Soil Lead Contamination in Kansas State University Campus and Suggested Remediation Strategies

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Abstract

This study investigates soil lead (Pb) contamination across Kansas State University's (KSU) campus, aiming to identify spatial patterns relating to land use, and effective remediation strategies. Using portable X-Ray Fluorescence (XRF) spectroscopy, soil samples were analyzed at varying depths across natural areas, older and newer buildings, and agricultural sites. The results revealed significant variability in lead concentrations, reflecting historical land use and environmental factors. Natural areas generally exhibited baseline levels of lead, averaging 33.32 ± 2.82 ppm. There were some exceptions such as Campus Creek, where concentrations increased with depth from 35.15 ppm to 72.07 ppm at 5 cm to 15 cm, respectively; this indicates potential historical or environmental influences. Older buildings demonstrated elevated lead levels, averaging 183.70 ± 248.14 ppm, due to legacy contamination from lead-based paint, with Anderson Hall presenting the highest levels of lead averaging at 367.30 ± 339.47 ppm, requiring immediate remediation. In contrast, newer buildings showed low contamination levels, averaging at 20.55 ± 4.47 ppm, reflecting the success of modern construction standards. Agricultural areas displayed slightly elevated lead concentrations with an average reading of 25.5 ± 3.88 ppm, likely influenced by machinery and past land use practices.

The findings underscore the importance of targeted remediation efforts, including encapsulation of lead-based paint, in-situ soil stabilization using biochar and apatite amendments, and revegetation to stabilize soils and mitigate runoff. Long-term management strategies, such as regular monitoring and soil amendments, are recommended to maintain safe lead levels across the campus. This study highlights the ongoing challenges of managing legacy lead contamination and provides suggestions for sustainable and cost-effective remediation and environmental safety on university campuses.

Introduction

Study Objectives

The primary objective of this study is to assess lead concentrations across the Kansas State University campus to identify any areas with potentially elevated soil lead levels. By measuring lead levels near various structures and open spaces, we aim to understand how historical and environmental factors may influence contamination patterns. Our hypothesis is that open and natural spaces, as well as areas around newer buildings, will exhibit baseline lead levels due to minimal historical lead exposure. Conversely, we anticipate slightly elevated lead levels near older campus buildings, where legacy sources like lead-based paint may have contributed to localized contamination. However, as this is a university campus, we do not expect to encounter highly contaminated sites. Additionally, this study seeks to evaluate lead distribution geospatially, assuming relative uniformity of lead levels across similar areas within a given site. Based on our findings, we aim to propose targeted remediation strategies that align with the specific soil chemistry and spatial characteristics of any identified elevated lead sites, ensuring sustainable and practical solutions for the campus environment.

Selection of Study Site

The construction and evolution of buildings at Kansas State University reflect both the eras of their construction and the environmental challenges associated with legacy contaminants. Older structures predate these regulations and may be associated with lead-containing materials, such as paint or pipes. Additionally, the KSU campus's open areas present natural or conserved environments. These areas might have lower risks of lead contamination compared to urbanized or industrial regions. However, soil testing and proactive management are essential, especially in proximity to historic structures. Modern construction at KSU aligns with contemporary standards, emphasizing environmental safety and sustainability. These buildings showcase how modern architecture integrates advancements in reducing exposure risks. The legacy of lead in the environment necessitates ongoing soil monitoring and management, especially on historic campuses like Kansas State University making it an ideal location for our study to take place.

Lead Contamination Literature Review

Chemistry

Lead (Pb) is a soft, malleable metal with a low melting point of 327.4 degrees C. Its atomic number is 82, and its atomic weight is 207.2 amu, the heaviest of all common metals. It is the stable product of uranium radioactive decay (Lovering, 1976). It is most common as Pb(II), forming insoluble ionic compounds. Conversely, Pb(IV) tends to form more soluble covalent compounds (Wuana & Okieimen, 2011).

In the natural world, lead is a major constituent in a large number of minerals. However, most of these minerals are rare with the exception of galena (PbS), anglesite ($PbSO_4$), and cerussite

($PbCO_3$). On average, Earth's crust contains only about 15 ppm of lead (Lovering, n.d.). The residence of lead in soils depends on many soil characteristics such as pH, amount of organic matter, and soil cations and anions (Zimdahl & Skogerboe, 1977). If the lead can be dissolved, it may leach through the profile. If the lead is largely insoluble, it may remain immobile. The three main factors in determining the immobilization of lead in soils are pH, cation-exchange capacity, and the amount of organic matter present.

<u>Importance</u>

Lead contamination in soil is a pressing environmental and public health issue due to its persistent nature and harmful impacts on human health. To address this concern, a project was conducted on the Kansas State University campus to measure lead levels in soil using portable X-ray fluorescence (XRF) technology and depth sampling methods. This investigation is essential as soil contamination contributes to broader environmental lead exposure through pathways such as ingestion, inhalation, and dermal contact (EPA 2020). The health implications are severe, particularly for children, as lead exposure can impair brain development, reduce IQ, and cause behavioral issues, while adults face risks of cardiovascular and renal diseases (CDC, 2024). Recognizing that no safe level of lead exists, the U.S. Environmental Protection Agency (EPA) recently lowered its residential soil screening guidelines from 400 ppm to 200 ppm to reflect updated understanding of lead toxicity (EPA, 2024). This study at Kansas State University aims to contribute to this body of knowledge by mapping lead contamination on campus and assessing potential remediation strategies.

