Partnership for Environmental Health:

Findings and Recommendations of Heavy Metal Contamination in Shymkent, Kazakhstan

TerraGraphics International Foundation (TIFO)

&

Environmental Health and Pollution Management Institute (EHPMI)

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Report on findings from 2025 assessment activities for review and comment by stakeholders.

Table of Contents

Executive Summary

Shymkent is the largest city in South Kazakhstan with a population of 1.1 million, including more than 480,000 children. During the Soviet era, Shymkent was developed as a major industrial center. In the 1930s, a lead and zinc refining and smelting center was constructed, which produced approximately 70% of all lead for the Soviet Union. In 2018, the Shymkent lead smelter ceased operations. **Throughout more than 80 years of operation, the smelter released enormous amounts of heavy metals, contaminating vast areas of the city, including residential areas and commercial properties.**

Heavy metal exposures in Shymkent have long been recognized as a serious concern. A 2011 study found that 95% of children living near the smelter had blood lead levels (BLLs) above 10 micrograms of lead per deciliter of blood (µg/dl). There is no safe level of lead in blood; the current WHO reference value for blood lead level is 5 µg/dl. It is estimated that approximately 40,000 children 0 to 6 years of age are affected by lead toxicity (American Industrial Hygiene Association, 2020). A news feature by Al Jazeera highlighted the severity of the environmental health crisis and interviewed multiple international and Kazakh experts who pointed to evidence of unsafe exposures among children in the city.

In May 2023, a team from Environmental Health and Pollution Management Institute (EHPMI), together with specialists from Kazakh NGOs Human Health Institute (HHI) and Public Association Bereke, began assessing lead soil contamination in the city of Shymkent using a portable X-ray fluorescence (XRF) spectrometer. The study showed that lead concentrations in the soil remain dangerously high: within 2 km from the smelter, concentrations of lead in soil exceeded 2,000 mg/kg, nearly 63 times higher than the standard adopted in Kazakhstan and 10-20 times higher than the US Environmental Protection Agency (USEPA) standards. In residential areas closer to the smelter, the concentrations of lead in soil reach 5,000 mg/kg.

In 2024, EHPMI, HHI and TerraGraphics International Foundation (TIFO) launched a Partnership in Environmental Health (PEH), with the goal of using collaboration and shared expertise to address environmental health risks in Shymkent. Partners developed a shared vision to work with local stakeholders to assess and address heavy metal contamination and develop practical and sustainable interventions to reduce children’s exposures to lead and other metals.

Objectives, methods, and results presented in this report are considered draft and open to discussion and edits based on feedback from government and other stakeholder groups. The overall objective of the 2025 PEH assessment was to collaborate with local stakeholders and other partners to characterize soil heavy metal exposures in the Shymkent area and to develop recommendations for reducing exposure, estimate the costs of different interventions, and work with local stakeholders to implement the best interventions.

The 2025 sampling results confirm that severe surface soil contamination remains throughout the city. Levels of lead, arsenic, and chromium are well above both Kazakh and US standards, often by orders of magnitude. It is well established that there is no safe level of lead exposure; soil lead levels in Shymkent put children at risk of developmental delays, behavioral problems, learning disabilities, and a lifetime of irreversible health issues ranging from kidney disease to cardiovascular disease. **At a population level, this exposure puts Shymkent at risk of lower economic productivity, higher healthcare costs, and measurable reductions in educational achievement compared to other cities in Kazakhstan.**

Geospatial analysis of the results shows clear patterns of concentration, with the highest concentrations near the smelter facility, where soil lead levels exceed 10,000 mg/kg in some areas (compared to the Kazakh standard of 32 mg/kg). Average lead concentrations are 715 mg/kg, with max values reaching 34,600 mg/kg. The Kazakh and US standards for Pb in soils are 32 mg/kg and 100 mg/kg, respectively, indicating results that pose immediate and severe risk to residents. Regular exposure to these metals is a serious risk to children, who have higher exposures and organ systems that are especially vulnerable to irreversible damage. Because exposures that occur in utero can be especially damaging to the fetus, women of childbearing age are also an important vulnerable group.

Despite the severity of the problem, this is a tractable issue. There are proven methods for addressing lead poisoning that can be adapted and adopted for Shymkent. This includes developing a coordinated strategy that's implemented at the local level, but supported from the national level. Establishing a formal coordination mechanism that brings together health, environment, housing, and social services sectors to synchronize efforts across monitoring, prevention, and remediation. Including non-governmental stakeholders, academic partners, industry representatives, and community leaders from schools and religious institutions is also important for generating community support for the project. This may be best accomplished by creating a local task force that includes affected families, local agencies, NGOs, and environmental experts. This model improves trust, shapes a better understanding of risk and more effective interventions, and ensures inclusive remediation planning.

We recommend consideration of a pilot program to remediate contaminated areas, implement medical monitoring and home follow-up, and assess secondary sources of lead exposure. Remediation of one of the frequently used playgrounds could be considered - this report includes estimated soil volumes that need to be removed and replaced to protect children's health in those neighborhoods. It's critical that Shymkent and national stakeholders discuss intervention options and chart a path forward. We recommend a gathering of stakeholders from Shymkent and the national level to review this information, develop plans, and assign roles and responsibilities for executing action items.

Introduction: Background and Project Description

Site Background

Shymkent, formerly known as Chimkent, is the largest city in South Kazakhstan with a population of 1.1 million. In 2023, 40.5% of the city's population was under 18, representing 483,033 children (Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2023, pp. 7). The childhood population is likely to increase as Shymkent has the third-highest birth rate in the nation (25.70 per 1000 people) and a steady increase in the number of women of reproductive age (Karibayeva et al., 2024; Times of Central Asia, 2024).

During the Soviet era, Shymkent was developed into a major industrial center, particularly during World War II, when the government moved 17 factories from central Russia to the city. In the 1930s, a lead and zinc refining and smelting center was built in Shymkent, utilizing ore from South and East Kazakhstan, and produced approximately 70% of all lead in the Soviet Union. The production of lead continued at full scale until 2008, when it decreased significantly for economic reasons. In 2018, the Shymkent lead smelter ceased operations. Throughout more than 80 years of operation, the smelter released enormous amounts of contaminated dust, which has contaminated vast areas of the city, including residential areas and commercial properties, with heavy metals.

Latest Assessments of Soil Contamination

Heavy metal exposures in Shymkent have long been recognized as a serious concern. A 2011 study found that 95% of Shymkent children living close to the smelter had blood lead levels (BLLs) above 10 micrograms of lead per deciliter of blood (µg/dl) at that time. The average blood lead level was 20 µg/dl, and the highest level measured in a child was 103 µg/dl. There is no safe level of lead in blood; the current WHO and US Centers for Disease Control and Prevention (CDC) reference values for blood lead level are 5 and 3.5 µg/dl, respectively. It is estimated that approximately 40,000 children 0 to 6 years of age are affected by lead toxicity (American Industrial Hygiene Association, 2020). A news feature by Al Jazeera highlighted the severity of the environmental health crisis and interviewed multiple international and Kazakh experts who pointed to evidence of unsafe exposures among children in the city.

In May 2023, a team from Environmental Health and Pollution Management Institute (EHPMI), together with specialists from Kazakh NGOs Human Health Institute and Public Association Bereke, began assessing lead soil contamination in the city of Shymkent using a portable X-ray fluorescence (XRF) spectrometer. The study showed that lead concentrations in the soil remain dangerously high. This preliminary study showed that at a distance of 2 km from the smelter, concentrations of lead in soil exceeded 2,000 mg/kg, nearly 63 times higher than the standard adopted in Kazakhstan – 32ug/kg - and 10-20 times higher than the US Environmental Protection Agency (USEPA) standards of 100-200 mg/kg. In residential areas closer to the smelter, the concentrations of lead in soil reach 5,000 mg/kg. At the time, EHPMI estimated that at least 200,000 people in Shymkent had an elevated risk of lead poisoning, which was higher than in any other city in Central Asia. Results from the 2025 sampling indicate that the actual number of individuals impacted may be significantly higher.

