Soil screening by high-school students to map lead contamination from mining in Peru

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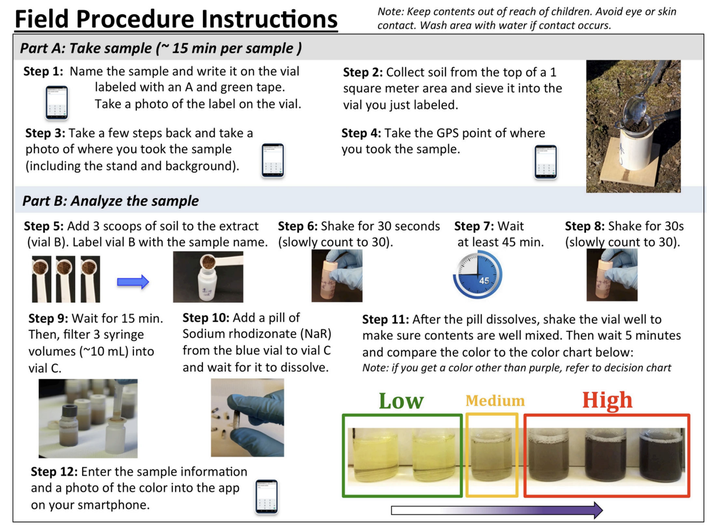
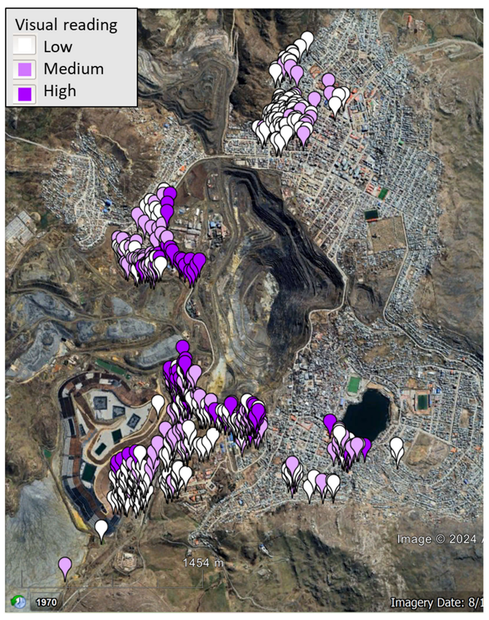
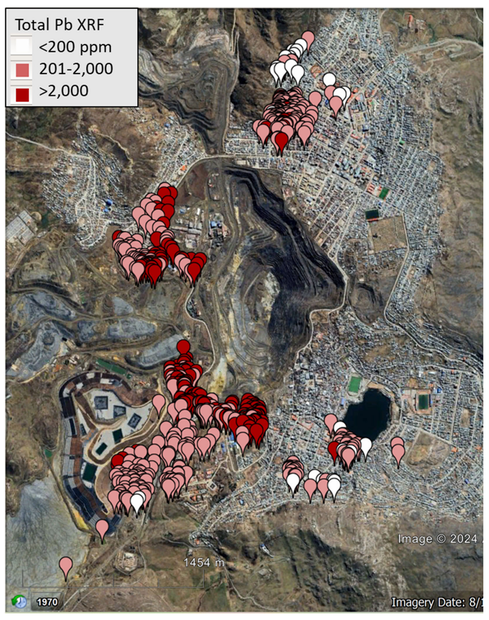
Motivation: Lead (Pb) contamination in soil is typically very heterogeneous, especially when the source is from industrial activities such as mining or battery recycling. This means that high-resolution mapping of soil Pb is required to identify areas where to prioritize actions to reduce child exposure. We have developed a field kit based on an EPA method to assess bioaccessible Pb in soil that is more realistic to use for high-resolution mapping than X-ray fluorescence, especially in developing countries. The kit is simple to use, not toxic, sensitive and specific enough for mapping, and could cost as little as $0.10/test to produce. An earlier version of the kit has been deployed in 2018-23 by 2,400 students from 15 high-schools across Peru under a USAID PEER program.