<u>Sources</u>

Lead contamination in soil has long been exacerbated by human activity, with significant contributions from leaded gasoline, industrial processes, and lead-based paints (EPA, 2020). Lead-based paint was used widely around homes from 1804 until they were banned in 1977 (Davis & Burns, 1999). Many of these paints remain on buildings, particularly the exteriors. Aged paint deteriorates due to a failure in the binder with UV exposure, causing it to chip and flake. This leads to an accumulation of lead pigment around these buildings. Additionally, leaded gasoline was used in the USA from the 1920s to 1986 (Laidlaw & Filippelli, 2008). It contained tetraethyl and tetramethyl lead as an antiknocking additive and to raise the octane rating. On average, automobiles release about 70-80% of the lead combusted and up to 130 mg Pb/mile to the roadside environment (Smith, 1976). This lead deposits directly beside the roadway and decreases with distance away from the road along either side. In this zone, lead is concentrated on the upper surface of the soil horizon. Despite efforts to phase out these sources, their historical use has left persistent deposits that continue to pose risks, particularly around roadways, older buildings, and industrial sites. As a metal that does not naturally break down, lead remains in the environment for decades, highlighting the importance of assessing and addressing its presence in urban and residential soils (Shan, et al., 2023).

Dangers

Human lead exposure has two main pathways: inhalation and ingestion. Lead accumulates in the organs, causing serious complications to the brain, nervous system, red blood cells, and kidneys (Wuana & Okieimen, 2011). In the body, lead is utilized like calcium largely due to a similarity in ionic radii and charge (Laidlaw & Filippelli, 2008). This then can be deposited on a neuron, causing mental deficits, or within bone, where it can become a long-term source of lead to the bloodstream.

Ingestion of soil or dust is the greatest concern with lead-contaminated soils. Plants do not take up large quantities of soil lead, and garden produce is generally safe in soils with lead levels below around 300 ppm (Wuana & Okieimen, 2011). Soil dust ingested as dust on the produce or within proximity to the outdoors is the greater risk. Lead ingestion is especially predominant in children. In adults, only about 5% of lead ingested is taken up in the body. In children, up to 50% of ingested lead can be taken up in the body due to a less-developed gastrointestinal pathway (Laidlaw & Filippelli, 2008). Additionally, the increase in hand-to-mouth behaviors in children can lead to an increased ingestion of lead-contaminated dust.

The recognition of lead's toxicological effects, particularly its severe impact on children's health, has driven both regulatory action and scientific efforts to address contamination. The U.S. banned lead-based paint in 1978 and fully phased out leaded gasoline by 1996, marking significant strides in reducing new lead inputs to the environment (*Lead-Based*, 2024; *EPA Takes*, 1996). However, these measures do not address the widespread legacy contamination still present in soils. Accurately measuring soil lead levels is crucial for determining whether contamination poses a risk to public health and the environment. When contamination is identified, remediation becomes essential to mitigate the bioavailability of lead and its potential harm.

Remediation

Remediation strategies for lead-contaminated soils focus on reducing exposure and environmental mobility. These approaches fall into two categories: in situ and ex situ remediation. In situ methods, such as immobilization with materials like biochar, phosphate, or apatite, stabilize lead within the soil, reducing its bioavailability while leaving the soil in place (Netherway, et al., 2020). In this method, the metal is placed in a configuration of a salt or a mineral that is insoluble over a wide range of pH and oxidation states. This insolubility of the metal salts and minerals can be calculated by their pH and pE (Porter et al., 2004). The most common amendments include clay, cement, zeolites, phosphates, organic composts, and microbes (Wuana & Okieimen, 2011). For example, phosphates prove to be a promising remediation amendment. These form lead phosphates, or pyromorphites, with particularly low solubility (Hettiarachchi & Pierzynski, 2004). Ex situ methods, including techniques like acid leaching, involve removing contaminated soil for treatment or replacement with clean soil (Lin, et al, 2024). Both approaches aim to minimize lead's impact, but the choice of method depends on factors such as contamination severity, site conditions, and available resources. Understanding lead levels through precise measurement is a critical first step toward implementing effective remediation strategies.

Materials and Methods

Geospatial Analysis

Soil sampling, conducted across various locations on campus or within the study area, is a fundamental step in assessing the environmental impacts of lead contamination. This methodology is designed to examine how historical and environmental factors, such as the presence of legacy contamination from lead-based paint or proximity to high-traffic areas, influence soil lead concentrations. GPS coordinates were recorded at each sampling site to facilitate precise geospatial analysis. The careful mapping of lead concentrations is crucial for understanding their distribution across different campus areas.

Sample locations at each site were chosen methodically and carefully. Lead can be transported away from buildings by stormwater runoff but does not dissolve in the water due to a low solubility. It then gets deposited onto the soil, where it is generally adsorbed and made immobile (Davis & Burns, 1999). As such, when sampling around buildings, sample locations will be chosen where runoff accumulates, such as off of gutters and areas of lower elevation. Additionally, due to the contamination distance of lead off of roadways, samples taken by roadways will follow a perpendicular transect approximately 10 m away from the roadway.

