/2013	0.772	10/10/2013	0.195
6/21/2013	0.133	8/17/2013	0.291	10/10/2013	0.201
6/21/2013	0.158	8/17/2013	0.280	10/13/2013	0.124
6/24/2013	0.054	8/20/2013	0.168	10/13/2013	0.116
6/24/2013	0.052	8/20/2013	0.175	10/16/2013	0.009

Appendix G-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Church Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
10/16/2013	0.009	12/12/2013	0.265	3/12/2014	0.005
10/19/2013	0.015	12/12/2013	0.253	3/18/2014	0.084
10/19/2013	0.009	12/15/2013	0.025	3/18/2014	0.081
10/22/2013	0.036	12/15/2013	0.028	3/24/2014	0.067
10/22/2013	0.037	12/18/2013	0.083	3/24/2014	0.070
10/25/2013	0.099	12/18/2013	0.082	3/30/2014	0.039
10/25/2013	0.098	12/21/2013	0.104	3/30/2014	0.036
10/28/2013	0.463	12/21/2013	0.104	4/5/2014	0.027
10/28/2013	0.480	12/24/2013	0.026	4/5/2014	0.027
10/31/2013	0.042	12/24/2013	0.028	4/11/2014	0.105
10/31/2013	0.032	12/27/2013	0.102	4/11/2014	0.111
11/3/2013	0.058	12/27/2013	0.100	4/17/2014	0.121
11/3/2013	0.058	12/30/2013	0.144	4/17/2014	0.129
11/6/2013	0.023	12/30/2013	0.140	4/23/2014	0.219
11/6/2013	0.022	1/5/2014	0.033	4/23/2014	0.221
11/9/2013	0.017	1/5/2014	0.025	4/29/2014	0.011
11/9/2013	0.010	1/11/2014	0.005	4/29/2014	0.010
11/12/2013	0.018	1/11/2014	0.005		
11/12/2013	0.014	1/17/2014	0.017		
11/15/2013	0.070	1/17/2014	0.016		
11/15/2013	0.077	1/23/2014	0.013		
11/18/2013	0.023	1/23/2014	0.014		
11/18/2013	0.017	1/29/2014	0.031		
11/21/2013	0.022	1/29/2014	0.027		
11/21/2013	0.020	2/4/2014	0.298		
11/24/2013	0.296	2/4/2014	0.299		
11/24/2013	0.271	2/10/2014	0.155		
11/27/2013	0.009	2/10/2014	0.163		
11/27/2013	0.006	2/16/2014	0.045		
11/30/2013	0.522	2/16/2014	0.045		
11/30/2013	0.585	2/22/2014	0.054		
12/3/2013	0.112	2/22/2014	0.058		
12/3/2013	0.108	2/28/2014	0.110		
12/6/2013	0.127	2/28/2014	0.108		
12/6/2013	0.093	3/6/2014	0.192		
12/9/2013	0.012	3/6/2014	0.188		
12/9/2013	0.011	3/12/2014	0.003		

Appendix H-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/1/2013	0.738	5/26/2013	0.799	6/23/2013	2.708
5/2/2013	0.060	5/27/2013	0.389	6/23/2013	2.411
5/2/2013	0.071	5/28/2013	0.117	6/24/2013	1.758
5/3/2013	0.005	5/29/2013	0.165	6/25/2013	0.030
5/4/2013	0.098	5/30/2013	0.638	6/25/2013	0.024
5/4/2013	0.085	5/31/2013	0.062	6/26/2013	0.405
5/5/2013	0.007	6/1/2013	0.235	6/27/2013	0.008
5/6/2013	0.010	6/2/2013	0.007	6/27/2013	0.007
5/6/2013	0.010	6/3/2013	0.158	6/28/2013	0.009
5/7/2013	0.175	6/4/2013	0.635	6/29/2013	0.012
5/8/2013	0.460	6/5/2013	0.239	6/29/2013	0.012
5/8/2013	0.353	6/5/2013	0.196	6/30/2013	0.010
5/9/2013	0.400	6/6/2013	0.015	7/1/2013	0.007
5/10/2013	0.009	6/7/2013	0.016	7/1/2013	0.007
5/10/2013	0.008	6/7/2013	0.013	7/2/2013	0.006
5/11/2013	0.015	6/8/2013	0.750	7/3/2013	0.493
5/12/2013	0.008	6/9/2013	0.311	7/3/2013	0.625
5/12/2013	0.006	6/9/2013	0.329	7/4/2013	0.693
5/13/2013	0.454	6/10/2013	0.105	7/5/2013	0.714
5/14/2013	0.083	6/11/2013	0.983	7/5/2013	0.763
5/14/2013	0.077	6/11/2013	0.911	7/6/2013	0.399
5/15/2013	0.025	6/12/2013	0.292	7/7/2013	0.053
5/16/2013	0.493	6/13/2013	0.014	7/7/2013	0.059
5/16/2013	0.469	6/13/2013	0.019	7/8/2013	0.347
5/17/2013	0.431	6/14/2013	0.313	7/9/2013	0.018
5/18/2013	0.290	6/15/2013	0.105	7/9/2013	0.019
5/18/2013	0.327	6/15/2013	0.105	7/10/2013	0.137
5/19/2013	1.039	6/16/2013	0.623	7/11/2013	0.014
5/20/2013	0.492	6/17/2013	1.156	7/11/2013	0.018
5/20/2013	0.520	6/17/2013	1.105	7/12/2013	0.225
5/21/2013	0.093	6/18/2013	0.023	7/13/2013	0.186
5/22/2013	0.011	6/19/2013	0.062	7/13/2013	0.185
5/23/2013	0.009	6/19/2013	0.059	7/14/2013	1.682
5/24/2013	0.146	6/20/2013	0.670	7/15/2013	1.329
5/24/2013	0.143	6/21/2013	0.209	7/15/2013	1.320
5/25/2013	0.805	6/21/2013	0.201	7/16/2013	1.307
5/26/2013	0.819	6/22/2013	0.439	7/17/2013	0.387