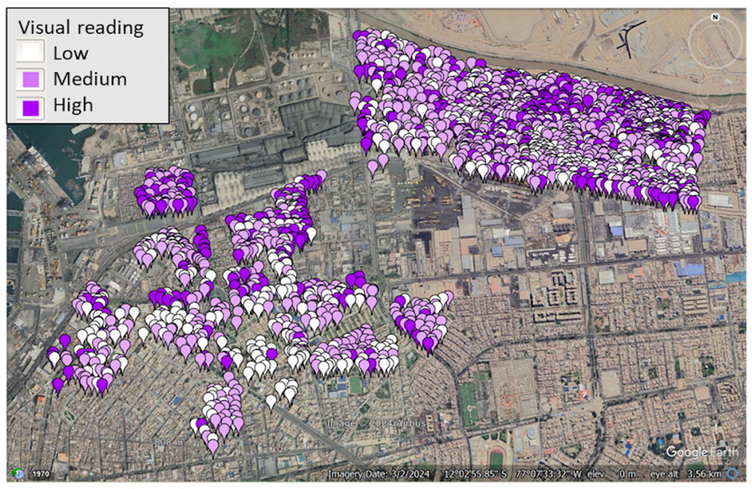




Figures 1-2 (above). CREEH staff helped high-school science teachers prepare a module spanning several sessions to explain the origin and potential consequences of Pb contamination in the local setting. The soil kit was presented and a sampling plan was devised with the class. Groups of students provided with a smartphone and sample vials then fanned out around their school to collect soil, record GPS coordinates, and photograph each site. At the next session in class, each student scooped 1.5 g of sieved soil into 15 mL of a 0.5 M glycine solution at pH 1.5 to release extractable Pb from the soil. After filtering the extract, a soluble capsule containing 10 mg of sodium rhodizonate was added and the intensity of a purple color indicative of Pb was recorded. A photograph of the vial and a pH strip dipped into the solution was recorded with a smartphone. Kit results were mapped and interpreted in a final class session.

Figures 5-6 (below). Residential areas surrounding the port of Callao north of Lima is another area that was tested with the soil kit by students from 5 local high schools. The tests show a proportion of high and medium readings similar to Cerro de Pasco but the XRF data indicate lower total Pb concentrations owith the exception of an area south of the port. The implication is that while total Pb concentration are not as high in Callao, the proportion of total Pb that is extractable is considerably higher than in Cerro de Pasco. One possible explanation is that processing of the ore before transport from Cerro de Pasco

Figures 3-4 (above). Kit results for the mining town of Cerro de Pasco shown in this map were generated over time by students from 7 schools surrounding a large open pit. The kit data show areas closest to the mine are most contaminated while other areas further away are much less so. CREEH staff reanalyzed the soil samples for total Pb by X-ray fluorescence and produced a map showing similar patterns.



