

High soil lead (Pb) concentrations resurfacing in Red Hook, Brooklyn

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Background

Exposure to lead (Pb) through the ingestion of contaminated soil can reduce the intellectual function of children. However, Pb is a toxic metal which can also harm the health of people of all ages in different ways. The US Environmental Protection Agency (EPA) developed soil screening objectives to reduce human exposure to lead (Pb), expressing concentrations in terms of mass units of parts per million (ppm). The primary EPA Pb standard defines 400 ppm and above as a soil lead hazard for bare soils in child play areas on residential properties and facilities occupied by children. In non-play areas, the EPA Pb standard for bare soil is 1200 ppm.

Sampling and analysis of Pb in soil

Sampling and analysis of soil Pb concentrations in Red Hook was conducted in March and April 2021 by students and faculty in the Columbia University School of Professional Studies Masters of Sustainability Science program and the Environmental Measurements class at Barnard College. Red Hook was selected because of legacy Pb contamination from historical sources such as the [Columbia Smelting and Refining Works](#) which operated in the area.¹ Sampling focused on Red Hook Park, the Red Hook East Houses, and the vicinity of these locations (**Figure 1**).

Since smaller, finer soil particle sizes are the ones most likely to stick to hands or objects and then be ingested, most surface soil samples and all core samples were dried and sieved to analyze grains <1 mm in size (or fine fraction) in the laboratory. Surface soil samples were collected from the top 1 inch of soil and soil cores with an average overall depth of 48 cm (~19 inches) were also collected in these areas. Total Pb concentrations for both surface

samples and soil cores were measured using a portable X-ray fluorescence (XRF) analyzer, an [EPA-approved method](#) for measuring Pb concentrations in soil.² A subset of surface soil was analyzed directly in the field with the XRF analyzer, and represents the Pb concentration for all of the different particle sizes together (or whole fraction). Whole fraction sampling centered on locations where high Pb concentrations had already been determined from earlier fieldwork. For this summary, we focus on the soil samples which were sieved.