2025 Objectives

In 2024, EHPMI and TerraGraphics International Foundation (TIFO) launched a Partnership in Environmental Health (PEH), with the goal of using collaboration and shared expertise to elevate and address environmental health issues in countries of the former Soviet Union. Shymkent was a top priority for this effort. EHPMI and TIFO worked with HHI to develop a shared vision and approach for engaging local stakeholders in assessing heavy metal contamination and developing practical and sustainable interventions that reduce children's exposure to lead and other contaminants.

Partners agreed that stakeholder engagement should be a top priority. HHI secured support from the Ministry of Ecology and Natural Resources of Kazakhstan and Ministry of Health and reached out to the Shymkent Aikimat to inform about results of contamination assessments and propose solutions to the potential problem of lead poisoning. In the meantime, partners developed plans for additional sampling needed to better understand both the extent and depth of contamination in the city.

The results and recommendations presented in this report are considered draft and open to discussion and edits based on feedback from government and other stakeholder groups. The overall objective of the 2025 PEH assessment was to work together with local stakeholders and other partners to characterize soil heavy metal exposures in the Shymkent area. We aimed to assess active heavy metal exposure pathways, develop recommendations for reducing exposure, estimate the costs of different interventions, and work with local stakeholders to pursue the best interventions, which may include health education, further exposure assessments, and remediation. Ideally, we would have had government engagement in the development of protocols used for sampling, but the timeline made that difficult to achieve during this sampling effort. We look forward to engaging with the local government on methodologies and approaches for continued work.

The objective to develop accurate cost estimates for intervention activities is especially important in informing funding needs for future years. These actions can include soil removal, soil capping, remediation of small priority areas, health awareness campaigns, and medical monitoring programs. The most appropriate intervention will depend on the priorities of local stakeholders *and* the efficacy of those interventions in effectively reducing exposures for children. Some interventions are complementary to others and not appropriate as stand-alone options (i.e., health education); all interventions must be developed, implemented, and sustained by local authorities to be successful in the long term.

The remainder of this document presents a summary of findings from the 2025 assessment and recommendations for interventions that stakeholders could consider for implementation. We intend this to help start conversations about next steps, needs, and capacity. Partners are committed to supporting efforts to improve health outcomes for Shymkent residents through environmental health programming and look forward to collaboration on this project in the years to come.

Sampling Approach

Sampling methods

The sampling approach was modeled after the United States Environmental Protection Agency (USEPA) methodology for determining soil metal concentrations using a field-portable XRF and USEPA Region 4 Superfund X-Ray Fluorescence Field Operations Guide (EPA, 2007, and Chan et al., 2017). The approach was modified for site-specific considerations. Soil sampling was conducted using two field portable XRFs owned by project partners. XRFs are non-destructive tools to screen for trace amounts of metals in soils and are routinely used by international NGOs and the USEPA at large contaminated sites.

Field Equipment Calibration, Maintenance, and Inspection

At the beginning and end of each field day, Standard Reference Material (SRM) tests were conducted. SRMs are small containers of soil containing known concentrations of metals provided by the XRF manufacturer Thermo Fisher. The provided and recommended SRMs with certified values, encompassing a range of concentrations, were used in this field study (Chan et al., 2017). After testing with the XRF, SRM results were compared with the known acceptable ranges and documented in the XRF tracking sheets. Using the TIFO SRMs, the TIFO XRF consistently underestimated concentrations greater than ~480 mg/kg for lead and ~75 mg/kg for arsenic. However, when testing EHPMI’s SRMs at a different project later in the month, the TIFO XRF results were within the acceptable range. Therefore, it may be safe to assume that the repackaging of the TIFO-owned SRMs affected XRF test results and that the XRF results from the field are reliable.

The system check calibration was performed on the XRF once per week. Between each field day, both XRF batteries were fully charged. The XRF was inspected daily for visible signs of wear. XRF data was downloaded daily.

In situ Soil Sampling

In situ sampling consisted of surface soil XRF tests. After determining the sample location(s), any surface litter (organic debris) was cleared using hand tools. The soil surface was analyzed through direct contact XRF (through a protective polyethylene cover). A whirlpack or ziplock-like plastic bag was used to cover the snout of the XRF and was wiped between tests, with a cloth or an antibacterial wipe, or replaced. Users may choose the duration of the XRF test, with shorter 30-second tests acceptable for initial screening and longer for higher precision (EPA, 2007). *In situ* sampling consisted of 30-60+ second XRF tests at 0cm (surface) and 3 cm. Most tests were for 70 seconds to include chromium concentrations. At select locations, hand tools were used to dig to a depth of 10 cm to collect depth data.

Ex situ Soil Sampling

At varying *in situ* surface locations, *ex situ* composite samples were collected for sieving and fixed lab analysis. *In situ* surface concentration measurements informed the *ex situ* collection locations to ensure a broad range of lead concentrations were collected. Composite samples were collected using the 5-point “envelope” method, in which a minimum of five aliquots of equal volume surface soil were collected from a roughly 2-3 m rectangle and from the center of the rectangle. Samples were collected in a plastic baggie (whirlpack or Ziplock type) for XRF bulk analysis, sieving, post-sieving XRF analysis, and potential fixed lab analysis. The *ex situ* sample ID represented information about the sample collection: which team collected the sample (A or B), type of sample (SSC = shallow soil composite, SS = shallow soil (grab), SSS = shallow soil sediment, and TP = test pit), and order/count collected. For example, Team A collected its third *ex situ* composite sample and created the sample ID: A-SSC-003.

Depth-Discrete Soil Sampling

Depth-discrete soil sampling was conducted at playgrounds, which are high-risk exposure sites for children. The objective was to assess the area extent and depth of contamination in order to estimate the level of effort and cost required to conduct a pilot remedial action/intervention. For the detailed site assessments, each playground was divided into 2-5 sub-areas of approximately equal size and, if applicable, the same soil type. Test pits were designated about 5m apart across the sub-areas and the entire playground. *In situ* soil samples were collected at 0 cm (surface), 3 cm, and 10 cm at each test ‘pit’. Every 5 test pits and/or if the measured concentration at 10 cm was greater than 100 ppm lead, a 20 cm pit was dug at the same location and tested. If the 20 cm pit contained more than 100 ppm lead, a 40 cm pit was dug at the same location and tested. If there was not an exceedance of 100 ppm at 20 cm, at least one 40 cm sample was collected per sub-area. Samples were not collected below 40 cm to avoid the risk of hitting underground utilities, including electrical lines known to be at approximately 50 cm. *Ex situ* grab samples were occasionally collected from test pits during depth-discrete detailed site assessments. Test pit excavations at playgrounds were conducted using clean stainless-steel trowels, shovels, and rock bars.

Lab Sample Preparation

XRFs are used to both screen surface concentrations and to predict ICP-MS or AAS-derived metal concentrations in *ex situ* samples sent to laboratories. All 36 ex situ soil samples were processed for lab preparation. Following aggregation of the composite sample, the material was vigorously mixed by hand agitation within the sample bag, and four XRF measurements were taken through different locations on the plastic sample bag, then labeled “XRF-Bulk” (Chan et al., 2017). All *ex situ* samples were sieved to 150 µm (0.15 mm) (Chan et al., 2017). If necessary, samples were air dried at ambient temperature prior to sieving (EPA, 2007, and Chan et al., 2017). Samples were not ground prior to sieving, as this alters the physical structure of the soil, while sieving preserves the particle size most relevant for ingestion and exposure risk. Samples were sieved from lowest to highest concentration, and the sieving equipment was decontaminated with antibacterial wipes, water, rubbing alcohol (to facilitate faster drying). Sieved samples were repackaged and then labeled “Sieved 100 mesh” (No. 100 mesh is equal to 150 µm). Sieved samples were tested again with four XRF measurements taken through different locations on the plastic sample bag, then labeled “sieved XRF”.