Appendix H-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
7/17/2013	0.408	8/11/2013	0.217	9/5/2013	0.393
7/18/2013	0.528	8/12/2013	0.110	9/6/2013	0.311
7/19/2013	0.137	8/12/2013	0.109	9/7/2013	0.019
7/19/2013	0.143	8/13/2013	0.008	9/7/2013	0.019
7/20/2013	0.227	8/14/2013	0.048	9/8/2013	1.621
7/21/2013	0.195	8/15/2013	0.028	9/9/2013	0.165
7/21/2013	0.176	8/16/2013	0.018	9/9/2013	0.157
7/22/2013	0.067	8/16/2013	0.019	9/10/2013	0.120
7/23/2013	0.042	8/17/2013	0.076	9/11/2013	0.101
7/23/2013	0.052	8/18/2013	0.150	9/11/2013	0.105
7/24/2013	0.016	8/18/2013	0.138	9/12/2013	0.114
7/25/2013	0.230	8/19/2013	0.378	9/13/2013	0.011
7/25/2013	0.218	8/20/2013	0.605	9/13/2013	0.012
7/26/2013	0.073	8/20/2013	0.622	9/14/2013	0.563
7/27/2013	0.066	8/21/2013	0.067	9/15/2013	0.398
7/27/2013	0.064	8/22/2013	0.011	9/15/2013	0.394
7/28/2013	0.024	8/22/2013	0.013	9/16/2013	0.012
7/29/2013	0.865	8/23/2013	0.159	9/17/2013	0.436
7/29/2013	0.847	8/24/2013	0.512	9/17/2013	0.415
7/30/2013	1.534	8/24/2013	0.469	9/18/2013	0.669
7/31/2013	0.027	8/25/2013	0.405	9/19/2013	0.439
7/31/2013	0.026	8/26/2013	0.111	9/19/2013	0.394
8/1/2013	0.028	8/26/2013	0.103	9/20/2013	0.006
8/2/2013	0.459	8/27/2013	0.015	9/21/2013	0.008
8/2/2013	0.433	8/28/2013	0.016	9/21/2013	0.007
8/3/2013	0.055	8/28/2013	0.016	9/22/2013	0.170
8/4/2013	0.342	8/29/2013	0.029	9/23/2013	0.971
8/4/2013	0.348	8/30/2013	0.274	9/23/2013	0.895
8/5/2013	1.098	8/30/2013	0.258	9/24/2013	0.576
8/6/2013	0.620	8/31/2013	0.020	9/25/2013	0.284
8/6/2013	0.596	9/1/2013	0.067	9/25/2013	0.263
8/7/2013	0.454	9/1/2013	0.060	9/26/2013	0.919
8/8/2013	0.098	9/2/2013	0.006	9/27/2013	1.578
8/8/2013	0.105	9/3/2013	0.018	9/27/2013	1.749
8/9/2013	0.177	9/3/2013	0.016	9/28/2013	0.560
8/10/2013	0.018	9/4/2013	0.291	9/29/2013	0.018
8/10/2013	0.017	9/5/2013	0.361	9/29/2013	0.017

Appendix H-3. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
9/30/2013	0.294	10/25/2013	0.284	11/18/2013	0.006
10/1/2013	0.663	10/25/2013	0.254	11/19/2013	0.383
10/1/2013	0.632	10/26/2013	0.013	11/20/2013	1.553
10/2/2013	0.237	10/27/2013	0.651	11/20/2013	1.440
10/3/2013	0.078	10/27/2013	0.669	11/21/2013	0.932
10/3/2013	0.073	10/28/2013	0.696	11/22/2013	0.015
10/4/2013	0.152	10/29/2013	2.150	11/22/2013	0.011
10/5/2013	0.265	10/29/2013	2.099	11/23/2013	0.005
10/5/2013	0.271	10/30/2013	0.572	11/24/2013	0.749
10/6/2013	0.012	10/31/2013	0.062	11/24/2013	0.758
10/7/2013	0.020	10/31/2013	0.057	11/25/2013	0.233
10/7/2013	0.018	11/1/2013	0.007	11/26/2013	0.018
10/8/2013	0.362	11/2/2013	0.010	11/26/2013	0.014
10/9/2013	0.675	11/2/2013	0.010	11/27/2013	0.005
10/9/2013	0.730	11/3/2013	2.097	11/28/2013	0.167
10/10/2013	0.667	11/4/2013	2.075	11/28/2013	0.136
10/11/2013	0.895	11/4/2013	1.762	11/29/2013	2.306
10/11/2013	0.919	11/5/2013	1.181	11/30/2013	0.655
10/12/2013	0.971	11/6/2013	0.023	11/30/2013	0.620
10/13/2013	0.011	11/6/2013	0.018	12/1/2013	0.195
10/13/2013	0.011	11/7/2013	0.006	12/2/2013	1.546
10/14/2013	0.686	11/8/2013	0.383	12/2/2013	1.603
10/15/2013	0.892	11/8/2013	0.317	12/3/2013	1.242
10/15/2013	0.817	11/9/2013	0.010	12/4/2013	1.090
10/16/2013	0.006	11/10/2013	0.041	12/4/2013	0.974
10/17/2013	0.008	11/10/2013	0.039	12/5/2013	0.057
10/17/2013	0.009	11/11/2013	0.036	12/6/2013	0.030
10/18/2013	0.006	11/12/2013	0.008	12/6/2013	0.036
10/19/2013	0.009	11/12/2013	0.004	12/7/2013	0.010
10/19/2013	0.007	11/13/2013	0.030	12/8/2013	0.199
10/20/2013	0.032	11/14/2013	0.078	12/8/2013	0.215
10/21/2013	0.011	11/14/2013	0.068	12/9/2013	0.008
10/21/2013	0.011	11/15/2013	0.313	12/10/2013	0.009
10/22/2013	0.104	11/16/2013	0.626	12/10/2013	0.009
10/23/2013	0.005	11/16/2013	0.523	12/11/2013	0.014
10/23/2013	0.005	11/17/2013	0.016	12/12/2013	1.547
10/24/2013	0.011	11/18/2013	0.005	12/12/2013	1.428