Geospatial techniques such as kriging and spatial autocorrelation are employed to model and interpret lead concentration patterns, accounting for spatial dependencies in the data. Kriging, a form of spatial interpolation, allows for the estimation of lead concentrations at unsampled locations, which is especially valuable for creating continuous maps of contamination levels across large areas (Mielke et al., 1984; Masri et al., 2020). Spatial autocorrelation, specifically methods like Moran's I, helps identify clusters of high or low contamination, indicating areas of potential concern that warrant further investigation. These techniques are particularly effective when analyzing environmental contamination that does not follow a simple uniform distribution.

In addition to these advanced techniques, simpler methods like heat or choropleth maps are employed to provide clear visual representations of contamination hotspots created from XY datasets. These methods aggregate the spatial data and allow for rapid identification of areas with high concentrations of lead, facilitating decision-making about where remediation efforts should be focused. These techniques are common in environmental studies and public health assessments, where visual patterns in data can reveal critical insights about the distribution of pollutants (Caballero-Gómez et al., 2022).

The integration of geospatial analysis with historical data, such as the age of buildings and traffic density, is key to understanding the factors contributing to lead contamination. For example, older buildings may have higher concentrations of lead due to the use of lead-based paints, while areas with high foot traffic or proximity to industrial sites could show elevated lead levels due to human activity and urban runoff. Mapping soil lead concentrations allows for the identification of these "hotspots," or areas that require targeted remediation efforts. Additionally, geospatial analysis can reveal potential inequities, such as how certain parts of the campus may experience higher contamination due to socio-economic factors or historical land use, which can disproportionally affect vulnerable populations (Schwarz et al., 2012).

The analysis of spatial variability is essential for developing context-specific remediation strategies. Geospatial data helps identify not only where contamination is most severe but also the underlying factors that contribute to its distribution, providing a basis for selecting appropriate intervention methods. For example, areas with high contamination near historical buildings may require specialized remediation, such as lead paint removal or soil excavation, while open spaces with low contamination may benefit from less intensive strategies, such as soil amendments or monitoring (Wade et al., 2021). The use of ArcGIS and other spatial data analysis tools is critical for visualizing these complex data sets into actionable insights. These tools allow for the integration of multiple layers of information, from sampling locations to environmental variables, facilitating a more holistic understanding of soil contamination patterns. By transforming raw data into visual representations, geospatial analysis supports both public health assessments and environmental management efforts.

X-Ray Fluorescence

A Thermo Scientific Niton XL3t X-Ray Fluorescence (XRF) Analyzer was utilized to determine the lead concentrations in soil samples both in the field and laboratory settings. The XRF was calibrated using the NIST Standard Reference Material 2711a, ensuring precision and reproducibility of measurements (Shefsky & Corporation, n.d). The analytical procedure adhered to guidelines specified by Shefsky & Corporation, emphasizing the preparation of samples to be dried, mixed, and cleared of debris. Each sample was analyzed for a duration of 120 seconds to optimize sensitivity and minimize variability.

XRF Technology

XRF spectroscopy is a non-destructive analytical technique used to determine the elemental composition of materials. It operates on the principle of irradiating a sample with high-energy X-rays, which causes electrons in the inner atomic orbitals to be ejected. This ejection creates a vacancy, and electrons from higher energy levels transition to fill the gap. The energy difference released during these transitions is emitted as fluorescent X-rays, which are characteristic of specific elements in the sample (Peinado et al., 2010).

Functionality of the Niton XL3t Analyzer

The Thermo Scientific Niton XL3t is a handheld, portable XRF device engineered for rapid and precise field analysis of soil contamination. It utilizes a high-performance X-ray tube as the excitation source and a silicon drift detector (SDD) to capture the emitted fluorescent X-rays. The device employs advanced signal processing algorithms to resolve overlapping spectral peaks and deliver quantifiable results for lead (Pb) and other trace elements (*Niton*, 2024).

Sample Preparation and Measurement Protocol

Proper sample preparation is crucial for reliable XRF analysis. Soil samples were air-dried, finely crushed and mixed, and visually inspected to remove debris such as rocks or organic material. This ensured homogeneity, which could interfere with the accuracy of the XRF readings (Shefsky & Corporation, n.d). Once prepared, the samples were analyzed directly using the XRF analyzer, following the established protocol of 120-second readings to enhance the sensitivity for lead detection.

Calibration and Quality Assurance

Calibration of the XRF analyzer was performed using NIST 2711a, a certified reference material with known concentrations of lead. This calibration step accounted for instrumental drift and environmental factors, ensuring consistency in results across multiple samples and conditions.

<u>Location of Study</u>

Kansas State University's campus presents a diverse landscape ideal for assessing soil lead levels across various land uses, structures, and historical contexts. Our research focuses on four primary categories: agricultural areas, natural or conserved spaces, older buildings, and newer buildings.

Agricultural Areas

The North Farm serves as a representative agricultural site, encompassing facilities such as the vehicle garage, cornfields, and a compost facility. These locations offer a contrast between disturbed and cultivated land, providing insights into how agricultural practices may influence soil lead concentrations. Agricultural soils can accumulate lead through the use of lead-containing pesticides, previous use of leaded gasoline, and atmospheric deposition from industrial activities (Hamel, et al., 2010).