All processed *ex situ* soil samples were sent to the Science Analytic Centre laboratory in Almaty for analysis with AAC and ICP-AES methods. Twenty samples were split into two separate whirlpacks of approximately equal volume. To not unintentionally self-select for larger or smaller particles, spoons were used to alternately scoop the sieved sample into two separate bags. To ensure this process was adequate, four XRF measurements were taken through different locations on the plastic sample bag again, and the results were compared to the “sieved XRF” measurements. No significant difference in concentrations was found before or after splitting (see appendix). Half of the split samples were sent to the Science Analytic Centre laboratory in Almaty to be tested for lead and arsenic using GOST 32221-2013 Standard methodology. Six samples were selected for chromium analysis, in addition to Pb and As. For interlab comparison, the other half of the split samples were sent to the Far Eastern National University, Vladivostok, Russia, to be tested for lead using AAC methodology.

Comparison of pre- and post-sieved XRF results and XRF versus laboratory results are presented in the results section of the report.

Sediment Sampling

Two sediment samples were collected from the shores of the Badam River on the southern edge of the smelter. Sediment samples were collected as ‘grab’ samples from the surface. Sediment samples were not tested with the XRF because moisture can result in significant error (EPA, 2007). One sediment sample was sent to Astana, the other was split and sent to both the Astana and Vladivostok labs. Results will indicate potential bioaccumulation of heavy metals in the food web.

No water samples were collected during this sample event. Water samples may be collected in the future to assess potential risk to human health for the population and individuals through the ingestion pathway. Samples could include surface water, groundwater, municipal water, or individual domestic sources.

Sample Tracking

All XRF tests were recorded in one or more tracking systems.

Digital sample tracking forms for shallow soil, depth discrete, and water were created through ESRI’s Survey123. Through the mobile app, samplers were able to download the forms and update them in real-time. The forms included fields for sample ID (when applicable), automatic date and time, queryable latitude and longitude, XRF serial number (to distinguish which XRF was used for that test), XRF test number, depth of test, Pb, As, and Hg concentrations, photo of location, type of site, sampler’s name, and notes. Survey form entries were downloaded daily to be merged with downloaded XRF data by XRF test number into a digital database.

For XRF tests that didn’t apply to environmental locations, such as SRMs, playground equipment, a 4-test series of the *ex situ* samples, and accidental tests, sample information was handwritten on an XRF logging sheet. The fields on the sheet included sample ID, date, location description, XRF used, XRF test number, Pb, As, and Hg concentrations, sampler’s name, and notes. This information was matched via XRF test number and manually added to the database.

For the detailed site assessments of the playgrounds, site maps were drawn to track site areas, pit numbers, concentrations, frequency of depth checks, and site information shared by residents. Test numbers and concentrations were entered both in Survey123 forms and on the drawn maps. The maps help estimate removal volumes.

Sampling locations

The previous 2023 assessment focused on XRF surface data collection in neighborhoods within 2km north, east, and south of the smelter. Almost all samples exceeded the Kazak soil standards; many exceeded US EPA RSLs for soils. Additional sampling was required to better define the extent and depth of contamination throughout Shymkent.

In May 2025, *in situ* XRF analysis of shallow soil was conducted to fill in data gaps from previous soil sampling efforts. New sampling occurred in the right-of-way throughout neighborhoods surrounding the smelter, with the main focus on regions not previously tested, but closest to the smelter region. Sampling focused on public areas: Right-of-ways (ROWs) along roadsides, public parks, and playgrounds. Other than the playgrounds adjacent to apartment complexes, no private residential areas were tested. In addition to surface and shallow soil sampling in these public areas, we thoroughly characterized contamination up to depths of 40 cm at five playgrounds.

As data was entered into Survey123, a live map showed each new sampling point color-coded by concentration. Data from the 2023 assessment were also uploaded as a map layer. The live map provided the field team with real-time information on sampling coverage, supporting planning for each field session. Additional clustered *in situ* sampling occurred 3-10 km north to southeast of the smelter, the assumed direction of prevailing winds, in an effort to identify the spatial extent of air deposition and contamination, as well as background lead concentrations.

The approximate depth of contamination and subsurface data is needed to estimate the cost of remediation options. Depth-discrete soil sampling investigations focused on playgrounds in neighborhoods closest to the smelter. Playgrounds are critical remediation sites because children and women of childbearing age, groups most frequently found at playgrounds, are most vulnerable to heavy metal exposures. Targeting these sites prioritizes addressing exposure risks for these sensitive groups.

Detailed site assessments were conducted at four playgrounds in the neighborhood closest to the smelter and where the highest surface concentrations were measured. Multiple playgrounds were assessed to identify trends in playground soil composition, identify exposure risk of the sites, and gather information on site history and any previous construction or remediation. For example, two playgrounds included areas that were previously outdoor swimming pools; site reconstruction occurred in the past 15-25 years. Additionally, some playground equipment was new within the past 10 years. It is important to note that XRF screening revealed the presence of lead-based paint on the equipment, which poses an additional lead exposure risk. At another playground, soils were brought in around 2018 to ‘cap’ over the contamination. Conversations with local residents were critical to obtaining the specific site histories.

Results from the detailed site assessment at the first four playgrounds showed no clear pattern of contamination at depth. The contamination levels were high at varying depths, possibly due to site mixing and soil turnover, or the import of contaminated soils during the site’s reconstruction. To better understand the potential spatial variance of playgrounds, a detailed site assessment was conducted at a fifth playground further from the smelter and in a neighborhood with slightly lower surface contamination levels. At this playground, contamination concentrations followed an expected pattern of decreasing concentrations with depth — a trend typically associated with air deposition sites. Additionally, a longtime resident informed us that there has been no site construction in the 60 years that he has lived around the playground. This information indicates the variance of playground concentrations in proximity to the smelter and will guide future remediation efforts.

A detailed site assessment was attempted at the school closest to the smelter, School No. 26, but the site was closed due to construction. With government partnership, future detailed site assessments may occur in private residences. Site areas will be defined by use, such as private gardens, recreation space, yard, etc. Indoors, dust and consumer goods may also be assessed.

Photographic and Video Documentation

The assessment team collected photos of the soil sampling process and sites visited. The photos are included in Appendix A of the report.

Assessment Results

Data Quality

Table 1 presents the average limit of detection (LOD) for all elements screened by XRF. The detection limit can vary for each XRF test depending on the concentration of other elements in the sample, the density of particles, the moisture content, and other matrix effects. For lead (Pb), there were no samples with non-detect lead values; thus, an average LOD could not be established. The average LODs for arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), and antimony (Sb), were below the U.S. RSL but above the Kazakh MPC, indicating that the XRF is reliable for screening those elements to meet US standards, but limited in applicability for meeting Kazakh MPCs. For cobalt (Co), the LOD was well above the U.S. and Kazakh soil standard, indicating the XRF is not reliable for assessing soil cobalt concentrations.

Element	**Avg. *In situ* LOD**	**N <LOD *in situ***	**Avg. *Ex situ* bulk LOD**	**N <LOD *ex situ* bulk**	**Avg. *Ex situ* sieved LOD**	**N <LOD *ex situ* sieved**	**USEPA RSL[1]**	**MPC**
Ag	8.34	571	6.55	135	6.61	133	390	NA
As	15.18	161	15.41	3	16.48	2	35	2
Au	8.20	1220	8.62	143	7.59	144	NA	NA
Ba	131.60	18	NA	0	22.24	2	15,000	NA
Ca	NA	0	NA	0	NA	0	NA	NA
Cd	13.69	358	10.28	89	10.27	74	7.1	NA
Co	125.99	1171	118.56	138	108.45	143	23	5
Cr	49.62	22	22.97	3	25.08	2	70	6
Cs	19.74	59	7.94	16	6.46	3	NA	NA
Cu	36.13	90	NA	0	9.26	2	3100	3
Fe	205.40	5	NA	0	NA	0	55000	NA
Hg	10.84	1208	10.08	138	8.99	127	7.1	2.1
K	NA	0	NA	0	NA	0	NA	NA
Mn	77.38	8	NA	0	NA	0	1800	NA
Mo	4.47	729	3.99	116	3.62	104	390	NA
Ni	33.07	552	33.96	4	19.63	2	820	4
Pb	22.01	6	NA	0	NA	0	100	32
Pd	9.55	619	7.74	141	7.74	141	NA	NA