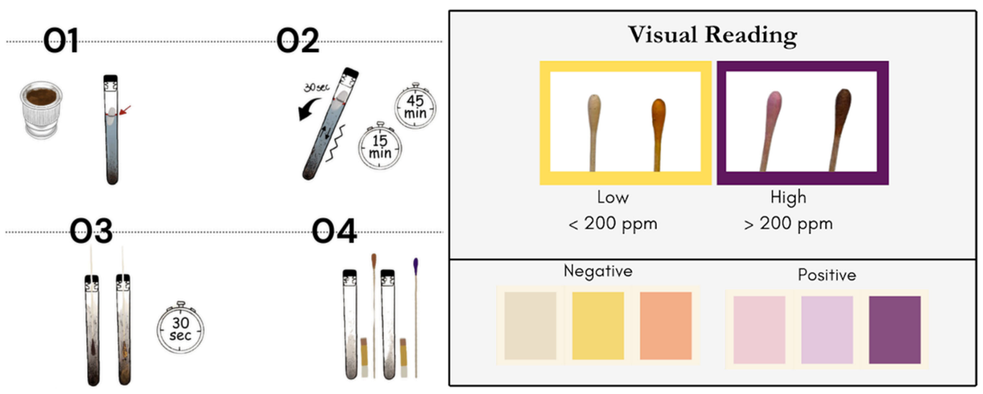


Figure 7 (left). The cost of the materials for the kit used in the USAID PEER project is relatively high at ~US$5/test. Filtration of the extract also requires some practice and dexterity to avoid mistakes. To address these issues, the kit was simplied by switching from scintillation vials to a test tube and replacing the spoon with the cap of the test tube to scoop a set quantity of soil. The soil:solution ratio (0.5 g in 5 mL) has not changed relative to the original method but sodium rhodizonate is added as a commercially-available cotton swab. Rather than the color of the solution, the color change of the swab indicates the presenc of Pb released to the extract. Another difference is that the extracting solution is made by adding a soluble capsule containing 0.2 g of glycine hydrochloride to tap water.

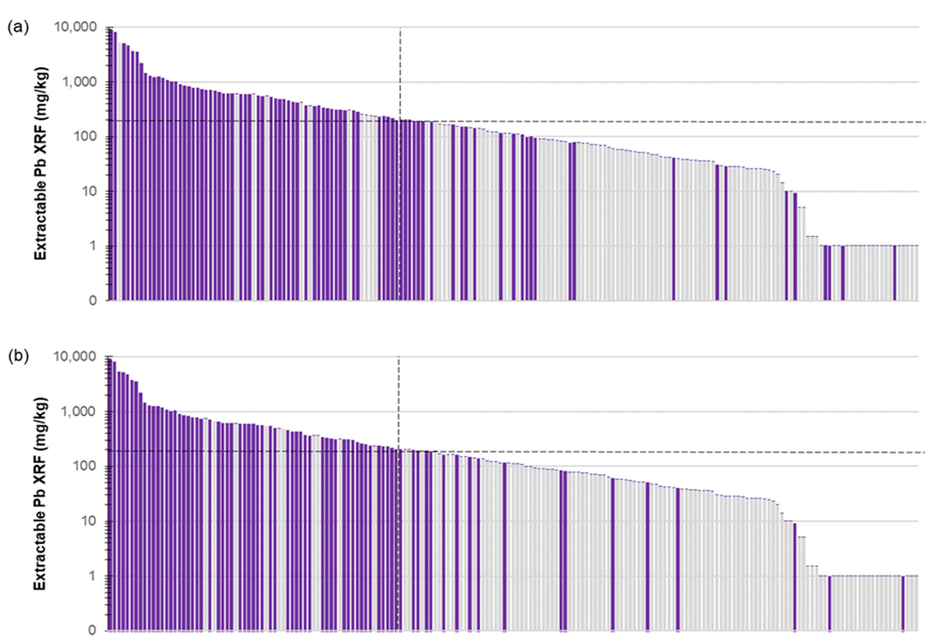


Figure 8a (left). The bar graph compares the ranked concentrations of Pb measured in 200 soil extracts by X-ray fluorescence to visual kit readings. Soil samples were collected in Peru, New York City and New Jersey. A purple bar indicates a high or medium reading. The data show that the proportion of purple bars increased markedly around a threshold of 100 mg/kg Pb in the extract, even if there are some deviations in both directions. For comparison, the US EPA recently lowered the remediation target for bare soil in residential areas where children play to total soil Pb concentrations of 200 mg/kg, assuming a third of the total is bioaccessible. Although the kit doesn't release as much Pb from soil as the EPA method for assessing the bioaccessible fraction, the kit detection limit lies somewhere near that of the previous threshold.

Figure 8b (left). The second bar shows the same XRF data obtained with the original kit method but for a duplicate set of extraction using the test tube and swab kit. The results are comparable and show a similar detection threshold. Interestingly, deviations from the XRF data are not necessarily the same in both sets of extractions and suggest heterogeneity in the distribution of the Pb contamination.

References

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Da Silva Moura S, D van der Molen, A van Geen. A simple kit to detect extractable lead concentrations in soil. Under review, May 2025.