Natural Areas

Areas like the quad, Anderson Lawn, the Department of Horticulture and Natural Resources' open space south of the Pittman Building, and Campus Creek represent natural or conserved environments. These sites are valuable for understanding baseline lead levels in minimally altered soils within the region. Natural areas typically exhibit lower lead concentrations; however, proximity to urban infrastructure can result in contamination from atmospheric deposition and runoff (*Protect*, 2024).

Old Buildings

The campus's historic structures, including Anderson Hall (built in 1879), Seaton Hall (1909), Waters Hall (1913), and the Gardens Visitors Center - converted from the old dairy barn (1933), were constructed prior to modern lead regulations implemented in the 1970s. These buildings may have utilized lead-based paints and other materials such as downspouts, potentially contributing to elevated soil lead levels in their vicinity. Lead-based paint was commonly used in structures built before 1978, and deteriorating paint can contaminate surrounding soils (*Protect*, 2024).

New Buildings

Structures such as the Business Building (2016), Leadership Studies Building (2009), and Engineering Hall (2015) exemplify post-regulation development. We anticipate that soil lead levels around these buildings will be close to baseline levels, reflecting modern construction practices that comply with stringent lead regulations. Contemporary building codes and materials have significantly reduced the use of lead, minimizing the risk of soil contamination (*Protect*, 2024).

This combination of historical, natural, and constructed environments on campus provides a comprehensive setting for studying the varied impacts of lead on soil across different land-use contexts. By analyzing these diverse sites, we aim to identify patterns of lead distribution and potential sources of contamination, informing effective remediation strategies and contributing to a safer campus environment.

Results/Analysis

Lead Distribution in Selected Areas

Our soil sample collection and laboratory analysis revealed several important findings regarding lead concentrations across the Kansas State University campus. These results highlight variations in lead levels based on land use categories, depths, and specific site characteristics.

Natural Areas

The natural areas demonstrated a mean lead level of 33.32 ± 2.82 ppm, slightly higher than anticipated. Notably, Campus Creek presented a unique case, with lead levels increasing with depth, 35.15 ppm at 5 cm, 55.36 ppm at 10 cm, and 72.07 ppm at 15 cm. This pattern is unexpected given that lead typically binds strongly to topsoil and does not leach easily. The cause of this anomaly requires further investigation to understand potential historical or environmental factors influencing these deeper accumulations. Similarly, Anderson Lawn displayed slightly elevated lead levels, with an average concentration of 39 ppm, which is above the expectations for natural spaces in this region. Conversely, the open space south of the Pittman Building, classified as NA1, measured 27.02 ppm, aligning more closely with baseline levels. Across all natural area samples, the standard deviation was 7.46, and the standard error was 2.82, indicating some variability but generally consistent results.

Old Buildings

Lead levels near older buildings were predictably higher than those in natural areas, reflecting legacy contamination. The old dairy barn exhibited a mean lead concentration of 62.31 ppm, while Seaton Hall averaged 75.89 ppm, likely influenced by agricultural machinery maintenance that regularly occurs near the testing site (Smith, 1976). Waters Hall also showed slightly elevated levels, with a mean of 75.29 ppm, though a single peeling window at the site was found to contain 83,000 ppm of lead, warranting immediate remediation. The most striking result came from Anderson Hall, where soil lead averaged 367.30 ppm. Upon inspection, peeling paint from the building's gutters, likely containing lead due to the building's age, was identified as a probable source. This site stands out as a priority for remediation efforts and preventative measures to curb further contamination. Overall, the old building category had a mean lead concentration of 183.70 ppm, with a standard deviation of 248.14 and a standard error of 68.82, reflecting significant variability between sites.

New Buildings

Surprisingly, soil near newer buildings exhibited lower lead levels than natural areas, likely due to construction practices involving the addition of clean soil, which may have diluted existing or baseline contamination. The Engineering Hall averaged 19.58 ppm, the Leadership Building averaged 21.55 ppm, and the Business Building measured 20.5 ppm. Collectively, the new building category had an average lead concentration of 20.55 ppm, a standard deviation of 4.27, and a standard error of 1.51, demonstrating consistent and relatively low contamination levels.

Agricultural Areas

Lead levels in agricultural areas generally met or slightly exceeded baseline expectations. The compost site (Farm 1) averaged 22.39 ppm, the cornfields (Farm 2) measured 23.25 ppm, and the vehicle garage showed a slightly elevated average of 30.86 ppm, likely influenced by machinery and gasoline use. The overall agricultural category yielded a mean of 25.5 ppm, a standard deviation of 11.65, and a standard error of 3.88, suggesting moderate variability across the sampled sites.

<u>Statistical Analysis</u>

All analyses were conducted using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA, 2016). Comparisons of site categories and individual locations were performed using ANOVA ($p < 0.05$) and post-hoc comparisons of means for total Pb. When the fixed effect F-value was statistically significant, relevant post-hoc tests of least square means (LSM) for categorical effects were evaluated. Additionally, Dunnett’s test was used to compare natural sites as a control to assess variations in Pb distribution with regrad to control.

Figure 1, below, shows the lead distribution at the surface level, 0-5cm, for all selected area types. This shows that all categories except for the old buildings were generally around background values with no major outliers. Old buildings had much greater values and were much more varied.