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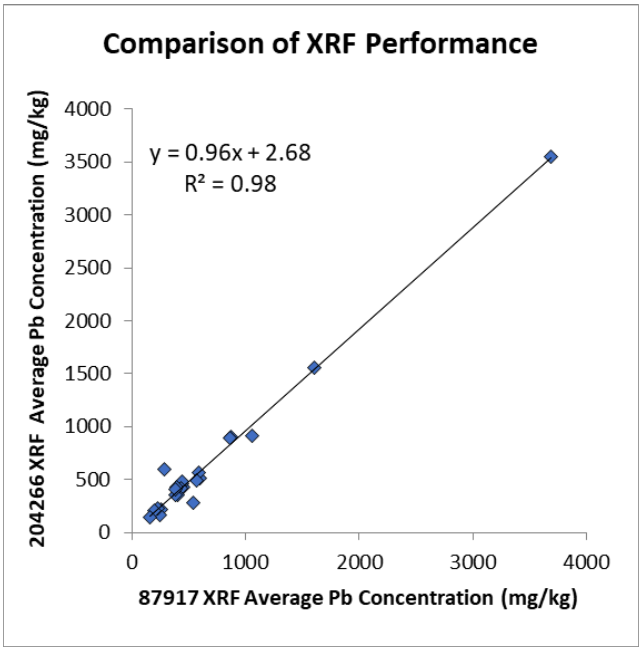
[1] See Table 2 for additional information about Regional Screening Level (RSL) values and selection of RSLs for priority contaminants.

Element	Avg. *In situ* LOD	N <LOD *in situ*	Avg. *Ex situ* bulk LOD	N <LOD *ex situ* bulk	Avg. *Ex situ* sieved LOD	N <LOD *ex situ* sieved	USEPA RSL[1]	MPC
Rb	4.37	6	NA	0	NA	0	NA	NA
S	536.68	529	560.03	87	589.83	109	1400000	160
Sb	18.30	184	11.96	82	12.02	54	31	4.5
Sc	151.03	79	147.27	5	NA	0	NA	NA
Se	4.83	1224	4.54	141	4.01	140	390	NA
Sn	9.94	367	7.63	117	7.65	96	47000	NA
Sr	5.09	5	NA	0	NA	0	47000	NA
Te	37.82	147	24.25	72	23.87	28	NA	NA
Th	6.84	273	7.05	3	2.34	1	NA	NA
Ti	NA	0	NA	0	NA	0	NA	NA
U	7.59	1019	7.89	96	6.99	74	16	NA
V	52.34	2989	NA	753	NA	648	390	150
W	46.84	1189	43.70	120	38.89	106	63	NA
Zn	19.03	5	NA	0	NA	0	23000	23
Zr	7.44	7	NA	0	NA	0	6.3	NA

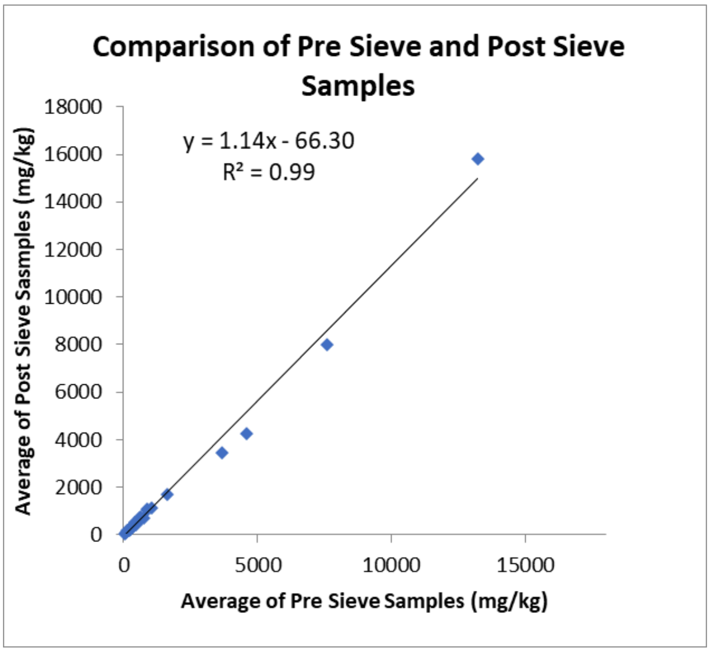
Table 1. Comparison of detection limits (mg/kg) between in situ, ex situ *bulk, and* ex situ *sieved XRF results. NA = not applicable; for XRF results, this indicates that no samples below the XRF limit of detection for that metal; for RSL and MPC columns, this indicates that the soil standard is not available for that element. Values highlighted in yellow indicate that the limit of detection exceeds one or both of the soil standards.*

Regressions

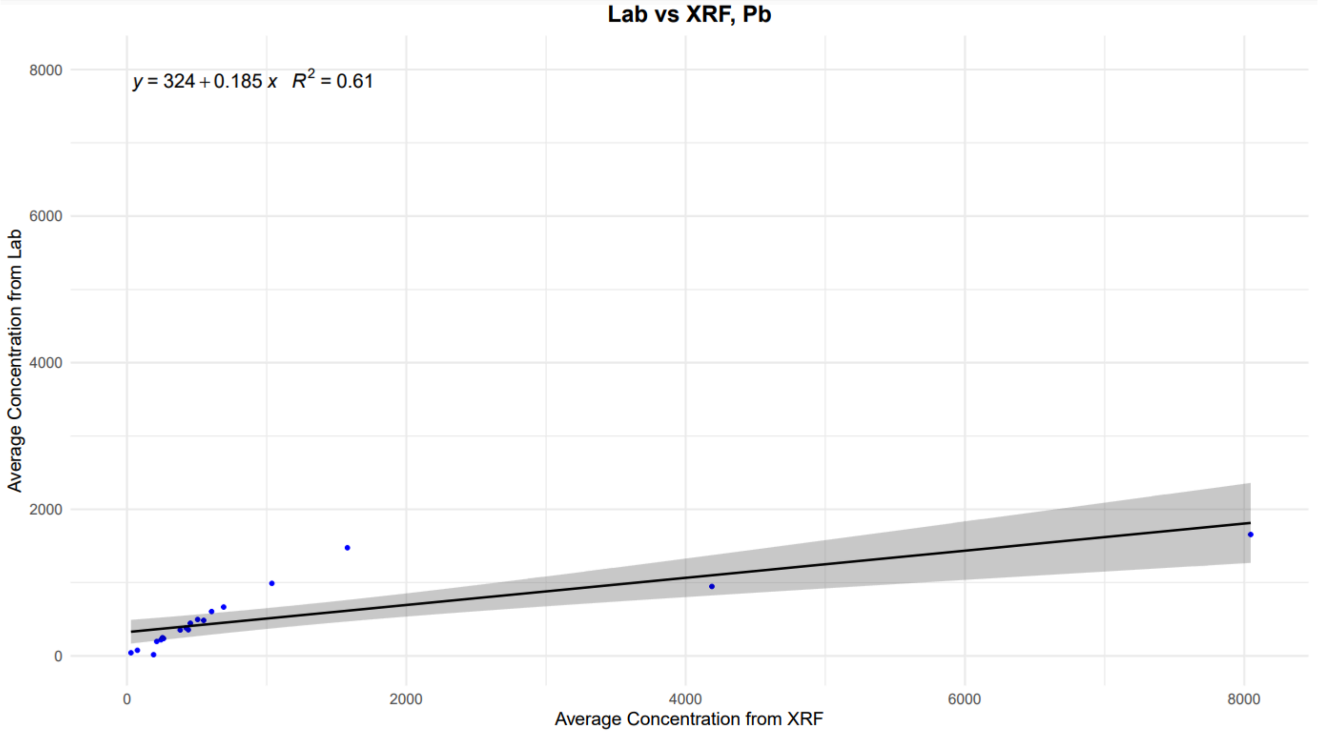
Two XRFs were used to assess concentrations of heavy metals in soil. The TIFO XRF serial number (SN) 87917 and the EHPMI XRF SN 204266. To ensure results between both units were comparable, 23 *ex situ* samples were analyzed by both XRFs (4 shots per bag, 70-second tests). The results of these were analyzed using linear regression, shown below. The high R^2 value (0.98) and nearly 1:1 slope (p-value <0.005) with insignificant intercept (p-value <0.005) indicate strong agreement between the two XRFs.