Appendix H-4. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
12/13/2013	1.121	1/7/2014	0.082	1/31/2014	0.008
12/14/2013	0.446	1/7/2014	0.078	2/1/2014	0.028
12/14/2013	0.426	1/8/2014	0.171	2/2/2014	0.006
12/15/2013	1.041	1/9/2014	0.737	2/2/2014	0.005
12/16/2013	1.095	1/9/2014	0.744	2/3/2014	0.011
12/16/2013	1.176	1/10/2014	1.235	2/4/2014	0.031
12/17/2013	0.011	1/11/2014	0.003	2/4/2014	0.034
12/18/2013	0.232	1/11/2014	0.004	2/5/2014	0.015
12/18/2013	0.246	1/12/2014	0.097	2/6/2014	0.006
12/19/2013	1.431	1/13/2014	0.003	2/6/2014	0.005
12/20/2013	0.022	1/13/2014	0.006	2/7/2014	0.472
12/20/2013	0.020	1/14/2014	0.008	2/8/2014	0.205
12/21/2013	0.004	1/15/2014	0.003	2/8/2014	0.209
12/22/2013	0.003	1/15/2014	0.005	2/9/2014	0.009
12/22/2013	0.003	1/16/2014	0.008	2/10/2014	0.007
12/23/2013	0.005	1/17/2014	0.017	2/10/2014	0.008
12/24/2013	0.210	1/17/2014	0.023	2/11/2014	0.155
12/24/2013	0.255	1/18/2014	0.068	2/12/2014	0.050
12/25/2013	0.086	1/19/2014	0.004	2/12/2014	0.058
12/26/2013	0.066	1/19/2014	0.003	2/13/2014	0.028
12/26/2013	0.081	1/20/2014	0.026	2/14/2014	0.044
12/27/2013	0.157	1/21/2014	0.043	2/14/2014	0.036
12/28/2013	0.168	1/21/2014	0.040	2/15/2014	0.153
12/28/2013	0.201	1/22/2014	0.054	2/16/2014	0.240
12/29/2013	0.021	1/23/2014	0.005	2/16/2014	0.262
12/30/2013	0.203	1/23/2014	0.004	2/17/2014	0.332
12/30/2013	0.191	1/24/2014	0.044	2/18/2014	0.108
12/31/2013	0.354	1/25/2014	0.018	2/18/2014	0.105
1/1/2014	0.250	1/25/2014	0.011	2/19/2014	0.211
1/1/2014	0.271	1/26/2014	0.020	2/20/2014	0.135
1/2/2014	0.037	1/27/2014	0.006	2/20/2014	0.144
1/3/2014	0.188	1/27/2014	0.003	2/21/2014	0.003
1/3/2014	0.184	1/28/2014	0.011	2/22/2014	0.068
1/4/2014	0.025	1/29/2014	0.030	2/22/2014	0.056
1/5/2014	0.072	1/29/2014	0.027	2/23/2014	0.011
1/5/2014	0.076	1/30/2014	0.083	2/24/2014	0.004
1/6/2014	0.012	1/31/2014	0.009	2/24/2014	0.012

Appendix H-5. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
2/25/2014	0.007	3/22/2014	0.004	4/18/2014	0.054
2/26/2014	0.006	3/22/2014	0.005	4/19/2014	0.365
2/26/2014	0.006	3/23/2014	0.008	4/19/2014	0.324
2/27/2014	0.016	3/24/2014	0.075	4/20/2014	0.254
2/28/2014	0.923	3/24/2014	0.071	4/21/2014	0.346
2/28/2014	0.875	3/25/2014	0.005	4/21/2014	0.345
3/1/2014	0.120	3/26/2014	0.326	4/22/2014	0.006
3/2/2014	0.044	3/26/2014	0.321	4/23/2014	0.742
3/2/2014	0.040	3/27/2014	0.096	4/24/2014	0.493
3/3/2014	0.028	3/28/2014	0.022	4/25/2014	0.303
3/4/2014	1.101	3/28/2014	0.009	4/26/2014	0.382
3/4/2014	1.137	3/29/2014	0.010	4/27/2014	0.749
3/5/2014	0.444	3/30/2014	0.241	4/28/2014	0.101
3/6/2014	0.082	3/30/2014	0.242	4/29/2014	0.008
3/6/2014	0.073	3/31/2014	0.331	4/30/2014	0.003
3/7/2014	0.281	4/1/2014	0.025		
3/8/2014	0.084	4/1/2014	0.023		
3/8/2014	0.078	4/2/2014	0.109		
3/9/2014	0.013	4/3/2014	0.164		
3/10/2014	0.010	4/4/2014	0.004		
3/10/2014	0.011	4/5/2014	0.022		
3/11/2014	0.029	4/6/2014	0.231		
3/12/2014	0.007	4/7/2014	0.007		
3/12/2014	0.006	4/8/2014	0.005		
3/13/2014	0.331	4/9/2014	0.005		
3/14/2014	0.008	4/10/2014	0.011		
3/14/2014	0.008	4/11/2014	0.089		
3/15/2014	0.289	4/11/2014	0.088		
3/16/2014	0.024	4/12/2014	0.080		
3/16/2014	0.017	4/13/2014	0.049		
3/17/2014	0.254	4/13/2014	0.047		
3/18/2014	0.928	4/14/2014	0.010		
3/18/2014	0.806	4/15/2014	0.068		
3/19/2014	0.009	4/15/2014	0.065		
3/20/2014	0.010	4/16/2014	0.376		
3/20/2014	0.010	4/17/2014	0.537		
3/21/2014	0.012	4/17/2014	0.534		

Appendix I-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/1/2013	0.670	6/8/2013	0.366	7/15/2013	1.212
5/2/2013	0.092	6/9/2013	0.508	7/16/2013	0.881
5/3/2013	0.041	6/10/2013	0.115	7/17/2013	0.431
5/4/2013	0.045	6/11/2013	1.271	7/18/2013	0.294
5/5/2013	0.025	6/12/2013	0.168	7/19/2013	0.159
5/6/2013	0.017	6/13/2013	0.061	7/20/2013	0.098
5/7/2013	0.131	6/14/2013	0.307	7/21/2013	0.105
5/8/2013	0.228	6/15/2013	0.127	7/22/2013	0.046
5/9/2013	0.297	6/16/2013	0.254	7/23/2013	0.043
5/10/2013	0.022	6/17/2013	0.505	7/24/2013	0.027
5/11/2013	0.029	6/18/2013	0.055	7/25/2013	0.225
5/12/2013	0.020	6/19/2013	0.111	7/26/2013	0.057
5/13/2013	0.224	6/20/2013	0.492	7/27/2013	0.062
5/14/2013	0.068	6/21/2013	0.167	7/28/2013	0.023
5/15/2013	0.021	6/22/2013	0.172	7/29/2013	0.392
5/16/2013	0.307	6/23/2013	0.909	7/30/2013	0.758
5/17/2013	0.345	6/24/2013	0.280	7/31/2013	0.066
5/18/2013	0.168	6/25/2013	0.047	8/1/2013	0.060
5/19/2013	0.276	6/26/2013	0.236	8/2/2013	0.252
5/20/2013	0.629	6/27/2013	0.018	8/3/2013	0.081
5/21/2013	0.072	6/28/2013	0.020	8/4/2013	0.436
5/23/2013	0.015	6/29/2013	0.015	8/5/2013	0.444
5/24/2013	0.243	6/30/2013	0.041	8/6/2013	0.109
5/25/2013	0.483	7/1/2013	0.010	8/7/2013	0.123
5/26/2013	0.547	7/2/2013	0.008	8/8/2013	0.107
5/27/2013	0.142	7/3/2013	0.246	8/9/2013	0.322
5/28/2013	0.048	7/4/2013	0.559	8/10/2013	0.053
5/29/2013	0.097	7/5/2013	0.450	8/11/2013	0.385
5/30/2013	0.112	7/6/2013	0.397	8/12/2013	0.121
5/31/2013	0.037	7/7/2013	0.066	8/13/2013	0.028
6/1/2013	0.045	7/8/2013	0.162	8/14/2013	0.133
6/2/2013	0.018	7/9/2013	0.033	8/15/2013	0.303
6/3/2013	0.325	7/10/2013	0.072	8/16/2013	0.075
6/4/2013	0.695	7/11/2013	0.027	8/17/2013	0.348
6/5/2013	0.333	7/12/2013	0.718	8/18/2013	0.178
6/6/2013	0.048	7/13/2013	0.568	8/19/2013	0.448
6/7/2013	0.060	7/14/2013	2.097	8/20/2013	0.207