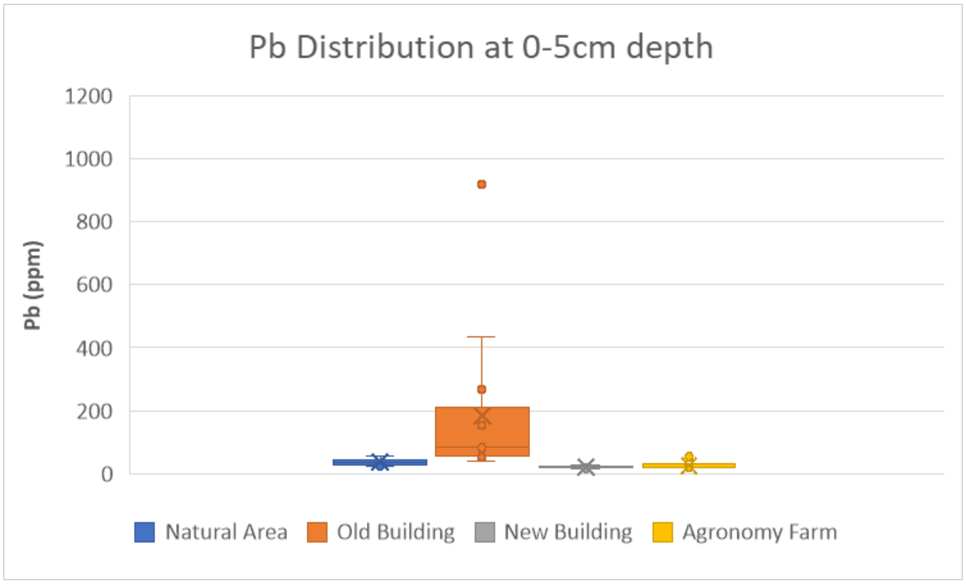

Figure 1. Distribution of Lead at 0-5cm depth

Figure 2, below, shows the lead distribution at the 5-10cm depth, for all selected area types. While the same trend from Figure 1 is noticeable, the Old Building category is smaller and less varied.

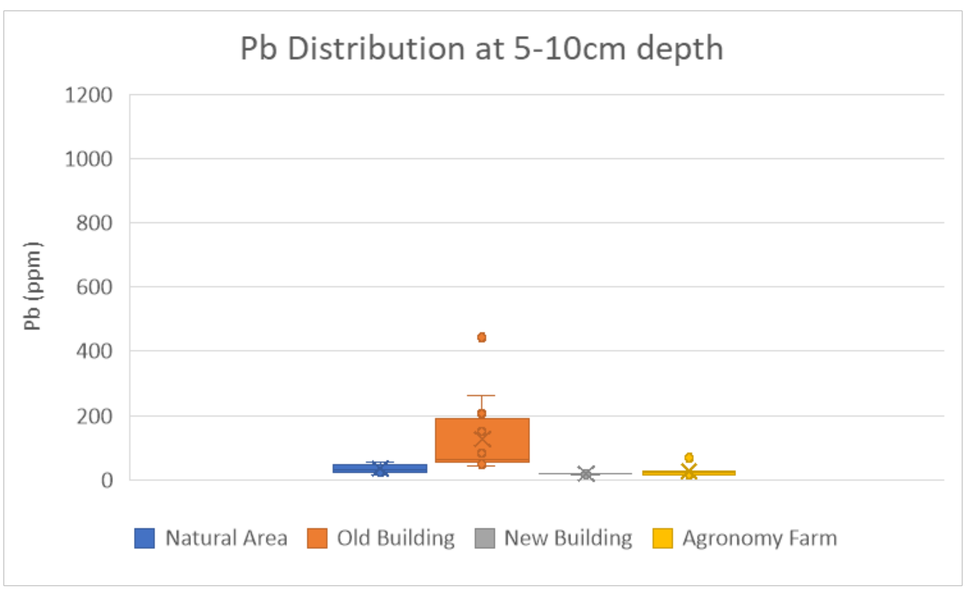

Figure 2. Distribution of Lead at 5-10cm depth

Figure 3, below, shows the lead distribution at the 10-15cm depth, for all selected area types. Here, the Old Building category is the closest to the other categories. This decrease in lead concentration over depth is characteristic of lead contamination due to the lead's insolubility in water (Zimdahl & Skogerboe, 1977).