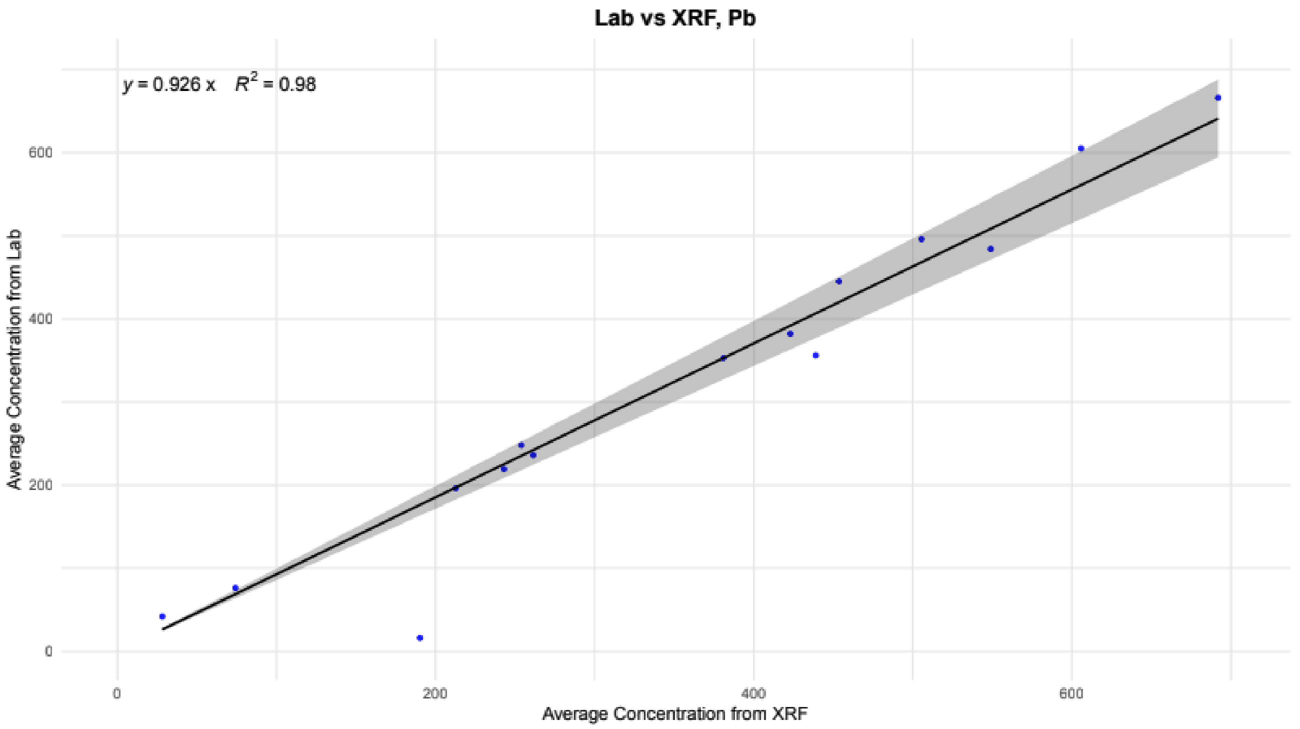
Ex situ samples were analyzed before and after sieving. All samples were tested 4 times for 70 seconds. All *ex situ* data shown below are from the TIFO XRF (Sn 87917). Sieving involves passing soil through a 150 µm sieve to select for particle sizes that pose the highest risk for incidental ingestion exposure. The results of pre- and post-sieving analysis are shown in the regression below. The R-squared value (0.99) indicates a strong correlation between the two values. Sieving appears to increase lead concentration by 1.14 times, meaning that the concentration of lead in the finer fraction material is higher and thus the risk is greater than represented in the *in situ* and bulk *ex situ* results. The intercept (66.30 mg/kg) was not significant (p = 0.197).



Twenty (20) *ex situ* samples were analyzed at the Pacific Institute of Geography lab in Vladivostok for lead. The results from the laboratory and XRF are compared in the regressions below. A comparison of lab to XRF results indicates a poorer relationship of lab to XRF at high concentrations, and a nearly 1:1 relationship at lower concentrations. At concentrations above 4000 mg/kg by XRF, the Vladivostok laboratory had lower lead recovery rates, indicating that the lead was precipitating out of solution before analysis. The R^2 value is 0.61, heavily influenced by low recovery of lead from lab analyses at samples above 4000 ppm.



However, at concentrations of 1000 mg/kg and less, the relationship between lab and XRF was very strong. The intercept was found to be insignificant on the first regression run (0.269, not shown), so the regression was run without an intercept (shown below), result in R^2=0.98, slope=0.926.



Assessment Findings

Table 2 below presents the number and rate of exceedances of US and Kazakh soil standards for heavy metals assessed by XRF. The respective standards for each metal are given where available, and the number and rate of exceedances for that standard are shown for or *in situ* (in position) and *ex situ* (bagged soil sample) testing. All *ex situ* (bagged) soil samples were tested before and after sieving to 150 µm to assess the effect of particle size on concentration, and to better represent particle sizes of greater concern for human health. Metals with exceedance rates of 20% or greater were prioritized for mapping and developing summary statistic tables. Lead concentrations exceeded Kazakh and US standards 98% and 94% (respectively) of *ex situ* (physical bagged samples) tested. Chromium and arsenic levels were above Kazakh and US standards 75-99% and 40-99% of the time, respectively.

	Exceedance of US RSL by testing category (number and % exceedance rate)							**Exceedance of Kazakh MPC by testing category (number and % exceedance rate)**						
Element	**RSL**[2]	*In situ* (N=1234)	*In Situ* %	*Ex situ* bulk (N=144)	*Ex situ* bulk %	*Ex situ* sieved (N=144)	*Ex situ* sieved %	**MPC**	*In situ* (N=1234)	*In situ* %	*Ex situ* bulk (N= 144)	*Ex situ* bulk %	*Ex situ* sieved (N= 144)	*Ex situ* sieved %
Ag	390	0	0	0	0	0	0	**NA**						

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[2] The USEPA Regional Screening Level (RSL) is not a cleanup criteria. It is a screening tool used in risk assessments to help identify contaminants that might require further investigation. These are derived from toxicological data and exposure assumptions for ingestion, dermal exposure, and inhalation of dusts. RSLs are not regulatory limits. Cleanup criteria typically incorporate information on background concentrations, feasibility of cleanup, land use assumptions, and other factors.