Appendix I-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
8/21/2013	0.058	9/27/2013	0.531	11/3/2013	0.611
8/22/2013	0.047	9/28/2013	0.155	11/4/2013	0.872
8/23/2013	0.364	9/29/2013	0.047	11/5/2013	0.558
8/24/2013	0.256	9/30/2013	0.200	11/6/2013	0.040
8/25/2013	0.237	10/1/2013	0.275	11/7/2013	0.035
8/26/2013	0.083	10/2/2013	0.114	11/8/2013	0.168
8/27/2013	0.025	10/3/2013	0.086	11/9/2013	0.025
8/28/2013	0.025	10/4/2013	0.050	11/10/2013	0.096
8/29/2013	0.050	10/5/2013	0.085	11/11/2013	0.041
8/30/2013	0.222	10/6/2013	0.017	11/12/2013	0.017
8/31/2013	0.022	10/7/2013	0.024	11/13/2013	0.024
9/1/2013	0.052	10/8/2013	0.259	11/14/2013	0.031
9/2/2013	0.018	10/9/2013	0.522	11/15/2013	0.168
9/3/2013	0.028	10/10/2013	0.496	11/16/2013	0.043
9/4/2013	0.350	10/11/2013	0.355	11/17/2013	0.018
9/5/2013	0.330	10/12/2013	0.135	11/18/2013	0.010
9/6/2013	0.314	10/13/2013	0.049	11/19/2013	0.781
9/7/2013	0.034	10/14/2013	0.863	11/20/2013	0.703
9/8/2013	0.207	10/15/2013	0.126	11/21/2013	0.331
9/9/2013	0.197	10/16/2013	0.039	11/22/2013	0.059
9/10/2013	0.082	10/17/2013	0.023	11/23/2013	0.060
9/11/2013	0.065	10/18/2013	0.017	11/24/2013	0.249
9/12/2013	0.125	10/19/2013	0.009	11/25/2013	0.212
9/13/2013	0.023	10/20/2013	0.028	11/26/2013	0.037
9/14/2013	0.277	10/21/2013	0.018	11/27/2013	0.057
9/15/2013	0.144	10/22/2013	0.061	11/28/2013	0.131
9/16/2013	0.036	10/23/2013	0.009	11/29/2013	0.929
9/17/2013	0.215	10/24/2013	0.011	11/30/2013	0.431
9/18/2013	0.140	10/25/2013	0.185	12/1/2013	0.231
9/19/2013	0.106	10/26/2013	0.044	12/2/2013	1.200
9/20/2013	0.015	10/27/2013	0.613	12/3/2013	0.720
9/21/2013	0.021	10/28/2013	1.150	12/4/2013	0.215
9/22/2013	0.360	10/29/2013	1.098	12/5/2013	0.075
9/23/2013	0.921	10/30/2013	0.713	12/6/2013	0.066
9/24/2013	0.552	10/31/2013	0.058	12/7/2013	0.040
9/25/2013	0.283	11/1/2013	0.078	12/8/2013	0.137
9/26/2013	0.591	11/2/2013	0.089	12/9/2013	0.017

Appendix I-3. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2013-2014 air quality monitoring station.

Date	Mean	Date	Mean
12/10/2013	0.018	4/5/2014	0.06
12/11/2013	0.023	4/11/2014	0.063
12/12/2013	1.053	4/17/2014	0.348
12/13/2013	0.698	4/23/2014	0.443
12/14/2013	0.107	4/29/2014	0.011
12/15/2013	0.444	4/5/2014	0.060
12/16/2013	0.199	4/11/2014	0.063
12/17/2013	0.031	4/17/2014	0.348
12/18/2013	0.134	4/23/2014	0.443
12/19/2013	0.606	4/29/2014	0.011
12/20/2013	0.023		
12/21/2013	0.014		
12/22/2013	0.016		
12/23/2013	0.020		
12/24/2013	0.102		
12/25/2013	0.026		
12/26/2013	0.051		
12/27/2013	0.087		
12/28/2013	0.109		
12/29/2013	0.022		
12/30/2013	0.133		
12/31/2013	0.090		
1/5/2014	0.061		
1/11/2014	0.008		
1/17/2014	0.013		
1/23/2014	0.024		
1/29/2014	0.022		
2/4/2014	0.074		
2/10/2014	0.019		
2/16/2014	0.214		
2/22/2014	0.071		
2/28/2014	0.350		
3/6/2014	0.149		
3/12/2014	0.010		
3/18/2014	0.212		
3/24/2014	0.051		
3/30/2014	0.077		