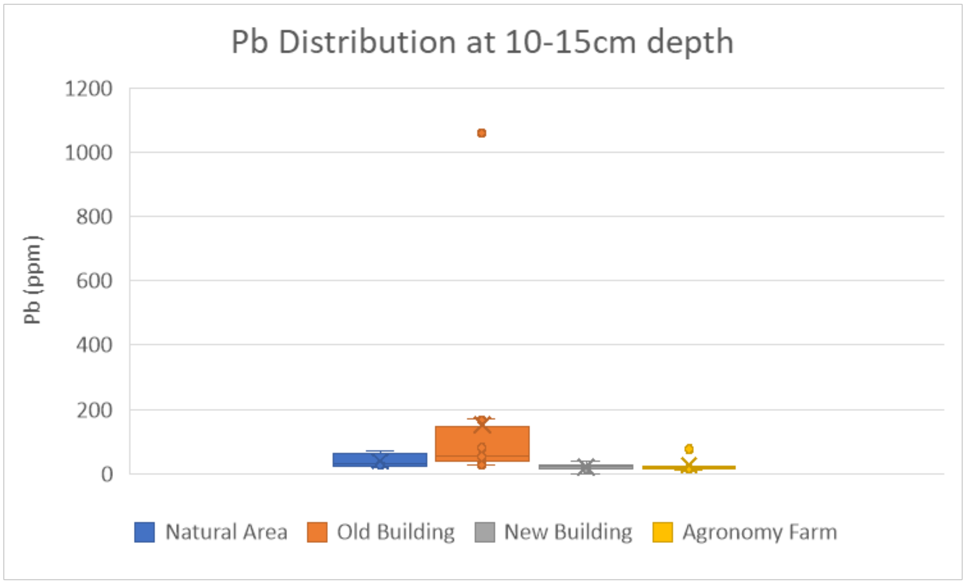

Figure 3. Distribution of Lead at 10-15cm depth

Shown in Figure 4, below, is a heat map created through ArcGIS Pro, produced from an XY dataset created through excel. This figure shows the lead distribution across all sampled points at the Kansas State University campus. Some areas have clusters of points, while others do not because the sample points are close enough to share the same coordinates. The figure highlights the lead contamination, with samples measuring close to 1000 ppm, around Anderson Hall.

Similarly, Figure 5 shows another map created through an XY data set on ArcGIS Pro. Each data point was then converted into a heat map, classified by lead concentration. Our input data was the mean lead levels for each site, at the surface (0-5cm depth), combined into one data point. The North Agronomy Farm had very low lead levels at each sampling site, except for moderate levels towards the buildings and gas pumps, showing shades of red.