	Exceedance of US RSL by testing category (number and % exceedance rate)							Exceedance of Kazakh MPC by testing category (number and % exceedance rate)						
Element	**RSL**[2]	*In situ* (N=1234)	*In Situ* %	*Ex situ* bulk (N=144)	*Ex situ* bulk %	*Ex situ* sieved (N=144)	*Ex situ* sieved %	**MPC**	*In situ* (N=1234)	*In situ* %	*Ex situ* bulk (N= 144)	*Ex situ* bulk %	*Ex situ* sieved (N= 144)	*Ex situ* sieved %
As	35[3]	413	33	73	51	57	40	2	1,074	87	142	99	143	99
Au	NA							NA						
Ba	15,000	0	0	0	0	0	0	NA						
Ca	NA							NA						
Cd	7.1	0	0	0	0	0	0	NA						
Co	23	64	5	7	5	2	1	5	64	5	7	5	2	1
Cr	70	929	75	130	90	143	99	6	1,156	94	142	99	143	99
Cs	NA							NA						
Cu	3,100	4	0	0	0	0	0	3	1,145	93	144	100	143	99
Fe	55,000	8	1	0	0	0	0	NA						
Hg	7.1[4]	27	2	7	5	18	13	2.1	27	2	7	5	18	13
K	NA							NA						
Mn	1,800	8	1	0	0	0	0	NA						
Mo	390	0	0	0	0	0	0	NA						
Ni	820	0	0	0	0	0	0	4	682	55	140	97	142	99
Pb	100[5]	856	69	136	94	135	94	32	1,126	91	141	98	141	98
Pd	NA							NA						
Rb	NA							NA						
S	1,400,000	0	0	0	0	0	0	160	647	52	57	40	35	24
Sb	31	140	11	13	9	23	16	4.5	437	35	62	43	90	63
Sc	NA							NA						
Se	390	0	0	0	0	0	0	NA						
Sn	47,000	0	0	0	0	0	0	NA						
Sr	47,000	0	0	0	0	0	0	NA						
Te	NA							NA						
Th	NA							NA						
Ti	NA							NA						
U	16	1	0	0	0	0	0	NA						

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[3] The USEPA provides Regional Screening Levels (RSLs) for carcinogenic and noncarcinogenic risks related for inorganic arsenic. The carcinogenic soil RSL, set to protect against a lifetime excess cancer risk of one in one million, is 0.68 mg/kg. In practice, this is below the limit of detection of the XRF, and in most cases is below background concentrations at most sites. For this reason, we have opted to use the noncarcinogenic RSL, recognizing that arsenic exposure presents a significant risk of cancer that is not addressed by using the less noncancer value.

[4] The USEPA provides RSLs for different forms of mercury. The RSL for mercuric chloride (and salts) is 23 mg/kg. We do not have data on which form of mercury is present at the site, and have elected to use the more conservative elemental mercury RSL as it is more similar to the Kazakh standard.

[5] Lead exposure risk is assessed differently in the United States, as there are biokinetic models that enable prediction of population blood lead levels based on multiple source inputs (soil, dust, water, paint, etc.). Under USEPA's updated guidance, the RSL for lead in soil is 200 mg/kg, *unless other sources of lead exposure are present*, in which case the RSL is 100 mg/kg. However, it is well accepted that no level of lead exposure is safe, and lower soil lead levels may be needed to ensure that population blood lead levels remain below target criteria.

	Exceedance of US RSL by testing category (number and % exceedance rate)							**Exceedance of Kazakh MPC by testing category (number and % exceedance rate)**						
Element	**RSL**[2]	*In situ* (N=1234)	*In Situ* %	*Ex situ* bulk (N=144)	*Ex situ* bulk %	*Ex situ* sieved (N=144)	*Ex situ* sieved %	**MPC**	*In situ* (N=1234)	*In situ* %	*Ex situ* bulk (N= 144)	*Ex situ* bulk %	*Ex situ* sieved (N= 144)	*Ex situ* sieved %
V	390	0	0	0	0	0	0	150	2	0	1	1	8	6
W	63	3	0	2	1	2	1	**NA**						
Zn	23,000	3	0	2	1	2	1	23	45	4	24	17	38	26
Zr	6.3	1227	99	144	100	144	100	**NA**						

Table 2. Comparison of U.S. Regional Screening Level (RSL) and Kazakh Maximum Permissible Concentration (MPC) soil heavy metal results to in situ*, ex situ bulk, and* ex situ *sieved XRF testing results. Metals with exceedance rates >=20% are indicated in orange text. NA=not available.*

Summary statistics for lead, arsenic, and chromium in Shymkent are shown in the following tables (Table 3 through Table 5). Interpolated areas are for data points within close proximity to the smelter site and <500m from another sample location, as opposed to cluster sampling that was done farther from the smelter in an effort to understand the distance of contamination.

Heavy metal concentrations varied with depth, indicating that significant mixing of soils has occurred in the sampled locations since smelter activity ceased. Heavy construction, including at the playgrounds characterized in 2025, has resulted in some contamination being buried under a thin layer of soil with a lower concentration. However, concentrations at the surface still frequently exceed Kazakh and other risk-based soil standards. Lead, arsenic, and chromium in soil pose a significant risk to Shymkent residents, especially children.

For lead, both average and geometric mean concentrations at all depths within the interpolated area exceed the Kazakh standard of 32 mg/kg and the U.S. standard of 100 mg/kg. Cluster sampling farther from the smelter revealed average and geometric mean results above the Kazakh standard but below the US standard. In the interpolated area, average lead concentrations are 715 mg/kg, with max values reaching 34,600 mg/kg. The Kazakh and US standards for Pb in soils are 32 mg/kg and 100 mg/kg, respectively, indicating results that pose immediate and severe risk to residents. In areas farther from the smelter, average concentrations are still more than twice the Kazakh standard, averaging 71 mg/kg, with maximum values reaching 267 mg/kg.

Pb	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	1268	10.43	34600.00	727.18	2122.61	240.49	3.79
	10 cm	209	12.38	4633.71	706.79	881.17	307.52	4.31
	20 cm	54	23.66	2287.92	614.22	537.78	383.17	3.04
	30 cm	8	114.61	1213.71	450.41	357.91	353.16	2.00

	40 cm	21	34.73	967.90	433.88	263.02	325.25	2.43
Interpolated Total		**1560**	**10.43**	**34600.00**	**715.17**	**1943.81**	**254.11**	**3.83**
Non interpolated Samples	Surface	113	9.40	267.17	71.62	46.26	59.06	1.89
	10 cm	1	54.88	54.88	NA	NA	NA	NA
Non Interpolated Total		**114**	**9.40**	**267.17**	**71.47**	**46.08**	**59.02**	**1.88**
Grand Total		**1674**	**9.40**	**34600.00**	**671.34**	**1883.45**	**230.06**	**3.88**

Table 3. In situ *soil lead (Pb) results by depth for interpolated area (closer proximity to smelter) and cluster sampling area (farther from smelter) in mg/kg (ppm). Concentrations obtained with handheld XRF. Surface XRF tests include 0-3 cm (after organic debris and rocks were removed, if needed), 10 cm tests include 4-10 cm, 20 cm tests include 11-20 cm, 30 cm tests include 21-30 cm, and 40 cm tests include 31-40 cm. The Kazakh and U.S. standards for Pb in soils are 32 mg/kg and 100 mg/kg, respectively.*

Mapping

XRF data were merged with Survey123 data to create maps of lead, arsenic, and chromium concentrations. The results of heavy metal contamination were mapped using geospatial analysis software. This enables project partners to review results spatially, assess for patterns in contamination, and determine areas of high, medium, and low concentration. Maps of discrete surface sample results were created for lead (shown below). To help visualize the continuous contamination across the site, interpolation maps were created for lead, arsenic, and chromium.

Geospatial analysis of soil lead concentrations is typically helpful in determining priority regions of a site for intervention activities. In Shymkent, visible spatial patterns emerge when reviewing surface soil lead data, with a general pattern of higher concentrations closer to the smelter site and lower concentrations at a distance from the site (see Figure 1 below). However, significant building and road construction activities have resulted in mixing, burying, and at times, dilution of soil lead concentrations. Despite this, surface lead concentrations exceed the 32 mg/kg MPC for Kazakh soil.