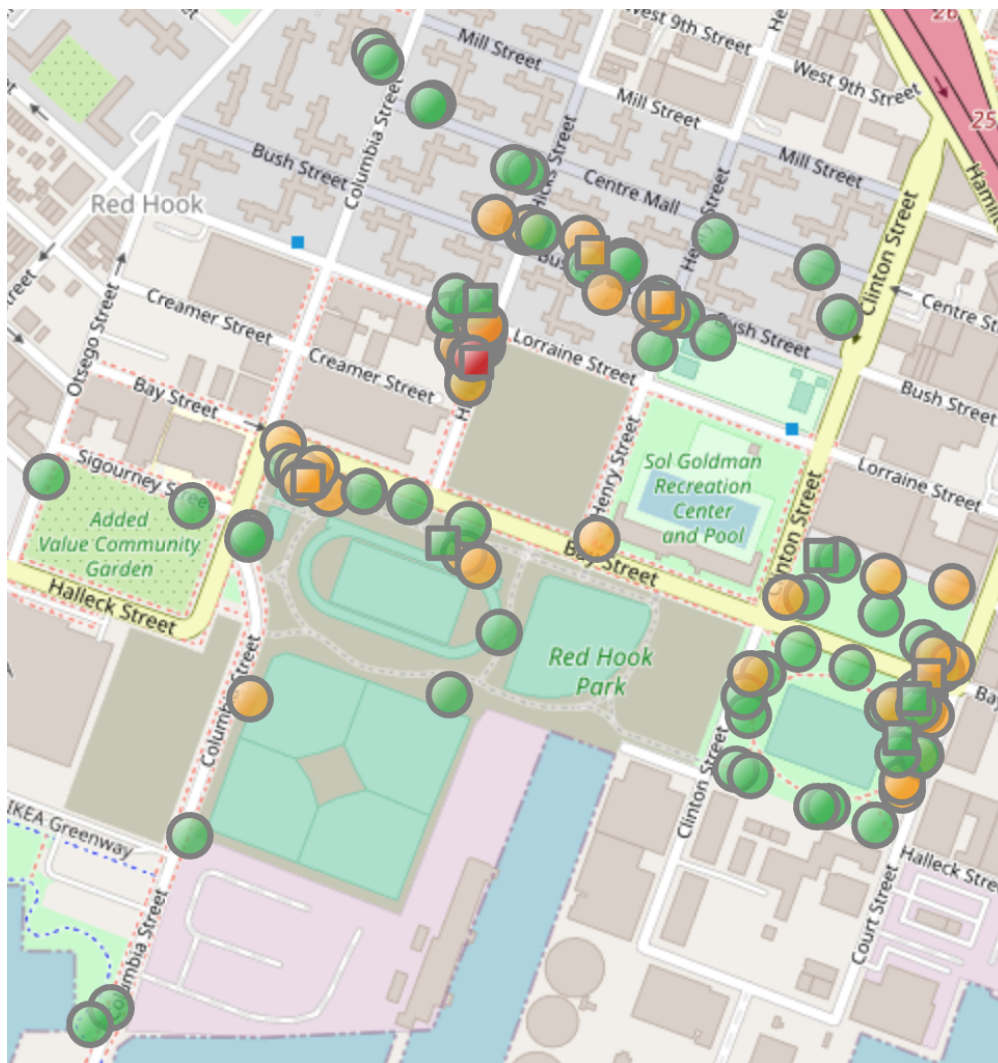


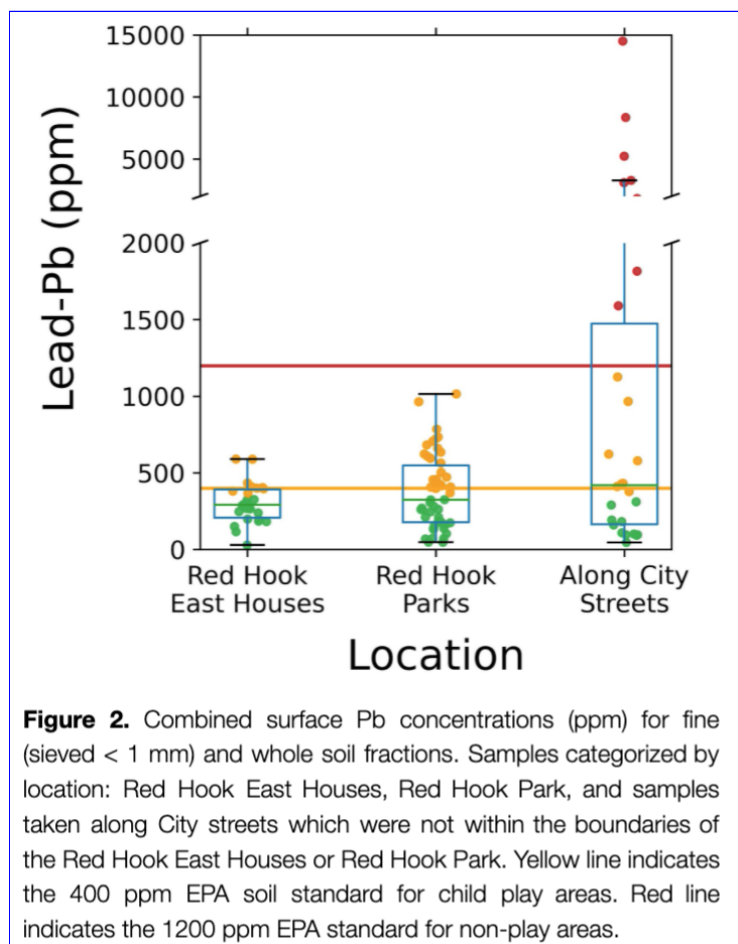
Figure 1. Map view of Red Hook, Brooklyn with all surface and core soil sampling sites. Circles represent surface soil Pb concentrations and squares represent the average soil Pb concentration for the entire core length. Green color indicates Pb concentrations less than 400 ppm, yellow indicates Pb concentrations over 400 ppm but less than 1200 ppm, and red indicates Pb concentrations over 1200 ppm. Interactive map is accessible online at the following URL: <https://bmaillou.github.io/RedHookLead/>