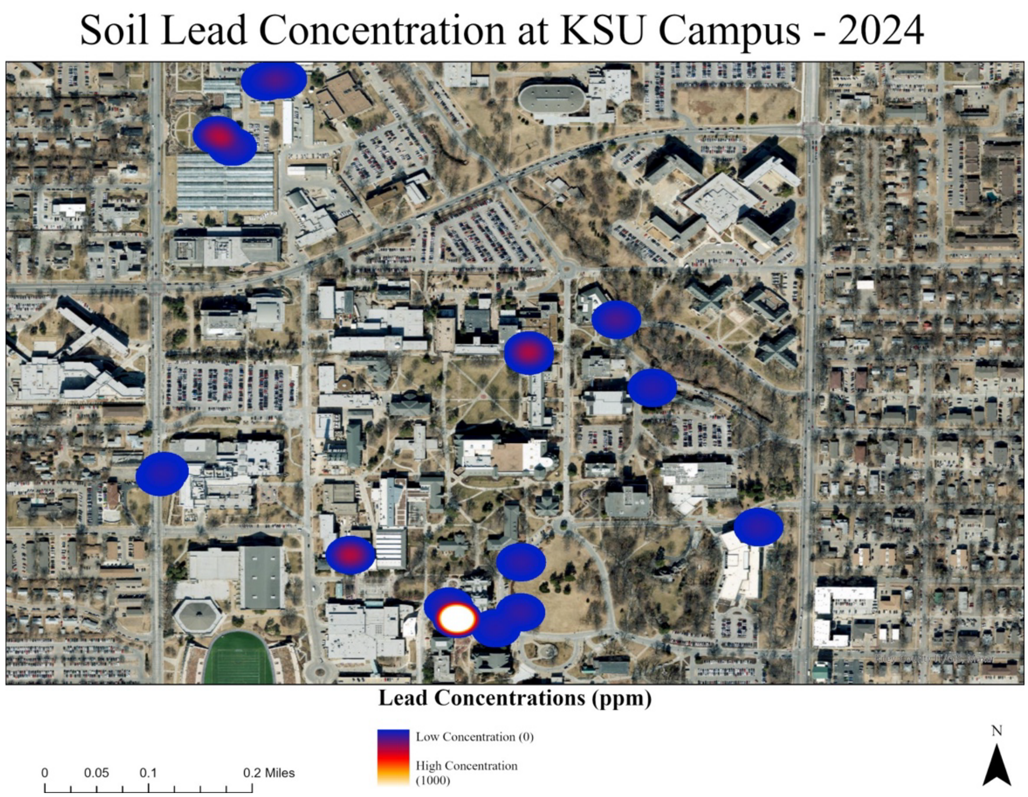

Figure 4. Heat Map of Soil Lead Distribution on Campus

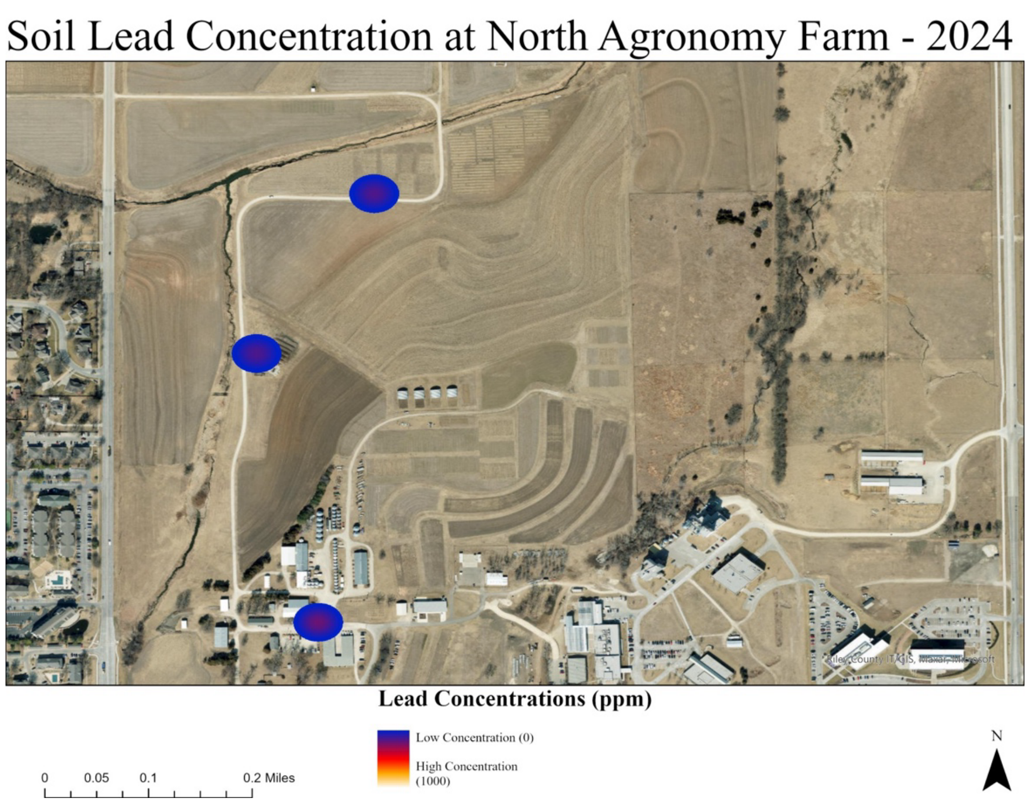

Figure 5. Heat Map of Soil Lead Distribution at the North Agronomy Farm

Discussion

This study examined soil lead contamination across KSU to identify spatial patterns, assess potential sources of contamination, and inform remediation strategies. Using XRF spectroscopy, lead levels were analyzed at various depths and across different land use categories, including natural areas, old and new buildings, and agricultural sites. The findings revealed distinct contamination patterns likely influenced by historical, environmental, and structural factors. Our lead level categories can be found in Table 1 along with proper protections suggested by the EPA and CDC to take for the respective lead level (Lead in Soil, 2020; CDC, 2024).

In natural areas, lead concentrations averaged 33.32 ppm, slightly exceeding expected baseline levels. Campus Creek acted as an outlier and showed an unusual pattern of increasing lead concentrations with depth, rising from 35.15 ppm at 5 cm to 72.07 ppm at 15 cm. This anomaly, contrary to the typical behavior of lead binding strongly to topsoil, suggests the need for further investigation into historical or environmental influences. Anderson Lawn also exhibited slightly elevated lead levels at 39 ppm, while other natural spaces, such as the area south of the Pittman Building, aligned more closely with baseline levels but just exceeding the natural categorization, averaging 27.02 ppm.

Lead concentrations near older buildings were significantly higher, reflecting legacy contamination from materials like lead-based paint (EPA, 2020). Anderson Hall stood out with an average soil lead level of 367.30 ppm, primarily attributed to peeling paint on the building's gutters. Seaton Hall and Waters Hall showed moderately elevated levels, with means of 75.89 ppm and 75.29 ppm, respectively. In Waters Hall, a peeling window was found to contain an alarming 83,000 ppm of lead, highlighting the urgency for remediation. The Old Dairy Barn averaged 62.31 ppm, likely influenced by past agricultural activity. Overall, older buildings exhibited a mean lead concentration at a level we consider contaminated and in need of remediation of 183.70 ppm, with considerable variability between sites.

Conversely, newer buildings showed lead levels categorized as natural, with levels averaging 20.55 ppm across all sites. The Engineering Hall, Leadership Building, and Business Building recorded averages of 19.58 ppm, 21.55 ppm, and 20.5 ppm, respectively. These low levels likely result from clean soil introduced during construction, which diluted any existing contamination and reflect the success of modern building practices in minimizing lead risks.

Agricultural areas displayed just over natural lead levels, with an overall mean of 25.5 ppm. The compost site and cornfields showed typical values of 22.39 ppm and 23.25 ppm, while the vehicle garage had a slightly elevated average of 30.86 ppm, potentially influenced by machinery use and gasoline residue. Statistical analyses, including ANOVA and post-hoc comparisons, revealed significant differences in lead concentrations across site categories, with old buildings demonstrating the highest variability. Natural areas served as the baseline for comparison, emphasizing notable variations in lead levels across different campus contexts.