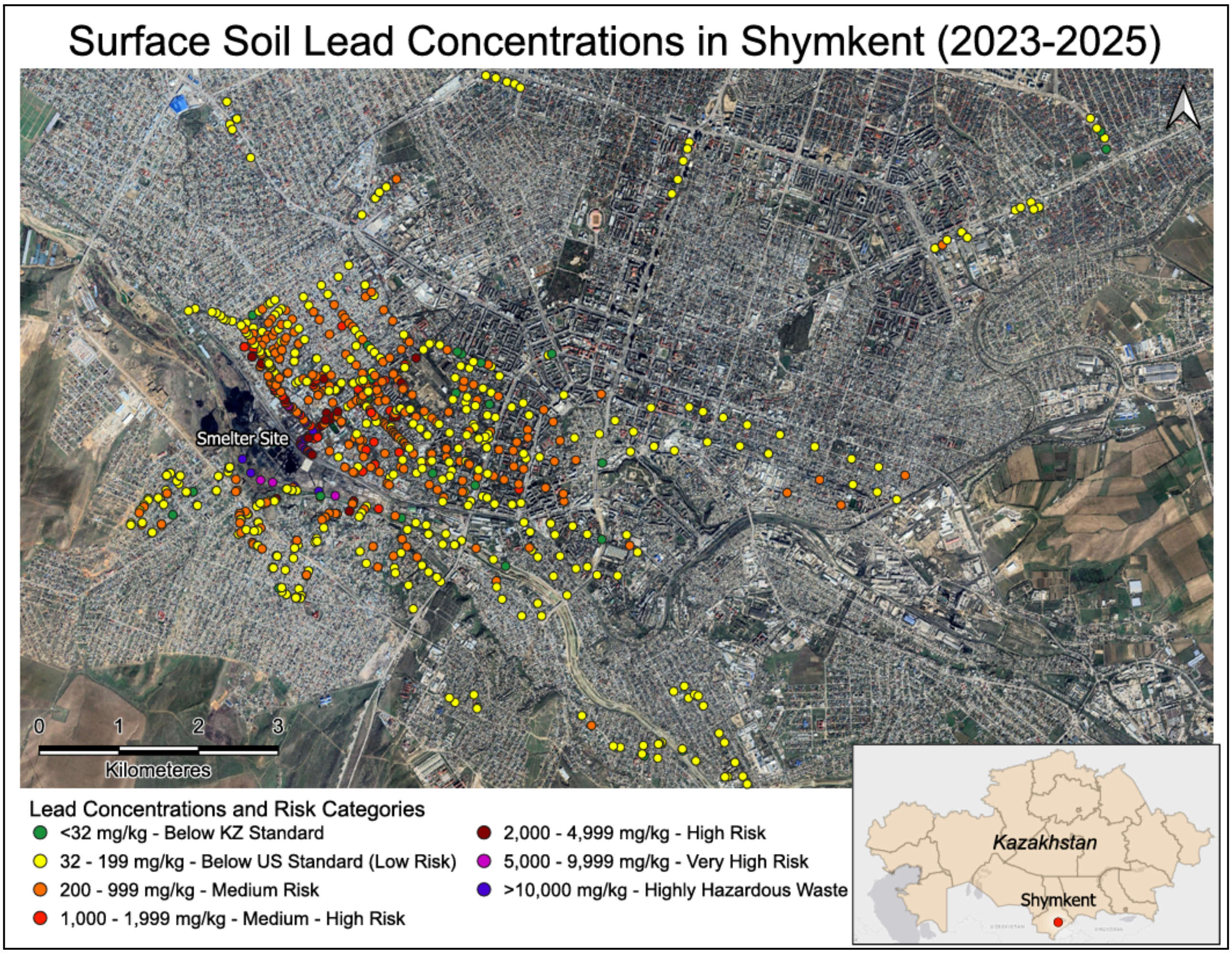

Figure 1. Surface soil lead concentrations from in situ *XRF testing efforts in 2023-2025 in Shymkent. Coloring of discrete sample locations indicates concentration category. Results in mg/kg Pb. The majority of surface sample results were 32-199 mg/kg (yellow, N=406).*

Interpolation is a method for estimating values at locations where you don't have measurements, based on the values of nearby known points. Multilevel B-spline interpolation does this by fitting smooth mathematical surfaces (B-splines) across a grid at different levels of detail, combining them to create a surface that best matches the measured data while filling in gaps smoothly. This method was chosen over kriging or other geostatistical approaches because the dataset was large and the goal was to generate smooth, continuous surfaces that were visually effective for displaying concentration patterns. Interpolation maps were also created using the open-source software QGIS©. The interpolations were created using multilevel B-spline interpolation via the SAGA processing provider (QGIS does not natively support multilevel B-spline). The interpolation was run across multiple levels, where each level consists of a B-spline generated from a lattice. A lattice is made from a grid of control points that are evenly distributed across an area encompassing all samples. The quantitative value of each control point is calculated by the least squares method, which determines the value that best minimizes differences between the B-spline surface and the surrounding known samples (measured concentrations).

At the first level, the lattice consists of only a few control points, giving it a very coarse resolution. A B-spline is then created that best fits the control points, which is known as a surface. The B-spline is a series of piecewise polynomials that are stitched together. Since the B-spline is built from several individual polynomials, each control point only affects a part of the B-spline, rather than the whole surface. From this first level, residuals are calculated by taking the difference between the measured concentrations and the surface. At the next level, a new lattice of control points is created, where the values of the control points are instead based on the residuals of the previous level. This lattice is made from a greater number of control points in the grid, resulting in a finer resolution compared to the previous level.

This process continues for each subsequent level. For the interpolations included in this report, 11 levels were used. Diminishing returns occur after 11 levels, requiring more processing for results that aren’t more accurate. Once each level has been generated, the surfaces of all levels are added together ($S_{total}=S_0+S_1+...+S_{10}$), then the B-spline refinement technique is employed to create an equivalent single spline surface to S_{total} that increases efficiency and creates the final interpolation.

Interpolation analysis results show a distinct plume of hazardous and very high-risk contamination in the populated areas immediately adjacent to the smelter. The heterogeneity of results <1000 mg/kg is also apparent, and reflects the movement and disturbance of soil over the past decades.