Results: Surface Pb concentrations

We categorized surface Pb soil concentrations into three different areas within Red Hook (**Figure 2**) and calculated the average (or mean) concentration, standard deviation (or the spread of the individual concentrations relative to the mean), median (or the middle value separating the lower half of the data from the higher half), maximum concentration, and minimum concentration for each of these areas. Summary statistics are listed in **Table 1**.

For the **Red Hook East Houses**, the average Pb surface soil concentration was 410 ± 120 ppm, which exceeds the EPA standard of 400 ppm for bare soil in areas where children

play. The variability in surface soil Pb concentrations for the housing complex and other areas is also considerable, and ranges from 270 to 590 ppm in the Red Hook East Houses. Average concentrations can give an indication of the potential Pb exposure, but within each area the need for remediation can vary.



For **Red Hook Park**, a complex of ball fields and recreational areas, the average surface Pb soil concentration was 420 ± 270 ppm, which also exceeds the EPA standard. One sample near the handball courts on Bay and Columbia streets had a concentration of 1000 ppm. This area of the park was open in March 2021 during sampling but is currently fenced off.

Samples outside of Red Hook Park and the Red Hook East Houses were mainly tree pits or small grassy areas alongside city streets. Most of these samples had surface Pb concentrations below the EPA standard for child play areas. However, we identified a Pb “hotspot” in a sidewalk border area on the corner of Hicks and Lorraine streets, just outside of the Red Hook East Houses and across from the historical site of the Columbia Smelting and Refining Works. The surface Pb concentration in

that location was 15,000 ppm, which is over 36 times the EPA standard for child play areas and 12 times the EPA standard for non-play areas.

Table 1. Average surface Pb concentrations in ppm as well as standard deviation, median, maximum and minimum concentrations for fine (sieved < 1 mm), whole (direct measurement of soil in the field), and total (combined fine and whole) soil samples for different areas of Red Hook, Brooklyn. The number of samples is indicated by “n.” **a.** Samples collected from Red Hook East Houses. **b.** Samples from within Red Hook Park. **c.** Samples taken along streets that are not within the boundaries of the Red Hook East Houses. **d.** All samples from all locations.

a. Houses					
<i>Fine</i>					
n	average	std dev	median	max	min
8	410	120	380	590	270
<i>Whole</i>					
n	average	std dev	median	max	min
18	250	100	260	410	30
<i>Total</i>					
n	average	std dev	median		
26	300	130	290		
b. Park					
<i>Fine</i>					
n	average	std dev	median	max	min
25	420	270	410	1000	50
<i>Whole</i>					
n	average	std dev	median	max	min
25	340	210	280	790	50
<i>Total</i>					
n	average	std dev	median		
50	380	240	330		
c. Street					
<i>Fine</i>					
n	average	std dev	median	max	min
7	2300	5400	290	15000	100
<i>Whole</i>					
n	average	std dev	median	max	min
19	1500	2200	579	8400	50
<i>Total</i>					
n	average	std dev	median		
26	1700	3200	420		
d. All					
<i>Fine</i>					
n	average	std dev	median	max	min
41	740	2200	370	15000	50
<i>Whole</i>					
n	average	std dev	median	max	min
62	670	1300	292	8400	30
<i>Total</i>					
n	average	std dev	median		
103	700	1700	324		

Results: Depth profiles of soil Pb concentrations

Depth profiles of soil Pb concentrations provide a better understanding of the potential exposure risks for an area than surface soil samples alone and can help determine what kind of remediation efforts are needed in the different locations where the cores were taken from.