Table 1. Risk Associated with Lead Levels in Soil to Adults, Children, and Pets and Protections to Minimize Lead Exposure

Lead Level (ppm)	Categorization	Proper Protections	
0-25	Natural	Adult	・N/A
		Child	・N/A
		Pet	・N/A
25-50	Slightly Elevated	Adult	・Wash hands thoroughly after contact with soil, especially before eating or touching the face ・Wear gloves if gardening or digging to minimize direct skin contact and prevent transfer to clothes ・Remove shoes before entering the home to reduce soil tracking indoors
		Child	・Ensure children wash hands frequently, particularly after playing outside and before eating ・If possible, avoid allowing young children to play directly in bare soil, as they may accidentally ingest it. Consider designating a safe play area with clean sand or mulch ・Clean toys used outside regularly to reduce soil transfer into the home
		Pet	・Wipe pets' paws before they come indoors to prevent tracking soil ・Discourage pets from digging or spending extended time in areas with exposed soil to reduce ingestion risk
50-100	Elevated	Adult	・Wash hands thoroughly after any contact with soil, particularly before eating or drinking ・Wear gloves while gardening or working in soil to prevent skin contact and avoid transfer to clothing ・Use dedicated shoes and clothing for outdoor work, remove them before entering the home, and launder separately
		Child	・Ensure children wash hands frequently, especially after outdoor play and before meals ・Supervise children closely to prevent direct play in bare soil. Consider covering play areas with clean sand, mulch, or turf to reduce soil exposure ・Clean toys and outdoor play items regularly to reduce soil residue, and discourage placing them in the mouth
		Pet	・Wipe pets' paws and fur before they enter the home to prevent tracking soil indoors ・Discourage pets from digging or spending extended periods in areas with exposed soil to reduce ingestion risk ・If possible, provide a safe, clean area for pets to play, minimizing their direct contact with bare soil
>100	Contaminated	Adult	・Wash hands meticulously after any soil contact and before eating, drinking, or smoking ・Wear gloves, long sleeves, and long pants to prevent soil contact with skin. Consider using coveralls or dedicated outdoor work clothing that is removed before entering the home ・Use separate shoes for outdoor activities in contaminated areas, leave them outside, and launder soil-exposed clothing separately from other household laundry
		Child	・Prevent children from playing directly in contaminated soil. Designate specific, clean play areas with barriers like mulch or clean sand to limit exposure to bare soil ・Encourage children to wash hands thoroughly after playing outdoors, especially before eating or drinking ・Clean toys, equipment, and outdoor items regularly to reduce soil residues, and discourage placing objects in their mouths
		Pet	・Wipe pets' paws and fur thoroughly when they come indoors to reduce soil transfer to indoor areas ・Limit pets' access to bare soil in contaminated areas and discourage digging, as this can increase ingestion of contaminated soil particles ・Provide a clean, controlled area for pets to play, ideally covered or with artificial turf to minimize soil exposure

Recommendations

The findings underscore the need for immediate action in high-risk areas such as Anderson Hall. To address soil lead elevation and contamination across KSU's campus, a combination of targeted interventions and long-term management strategies is recommended. These strategies are designed to align with the soil characteristics of the region, the size of contaminated areas, and cost-effective practices to ensure both environmental safety and sustainability.

Anderson Hall

Anderson Hall exhibits the highest levels of lead contamination on campus, necessitating immediate attention. The peeling lead paint should be addressed following EPA protocols. Given that Anderson Hall is an outdoor space, covering the peeling paint with an appropriate encapsulant is the preferred method, as it minimizes the risk of releasing hazardous dust or particles during remediation (*Lead-Safe*, 2024). In addition, an in-situ amendment approach combining biochar and apatite is recommended to stabilize the lead in the soil and reduce its bioavailability (Ma, et al., 1993; Yang, et al., 2016). Enhancing the area with native vegetation will provide the benefit of physical stabilization in the soil from the plant roots will, preventing runoff. It is also essential to replace the existing mulch, which is currently inadequate in preventing erosion during the wet seasons or dust during the dry seasons and does not provide sufficient protection as a safety barrier.

Waters Hall

Waters Hall requires similar remedial actions. Covering any remaining lead paint in accordance with EPA guidelines will reduce the risk of further contamination (*Lead-Safe*, 2024). The use of the in-situ soil stabilization with biochar and amendments is also recommended (Ma, et al., 1993; Yang, et al., 2016). Following remediation, replacing the sod in the area will restore the landscape and provide a stabilized surface.

Campus Creek

Campus Creek presents unique challenges, as lead concentrations increase with soil depth. Further investigation is needed to identify the underlying causes and the depth at which lead levels begin to diminish. Once this is determined, the area should be treated using the same in-situ technique as other contaminated sites. Stabilizing the creek bank with native vegetation that is floodplain-appropriate will mitigate the risk of lead-contaminated soil washing downstream during heavy rains or flooding events. This approach will also enhance the ecological health and resilience of the creek area.

Other Old Buildings and Areas with Slight Elevation

For areas exhibiting elevated and slightly elevated lead levels without obvious current sources, a simpler, cost-effective approach is recommended. Applying a layer of topsoil to dilute the elevated lead levels through mixing will effectively reduce the overall concentration. Afterward, these areas should be re-sodded or mulched as necessary to ensure a stable and safe surface.

Long-Term Strategies

To maintain safe lead levels across the campus, regular monitoring should be implemented as part of an ongoing environmental management plan. This will ensure that lead concentrations remain below harmful thresholds and help identify any emerging issues early. In-situ stabilization methods using soil amendments, combined with maintaining appropriate vegetation, will provide a sustainable approach to managing contamination over time.

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