Appendix J-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Church Street 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/2/2018	0.021	8/24/2018	0.006	12/10/2018	0.030
5/2/2018	0.155	8/24/2018	0.006	12/16/2018	0.005
5/8/2018	0.066	8/30/2018	0.040	12/16/2018	0.007
5/8/2018	0.085	8/30/2018	0.042	12/22/2018	0.006
5/14/2018	0.015	9/5/2018	0.011	12/22/2018	0.014
5/14/2018	0.015	9/5/2018	0.014	12/28/2018	0.018
5/20/2018	0.005	9/11/2018	0.034	12/28/2018	0.004
5/20/2018	0.017	9/11/2018	0.030	1/3/2019	0.096
5/26/2018	0.019	9/17/2018	0.009	1/3/2019	0.104
5/26/2018	0.019	9/17/2018	0.004	1/9/2019	0.002
6/1/2018	0.025	9/23/2018	0.100	1/9/2019	0.004
6/1/2018	0.016	9/23/2018	0.101	1/15/2019	0.006
6/7/2018	0.028	9/29/2018	0.047	1/15/2019	0.015
6/7/2018	0.112	9/29/2018	0.046	1/21/2019	0.072
6/13/2018	0.029	10/5/2018	0.009	1/21/2019	0.075
6/13/2018	0.029	10/5/2018	0.014	1/27/2019	0.049
6/19/2018	0.010	10/11/2018	0.002	1/27/2019	0.048
6/19/2018	0.007	10/11/2018	0.002	2/2/2019	0.040
6/25/2018	0.043	10/17/2018	0.008	2/2/2019	0.042
6/25/2018	0.092	10/17/2018	0.009	2/8/2019	0.003
7/1/2018	0.015	10/23/2018	0.056	2/8/2019	0.006
7/1/2018	0.024	10/23/2018	0.054	2/14/2019	0.077
7/7/2018	0.159	10/29/2018	0.066	2/14/2019	0.072
7/13/2018	0.049	10/29/2018	0.097	2/20/2019	0.016
7/13/2018	0.045	11/4/2018	0.020	2/20/2019	0.063
7/19/2018	0.029	11/4/2018	0.006	2/26/2019	0.223
7/19/2018	0.031	11/10/2018	0.011	2/26/2019	0.252
7/25/2018	0.075	11/10/2018	0.025	3/4/2019	0.003
7/25/2018	0.072	11/16/2018	0.101	3/4/2019	0.001
7/31/2018	0.021	11/16/2018	0.098	3/10/2019	0.002
7/31/2018	0.022	11/22/2018	0.019	3/10/2019	0.008
8/6/2018	0.051	11/22/2018	0.018	3/16/2019	0.019
8/6/2018	0.056	11/28/2018	0.117	3/16/2019	0.024
8/12/2018	0.043	11/28/2018	0.111	3/22/2019	0.015
8/12/2018	0.036	12/4/2018	0.002	3/22/2019	0.019
8/18/2018	0.025	12/4/2018	0.008	3/28/2019	0.063
8/18/2018	0.016	12/10/2018	0.011	3/28/2019	0.069

Appendix J-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Church Street 2018-2019 air quality monitoring station.

Date	Mean
4/3/2019	0.123
4/3/2019	0.128
4/9/2019	0.119
4/9/2019	0.114
4/15/2019	0.052
4/15/2019	0.093
4/21/2019	0.013
4/21/2019	0.020
4/27/2019	0.012
4/27/2019	0.014

Appendix K-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/1/2018	0.210	5/29/2018	0.270	6/26/2018	0.036
5/2/2018	0.042	5/30/2018	0.017	6/27/2018	0.029
5/2/2018	0.039	5/31/2018	0.038	6/28/2018	0.190
5/3/2018	0.036	6/1/2018	0.725	6/28/2018	0.189
5/4/2018	0.011	6/1/2018	0.773	6/29/2018	0.225
5/5/2018	0.131	6/2/2018	0.683	6/30/2018	0.120
5/5/2018	0.139	6/3/2018	0.014	7/1/2018	0.023
5/6/2018	0.019	6/4/2018	0.020	7/1/2018	0.021
5/7/2018	0.018	6/4/2018	0.017	7/2/2018	0.048
5/8/2018	0.566	6/5/2018	0.010	7/3/2018	0.199
5/8/2018	0.605	6/6/2018	0.066	7/4/2018	0.045
5/9/2018	0.435	6/7/2018	0.039	7/4/2018	0.049
5/10/2018	0.018	6/7/2018	0.033	7/5/2018	0.078
5/11/2018	0.072	6/8/2018	0.020	7/6/2018	0.021
5/11/2018	0.079	6/9/2018	0.024	7/7/2018	0.006
5/12/2018	0.049	6/10/2018	0.014	7/7/2018	0.006
5/13/2018	0.021	6/10/2018	0.014	7/8/2018	0.025
5/14/2018	0.029	6/11/2018	0.053	7/9/2018	0.043
5/14/2018	0.036	6/12/2018	0.041	7/10/2018	0.053
5/15/2018	0.013	6/13/2018	0.008	7/10/2018	0.050
5/16/2018	0.009	6/13/2018	0.009	7/11/2018	0.025
5/17/2018	0.106	6/14/2018	0.180	7/12/2018	0.195
5/17/2018	0.096	6/15/2018	0.139	7/13/2018	0.233
5/18/2018	0.021	6/16/2018	0.060	7/13/2018	0.210
5/19/2018	0.014	6/16/2018	0.065	7/14/2018	0.238
5/20/2018	0.050	6/17/2018	0.012	7/15/2018	0.097
5/21/2018	0.132	6/18/2018	0.007	7/16/2018	0.009
5/22/2018	0.039	6/19/2018	0.018	7/16/2018	0.010
5/23/2018	0.086	6/19/2018	0.016	7/17/2018	0.007
5/23/2018	0.071	6/20/2018	0.046	7/18/2018	0.144
5/24/2018	0.112	6/21/2018	0.007	7/19/2018	0.245
5/25/2018	0.033	6/22/2018	0.002	7/19/2018	0.216
5/26/2018	0.029	6/22/2018	0.003	7/20/2018	0.010
5/26/2018	0.028	6/23/2018	0.068	7/21/2018	0.010
5/27/2018	0.028	6/24/2018	0.088	7/22/2018	0.005
5/28/2018	0.036	6/25/2018	0.069	7/22/2018	0.004
5/29/2018	0.336	6/25/2018	0.077	7/23/2018	0.003