Soil core analysis for **Red Hook Park** and the **Red Hook East Houses** indicates that Pb concentrations increased substantially with depth (**Table 2**). For Red Hook Park, the average Pb concentration at 2.5 cm was 350 ± 280 ppm, which is slightly lower than the 400 ppm EPA standard for child play areas. At 32.5 cm, the average Pb concentration in the park increased to 800 ± 1200 ppm and average Pb concentrations for the remainder of the core intervals were above the 400 ppm or the 1,200 ppm EPA standards.

For the Red Hook East Houses, the average Pb concentration at 2.5 cm was 600 ± 450 ppm, exceeding the EPA standard for child play areas. At 32.5 cm, average Pb concentrations in cores from the housing complex increased to $2,300 \text{ ppm} \pm 670$ ppm, almost double the

1,200 ppm EPA standard. Average Pb concentrations decreased after this peak, but also remained above EPA standards for play and non-play areas.

A hotspot was identified at Hicks and Lorraine streets, corroborating surface sampling. The soil Pb concentration at 2.5 cm was 12,000 ppm, but unlike the depth profiles from Red Hook Park and the Red Hook East Houses, the Pb concentration declined sharply to 1,200 ppm at 12.5 cm and further still to 100 ppm at 22.5 cm. At 27.5 cm, the final depth obtained for this core, the Pb concentration again increased to 1,200 ppm. The core results from this street area validate a previous very high surface Pb concentration measurement. We recommend further testing and analysis here.

Table 2. Average soil Pb concentrations and standard deviation in ppm for 5 cm core depth intervals. Averages are given for 3 cores from the Red Hook East Houses (Houses), 6 cores from Red Hook Park (Park), the combined Pb average for the park and houses (Combined), and one “hotspot” location along the street (Hotspot). Yellow highlights denote depths with Pb concentrations above 400 ppm and below 1200 ppm. Red denotes depths with Pb concentrations 1200 ppm or above.

Core Depth (cm)	Houses		Park		Combined		Hotspot
	average	std dev	average	std dev	average	std dev	average
2.5	600	450	350	280	440	340	12000
7.5	360	250	420	200	400	200	7600
12.5	450	140	350	330	380	280	1200
17.5	470	210	410	340	430	290	120
22.5	610	470	390	440	470	430	100
27.5	980	700	280	330	580	600	1200
32.5	2300	670	800	1200	1300	1300	-
37.5	1500	510	870	710	1100	690	-
42.5	1700	830	520	55	1000	790	-
47.5	1200	880	690	690	920	690	-
52.5	820	390	1400	-	1000	440	-
57.5	-	-	1700	-	1700	-	-

Plotting all of the soil cores together demonstrates that although there may be variability throughout each individual core, the general trend discussed earlier—soil Pb concentrations increase with depth—can still be observed (**Figure 3**). There appears to be a consistent increase in soil Pb concentrations in the middle of the cores, starting around 25-35 cm (approximately 8-14 inches). This increase likely reflects legacy Pb contamination from historical sources such as the smelter, which in most areas has been diluted by the addition of cleaner soil at the top.

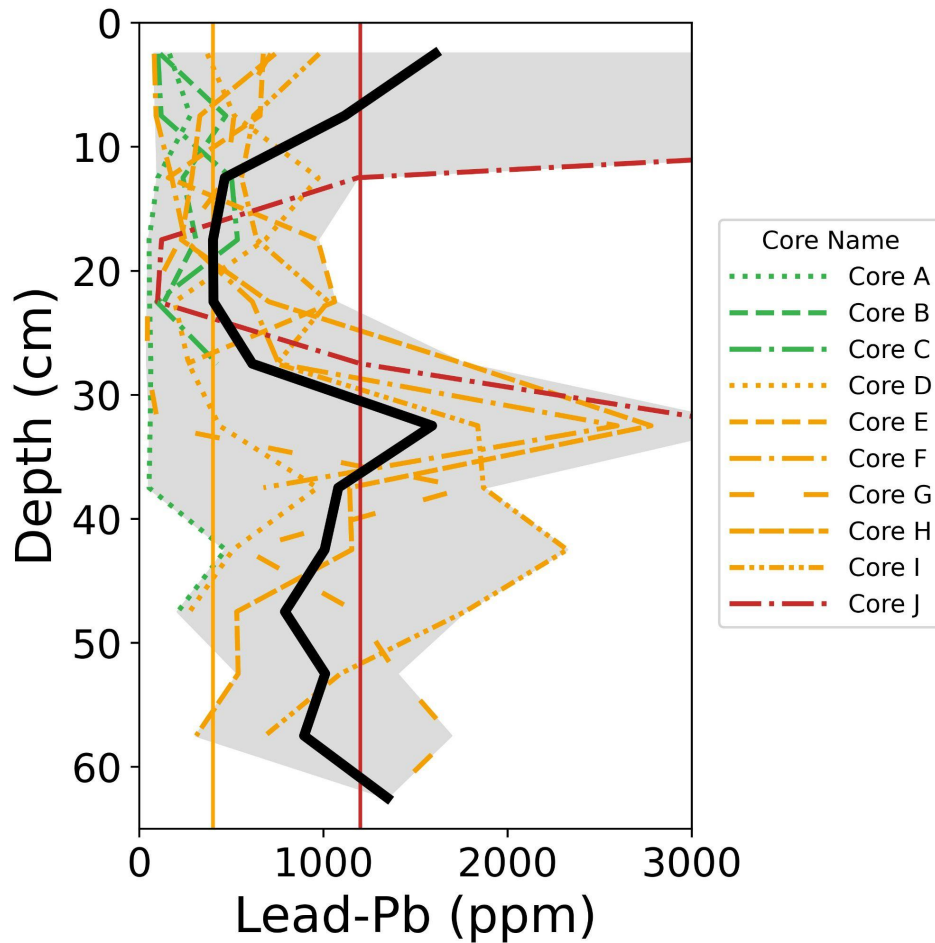


Figure 3. The Pb concentration depth profile in ppm for soil cores in Red Hook. The black line represents the median Lead-Pb concentration of all the cores obtained in Red Hook. The yellow vertical line represents the EPA 400 ppm soil Pb standard for child play areas, and the red vertical line represents the EPA 1200 ppm soil Pb standard for child play areas.

In Red Hook, our biggest concern for Pb exposure relates to construction currently underway in the Red Hook East Houses. During the ongoing [Sandy Recovery and Resiliency Project](#), a large quantity of soil was dug up during construction and there are now large mounds of soil surrounding many of the residential buildings.³ Average surface Pb concentrations for the Red Hook East Houses already exceed the EPA standards for child play areas on residential properties. The ongoing construction has removed soil that is deeper than the soil cores analyzed in this research and some of it is likely to considerably exceed the EPA standard of 400 ppm. We expect that if the soil in the mounds is the old soil with Pb contamination from historical sources, and it is used to fill in the areas currently under construction, future surface soil Pb concentrations could potentially be even higher than they currently are in the housing complex. We recommend ongoing monitoring and discussions with appropriate NYC authorities about the origin and future of these soil mounds in Red Hook. We

also recommend a high-resolution surface Pb concentration survey by handheld XRF in the Red Hook East Houses once construction is completed and the results from this existing research have been reported to the community.

References

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3. NYCHA Superstorm Sandy Recovery Program (2019). *Red Hook Kick Off Final Phase [PowerPoint slides]*. Department of Recovery and Resilience, New York City Housing Authority. www1.nyc.gov/assets/nycha/downloads/pdf/2019_11_21_Red_Hook_Kickoff_Final_Phase.pdf