Appendix K-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
7/24/2018	0.006	8/24/2018	0.006	9/17/2018	0.004
7/25/2018	0.019	8/24/2018	0.006	9/17/2018	0.004
7/25/2018	0.020	8/30/2018	0.040	9/18/2018	0.012
7/26/2018	0.008	8/30/2018	0.042	9/19/2018	0.119
7/27/2018	0.065	8/23/2018	0.060	9/20/2018	0.101
7/28/2018	0.045	8/24/2018	0.095	9/20/2018	0.103
7/28/2018	0.040	8/24/2018	0.104	9/21/2018	0.017
7/29/2018	0.045	8/25/2018	0.008	9/22/2018	0.012
7/31/2018	0.003	8/26/2018	0.003	9/23/2018	0.013
7/31/2018	0.004	8/27/2018	0.047	9/23/2018	0.014
8/2/2018	0.125	8/27/2018	0.049	9/24/2018	0.064
8/3/2018	0.128	8/28/2018	0.066	9/25/2018	0.015
8/3/2018	0.156	8/29/2018	0.030	9/26/2018	0.003
8/4/2018	0.225	8/30/2018	0.084	9/26/2018	0.002
8/5/2018	0.172	8/30/2018	0.087	9/27/2018	0.050
8/6/2018	0.148	8/31/2018	0.102	9/28/2018	0.006
8/6/2018	0.150	9/1/2018	0.008	9/29/2018	0.118
8/7/2018	0.047	9/2/2018	0.043	9/29/2018	0.124
8/8/2018	0.118	9/2/2018	0.048	9/30/2018	0.106
8/9/2018	0.108	9/3/2018	0.058	10/1/2018	0.136
8/9/2018	0.099	9/4/2018	0.113	10/2/2018	0.082
8/10/2018	0.057	9/5/2018	0.144	10/2/2018	0.095
8/11/2018	0.009	9/5/2018	0.136	10/3/2018	0.061
8/12/2018	0.017	9/6/2018	0.153	10/4/2018	0.008
8/13/2018	0.129	9/7/2018	0.084	10/5/2018	0.032
8/14/2018	0.141	9/8/2018	0.001	10/5/2018	0.030
8/15/2018	0.017	9/8/2018	0.001	10/6/2018	0.024
8/15/2018	0.015	9/9/2018	0.047	10/7/2018	0.375
8/16/2018	0.007	9/10/2018	0.007	10/8/2018	0.904
8/17/2018	0.003	9/11/2018	0.046	10/8/2018	0.928
8/18/2018	0.042	9/11/2018	0.045	10/9/2018	0.755
8/18/2018	0.039	9/12/2018	0.091	10/10/2018	0.008
8/19/2018	0.107	9/13/2018	0.049	10/11/2018	0.004
8/20/2018	0.017	9/14/2018	0.088	10/11/2018	0.002
8/21/2018	0.002	9/14/2018	0.084	10/12/2018	0.009
8/21/2018	0.003	9/15/2018	0.182	10/13/2018	0.062
8/22/2018	0.006	9/16/2018	0.024	10/14/2018	0.008

Appendix K-3. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
10/14/2018	0.008	11/12/2018	0.008	12/10/2018	0.006
10/15/2018	0.002	11/13/2018	0.002	12/10/2018	0.007
10/16/2018	0.001	11/13/2018	0.002	12/11/2018	0.012
10/17/2018	0.003	11/14/2018	0.007	12/12/2018	0.012
10/17/2018	0.004	11/15/2018	0.019	12/13/2018	0.136
10/18/2018	0.131	11/16/2018	0.016	12/13/2018	0.132
10/19/2018	0.016	11/16/2018	0.015	12/14/2018	0.003
10/20/2018	0.005	11/17/2018	0.099	12/15/2018	0.005
10/20/2018	0.005	11/18/2018	0.003	12/16/2018	0.004
10/21/2018	0.015	11/19/2018	0.002	12/16/2018	0.003
10/22/2018	0.025	11/19/2018	0.002	12/17/2018	0.034
10/23/2018	0.007	11/20/2018	0.006	12/18/2018	0.261
10/24/2018	0.058	11/21/2018	0.026	12/19/2018	0.073
10/25/2018	0.089	11/22/2018	0.070	12/19/2018	0.073
10/26/2018	0.003	11/22/2018	0.069	12/20/2018	0.040
10/26/2018	0.003	11/23/2018	0.251	12/21/2018	0.001
10/27/2018	0.014	11/24/2018	0.015	12/22/2018	0.013
10/28/2018	0.011	11/25/2018	0.044	12/22/2018	0.014
10/29/2018	0.151	11/25/2018	0.042	12/23/2018	0.003
10/29/2018	0.149	11/26/2018	0.003	12/24/2018	0.034
10/30/2018	0.094	11/27/2018	0.002	12/25/2018	0.064
10/31/2018	0.005	11/28/2018	0.494	12/25/2018	0.057
11/1/2018	0.014	11/28/2018	0.465	12/26/2018	0.403
11/1/2018	0.015	11/29/2018	0.180	12/27/2018	0.171
11/2/2018	0.063	11/30/2018	0.019	12/28/2018	0.001
11/3/2018	0.213	12/1/2018	0.083	12/28/2018	0.001
11/4/2018	0.027	12/1/2018	0.081	12/29/2018	0.032
11/4/2018	0.028	12/2/2018	0.002	12/30/2018	0.040
11/5/2018	0.227	12/3/2018	0.002	12/31/2018	0.004
11/6/2018	0.002	12/4/2018	0.002	12/31/2018	0.004
11/7/2018	0.008	12/4/2018	0.001	1/1/2019	0.002
11/7/2018	0.008	12/5/2018	0.004	1/2/2019	0.003
11/8/2018	0.005	12/6/2018	0.021	1/3/2019	0.131
11/9/2018	0.004	12/7/2018	0.005	1/3/2019	0.131
11/10/2018	0.141	12/7/2018	0.006	1/4/2019	0.011
11/10/2018	0.148	12/8/2018	0.009	1/5/2019	0.009
11/11/2018	0.055	12/9/2018	0.003	1/6/2019	0.174

Appendix K-4. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
1/6/2019	0.165	2/5/2019	0.085	3/7/2019	0.647
1/7/2019	0.019	2/6/2019	0.066	3/8/2019	0.020
1/8/2019	0.004	2/7/2019	0.098	3/9/2019	0.026
1/9/2019	0.009	2/8/2019	0.002	3/10/2019	0.002
1/9/2019	0.003	2/8/2019	0.001	3/10/2019	0.002
1/10/2019	0.043	2/9/2019	0.025	3/11/2019	0.040
1/12/2019	0.006	2/10/2019	0.030	3/12/2019	0.684
1/12/2019	0.008	2/11/2019	0.007	3/13/2019	0.255
1/13/2019	0.003	2/11/2019	0.006	3/13/2019	0.274
1/14/2019	0.003	2/12/2019	0.003	3/14/2019	0.003
1/15/2019	0.004	2/13/2019	0.399	3/15/2019	0.002
1/15/2019	0.004	2/14/2019	0.032	3/16/2019	0.011
1/16/2019	0.053	2/14/2019	0.033	3/16/2019	0.011
1/17/2019	0.163	2/15/2019	0.003	3/17/2019	0.005
1/18/2019	0.062	2/16/2019	0.013	3/18/2019	0.015
1/18/2019	0.067	2/17/2019	0.011	3/19/2019	0.344
1/19/2019	0.014	2/17/2019	0.014	3/19/2019	0.327
1/20/2019	0.014	2/20/2019	0.033	3/20/2019	0.015
1/21/2019	0.463	2/21/2019	0.045	3/21/2019	0.003
1/21/2019	0.420	2/22/2019	0.004	3/22/2019	0.005
1/22/2019	0.307	2/23/2019	0.047	3/22/2019	0.005
1/23/2019	0.020	2/23/2019	0.052	3/23/2019	0.099
1/24/2019	0.003	2/24/2019	0.002	3/24/2019	0.025
1/24/2019	0.011	2/25/2019	0.660	3/25/2019	0.004
1/25/2019	0.007	2/26/2019	0.026	3/25/2019	0.004
1/26/2019	0.033	2/26/2019	0.030	3/26/2019	0.026
1/27/2019	0.055	2/27/2019	0.022	3/27/2019	0.198
1/27/2019	0.048	2/28/2019	0.005	3/28/2019	0.215
1/28/2019	0.016	3/1/2019	0.009	3/28/2019	0.202
1/29/2019	0.005	3/1/2019	0.010	3/29/2019	0.073
1/30/2019	0.014	3/2/2019	0.005	3/30/2019	0.004
1/30/2019	0.005	3/3/2019	0.014	3/31/2019	0.003
1/31/2019	0.149	3/4/2019	0.002	3/31/2019	0.003
2/1/2019	0.085	3/4/2019	0.002	4/1/2019	0.064
2/3/2019	0.089	3/5/2019	0.003	4/2/2019	0.005
2/4/2019	0.049	3/6/2019	0.082	4/3/2019	0.341
2/5/2019	0.095	3/7/2019	0.652	4/3/2019	0.302

Appendix K-5. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum Mott Street 2018-2019 air quality monitoring station.

Date	Mean
4/4/2019	0.371
4/5/2019	0.015
4/6/2019	0.370
4/6/2019	0.404
4/7/2019	0.027
4/8/2019	0.014
4/9/2019	0.058
4/9/2019	0.059
4/10/2019	0.336
4/11/2019	0.069
4/12/2019	0.003
4/12/2019	0.004
4/13/2019	0.008
4/14/2019	0.003
4/15/2019	0.230
4/15/2019	0.235
4/16/2019	0.991
4/17/2019	0.175
4/18/2019	0.006
4/18/2019	0.003
4/19/2019	0.005
4/20/2019	0.005
4/21/2019	0.063
4/21/2019	0.085
4/22/2019	0.159
4/23/2019	0.010
4/24/2019	0.029
4/24/2019	0.032
4/25/2019	0.003
4/26/2019	0.003
4/27/2019	0.019
4/28/2019	0.011
4/30/2019	0.039
4/30/2019	0.036

Appendix L-1. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
5/1/2018	0.073	6/11/2018	0.020	7/22/2018	0.014
5/2/2018	0.058	6/12/2018	0.022	7/23/2018	0.007
5/3/2018	0.006	6/14/2018	0.117	7/24/2018	0.008
5/4/2018	0.012	6/15/2018	0.075	7/25/2018	0.014
5/5/2018	0.105	6/16/2018	0.021	7/26/2018	0.009
5/6/2018	0.018	6/17/2018	0.012	7/27/2018	0.079
5/7/2018	0.021	6/18/2018	0.016	7/28/2018	0.040
5/9/2018	0.032	6/19/2018	0.012	7/29/2018	0.011
5/10/2018	0.016	6/20/2018	0.022	7/30/2018	0.019
5/11/2018	0.074	6/22/2018	0.007	7/31/2018	0.020
5/12/2018	0.038	6/23/2018	0.045	8/1/2018	0.072
5/13/2018	0.019	6/25/2018	0.086	8/2/2018	0.075
5/14/2018	0.027	6/26/2018	0.026	8/3/2018	0.093
5/15/2018	0.017	6/27/2018	0.031	8/4/2018	0.124
5/16/2018	0.010	6/28/2018	0.139	8/5/2018	0.046
5/17/2018	0.149	6/29/2018	0.111	8/6/2018	0.117
5/18/2018	0.025	6/30/2018	0.013	8/7/2018	0.050
5/19/2018	0.019	7/1/2018	0.010	8/8/2018	0.291
5/20/2018	0.021	7/2/2018	0.054	8/9/2018	0.111
5/21/2018	0.069	7/3/2018	0.152	8/10/2018	0.069
5/22/2018	0.033	7/4/2018	0.039	8/11/2018	0.022
5/23/2018	0.083	7/6/2018	0.021	8/14/2018	0.088
5/24/2018	0.041	7/7/2018	0.017	8/15/2018	0.013
5/25/2018	0.032	7/8/2018	0.059	8/16/2018	0.009
5/26/2018	0.029	7/9/2018	0.062	8/17/2018	0.013
5/27/2018	0.027	7/10/2018	0.092	8/18/2018	0.039
5/28/2018	0.093	7/11/2018	0.077	8/19/2018	0.042
5/29/2018	0.949	7/12/2018	0.132	8/20/2018	0.004
5/30/2018	0.147	7/13/2018	0.130	8/21/2018	0.004
5/31/2018	0.189	7/14/2018	0.062	8/22/2018	0.014
6/1/2018	0.297	7/15/2018	0.033	8/23/2018	0.020
6/4/2018	0.091	7/16/2018	0.015	8/24/2018	0.031
6/5/2018	0.009	7/17/2018	0.020	8/25/2018	0.010
6/6/2018	0.057	7/18/2018	0.250	8/26/2018	0.008
6/7/2018	0.037	7/19/2018	0.190	8/27/2018	0.011
6/9/2018	0.022	7/20/2018	0.016	8/28/2018	0.008
6/10/2018	0.013	7/21/2018	0.019	8/29/2018	0.016

Appendix L-2. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
8/30/2018	0.056	10/6/2018	0.015	11/13/2018	0.004
8/31/2018	0.057	10/7/2018	0.165	11/14/2018	0.015
9/1/2018	0.007	10/8/2018	0.162	11/15/2018	0.011
9/2/2018	0.010	10/9/2018	0.204	11/16/2018	0.030
9/3/2018	0.011	10/10/2018	0.011	11/17/2018	0.048
9/4/2018	0.072	10/11/2018	0.010	11/18/2018	0.004
9/5/2018	0.054	10/12/2018	0.017	11/19/2018	0.002
9/6/2018	0.214	10/13/2018	0.033	11/20/2018	0.015
9/7/2018	0.133	10/14/2018	0.011	11/21/2018	0.031
9/8/2018	0.009	10/15/2018	0.005	11/22/2018	0.056
9/9/2018	0.067	10/16/2018	0.004	11/23/2018	0.054
9/10/2018	0.012	10/17/2018	0.002	11/24/2018	0.019
9/11/2018	0.045	10/18/2018	0.097	11/25/2018	0.015
9/12/2018	0.080	10/19/2018	0.009	11/26/2018	0.004
9/13/2018	0.054	10/20/2018	0.009	11/27/2018	0.004
9/14/2018	0.073	10/21/2018	0.011	11/28/2018	0.299
9/15/2018	0.097	10/22/2018	0.028	11/29/2018	0.163
9/16/2018	0.026	10/23/2018	0.008	11/30/2018	0.039
9/17/2018	0.007	10/24/2018	0.096	12/1/2018	0.051
9/18/2018	0.013	10/25/2018	0.099	12/2/2018	0.022
9/19/2018	0.106	10/26/2018	0.009	12/3/2018	0.009
9/20/2018	0.062	10/27/2018	0.018	12/4/2018	0.003
9/21/2018	0.014	10/28/2018	0.017	12/5/2018	0.004
9/22/2018	0.028	10/30/2018	0.124	12/6/2018	0.013
9/23/2018	0.131	10/31/2018	0.008	12/7/2018	0.006
9/24/2018	0.097	11/1/2018	0.014	12/8/2018	0.016
9/25/2018	0.011	11/2/2018	0.031	12/9/2018	0.005
9/26/2018	0.002	11/3/2018	0.042	12/11/2018	0.030
9/27/2018	0.040	11/4/2018	0.009	12/12/2018	0.018
9/28/2018	0.010	11/5/2018	0.174	12/13/2018	0.059
9/29/2018	0.109	11/6/2018	0.007	12/14/2018	0.006
9/30/2018	0.039	11/7/2018	0.012	12/15/2018	0.008
10/1/2018	0.167	11/8/2018	0.042	12/16/2018	0.006
10/2/2018	0.075	11/9/2018	0.014	12/17/2018	0.039
10/3/2018	0.046	11/10/2018	0.022	12/18/2018	0.146
10/4/2018	0.015	11/11/2018	0.041	12/19/2018	0.063
10/5/2018	0.016	11/12/2018	0.012	12/20/2018	0.019

Appendix L-3. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2018-2019 air quality monitoring station.

Date	Mean	Date	Mean	Date	Mean
12/21/2018	0.007	1/27/2019	0.024	3/5/2019	0.004
12/22/2018	0.014	1/28/2019	0.020	3/6/2019	0.050
12/23/2018	0.004	1/29/2019	0.010	3/7/2019	0.585
12/24/2018	0.041	1/30/2019	0.006	3/8/2019	0.052
12/25/2018	0.041	1/31/2019	0.054	3/9/2019	0.059
12/26/2018	0.555	2/1/2019	0.099	3/10/2019	0.025
12/27/2018	0.053	2/2/2019	0.224	3/11/2019	0.059
12/28/2018	0.030	2/3/2019	0.068	3/12/2019	0.295
12/29/2018	0.043	2/4/2019	0.012	3/13/2019	0.070
12/30/2018	0.020	2/5/2019	0.117	3/14/2019	0.017
12/31/2018	0.004	2/6/2019	0.056	3/15/2019	0.011
1/1/2019	0.002	2/7/2019	0.069	3/16/2019	0.014
1/2/2019	0.002	2/8/2019	0.013	3/17/2019	0.006
1/3/2019	0.060	2/9/2019	0.048	3/18/2019	0.020
1/4/2019	0.016	2/10/2019	0.014	3/19/2019	0.150
1/5/2019	0.011	2/11/2019	0.012	3/20/2019	0.012
1/6/2019	0.063	2/12/2019	0.005	3/21/2019	0.009
1/7/2019	0.020	2/13/2019	0.095	3/22/2019	0.019
1/8/2019	0.008	2/14/2019	0.020	3/23/2019	0.065
1/9/2019	0.002	2/15/2019	0.007	3/24/2019	0.020
1/10/2019	0.097	2/16/2019	0.051	3/25/2019	0.012
1/11/2019	0.245	2/17/2019	0.014	3/26/2019	0.075
1/12/2019	0.051	2/18/2019	0.007	3/27/2019	0.092
1/13/2019	0.019	2/19/2019	0.278	3/28/2019	0.140
1/14/2019	0.024	2/20/2019	0.085	3/29/2019	0.073
1/15/2019	0.017	2/21/2019	0.083	3/30/2019	0.011
1/16/2019	0.078	2/22/2019	0.033	3/31/2019	0.009
1/17/2019	0.184	2/23/2019	0.036	4/1/2019	0.051
1/18/2019	0.140	2/24/2019	0.005	4/2/2019	0.011
1/19/2019	0.031	2/25/2019	0.152	4/3/2019	0.246
1/20/2019	0.032	2/26/2019	0.049	4/4/2019	0.320
1/21/2019	0.157	2/27/2019	0.020	4/5/2019	0.034
1/22/2019	0.159	2/28/2019	0.010	4/6/2019	0.096
1/23/2019	0.021	3/1/2019	0.013	4/7/2019	0.040
1/24/2019	0.008	3/2/2019	0.005	4/8/2019	0.024
1/25/2019	0.009	3/3/2019	0.009	4/10/2019	0.277
1/26/2019	0.021	3/4/2019	0.002	4/11/2019	0.040

Appendix L-4. EPA air lead concentrations (arithmetic mean micrograms per cubic meter) recorded from Herculaneum North Cross 2018-2019 air quality monitoring station.

Date	Mean
4/12/2019	0.026
4/13/2019	0.024
4/14/2019	0.026
4/15/2019	0.072
4/16/2019	0.096
4/17/2019	0.088
4/18/2019	0.012
4/19/2019	0.009
4/20/2019	0.004
4/21/2019	0.012
4/22/2019	0.069
4/23/2019	0.161
4/24/2019	0.031
4/25/2019	0.002
4/26/2019	0.004
4/27/2019	0.009
4/28/2019	0.012
4/29/2019	0.035
4/30/2019	0.019