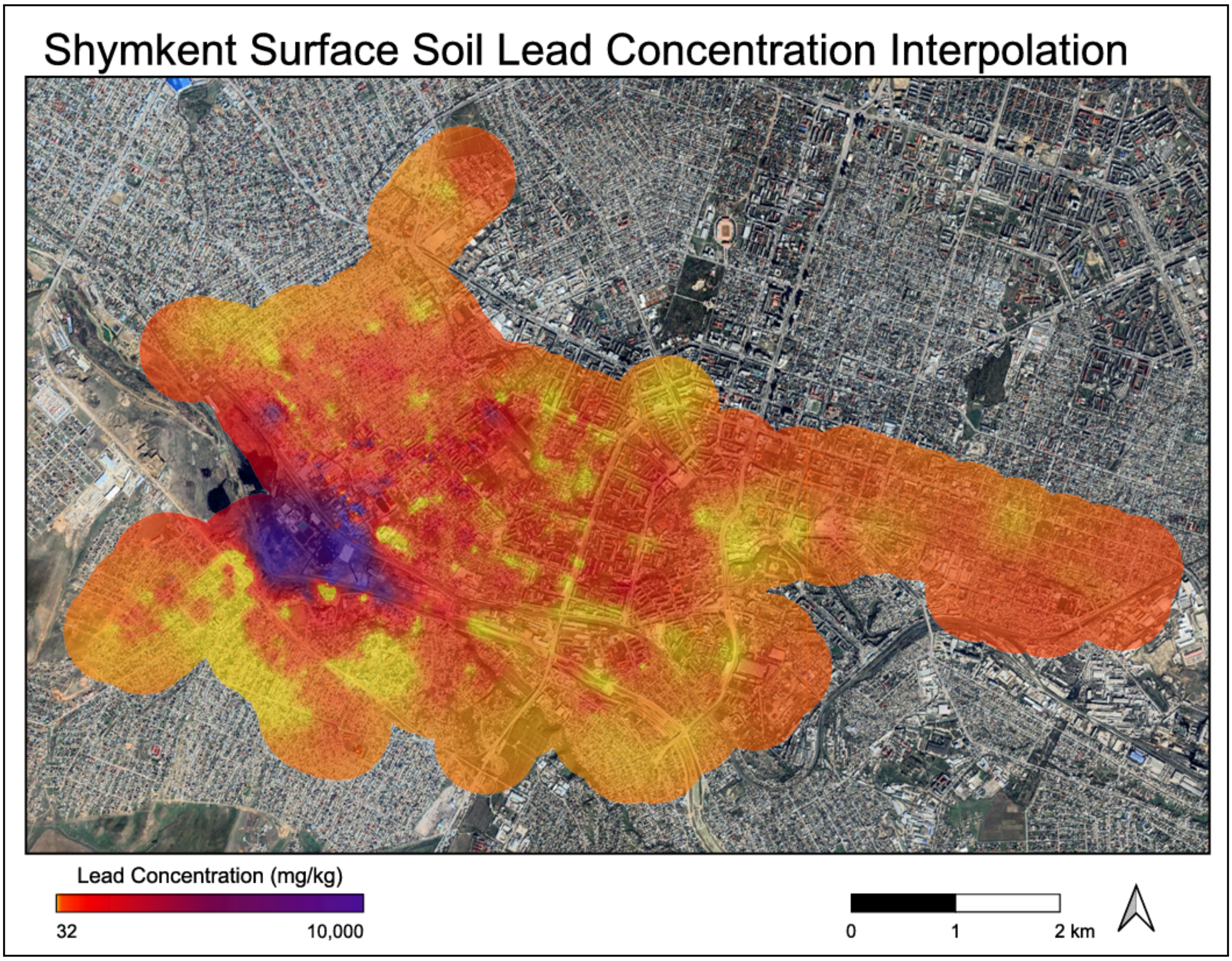

Figure 2. Interpolation of surface lead concentrations using samples shown in Figure 1.

Soil arsenic mean and geometric mean concentrations in the interpolated area also exceed Kazakh standards regardless of depth (Table 4 below); mean arsenic concentrations at all depths exceed US soil standards, but geometric mean concentrations exceed US standards from 10-20 cm. Cluster sampling results farther from the smelter show average As levels below the U.S. standard and above the Kazakh standard. In the interpolated area, average arsenic concentrations are 70 mg/kg, with max values reaching 5,764 mg/kg. The Kazakh and U.S. standards for As in soils are 2 mg/kg and 35 mg/kg, respectively, indicating results that pose immediate and severe risk to residents. In areas farther from the smelter, average concentrations remain more than 6 times the Kazakh standard, averaging 13 mg/kg, with max values reaching 26 mg/kg.

As	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev

Interpolated Samples	Surface	1243	2.79	5764	74.77	290	28.94	2.81
	10 cm	209	2.5	307.22	54.6	55.6	34.42	2.71
	20 cm	54	6.51	193.83	43.61	36	33.02	2.13
	30 cm	8	7.88	86.81	39.33	28.75	30.14	2.15
	40 cm	21	8.33	76.5	25.16	17.43	20.69	1.85
Interpolated Total		**1535**	**2.5**	**5764**	**70.07**	**262.05**	**29.64**	**2.77**
Non Interpolated Samples	Surface	113	2.97	26.1	12.72	5.44	11.36	1.67
	10 cm	1	16.98	16.98	NA	NA	NA	NA
Non Interpolated Total		**114**	**2.97**	**26.1**	**12.76**	**5.43**	**11.4**	**1.67**
Grand Total		**1649**	**2.5**	**5764**	**66.1**	**253.24**	**27.74**	**2.77**

Table 4. In situ *soil arsenic (As) results by depth for the interpolated area (closer proximity to smelter) and the cluster sampling area (farther from smelter) in mg/kg (ppm). Concentrations obtained with handheld XRF. Surface XRF tests include 0-3 cm (after organic debris and rocks were removed, if needed), 10 cm tests include 4-10 cm, 20 cm tests include 11-20 cm, 30 cm tests include 21-30 cm, and 40 cm tests include 31-40 cm. The Kazakh and US standards for As in soils are 2 mg/kg and 35 mg/kg, respectively.*

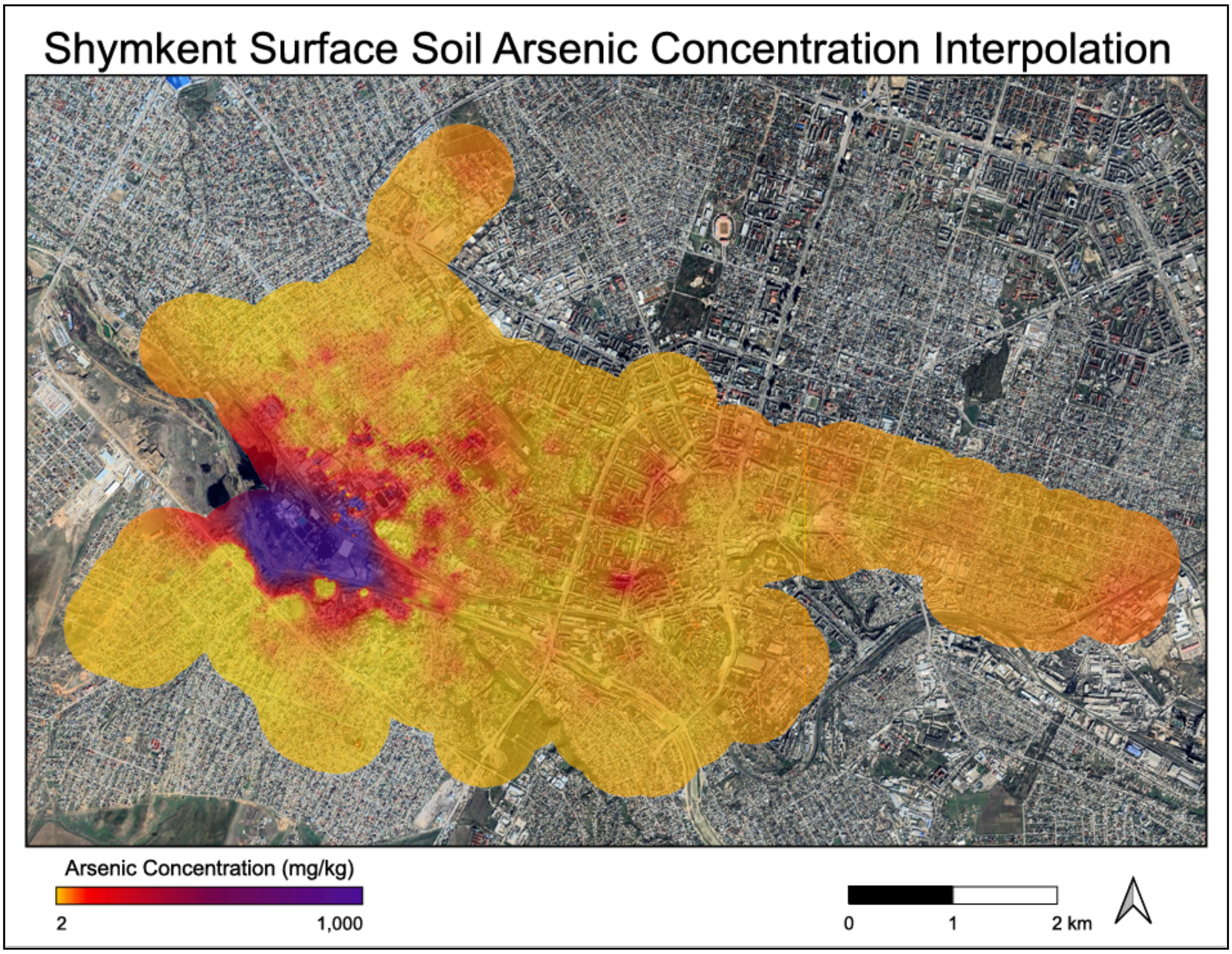

Figure 3. Interpolation of surface arsenic concentrations.

Soil chromium mean and geomean concentrations (Table 5 below) in the interpolated area exceed Kazakh and U.S. standards regardless of depth. Cluster sampling results farther from the smelter show average Cr results below the U.S. standard and above the Kazakh standard. In the interpolated area, average chromium concentrations are 103 mg/kg, with max values reaching 838 mg/kg. The Kazakh and U.S. standards for Pb in soils are 6 mg/kg and 70 mg/kg, respectively, indicating results that pose a risk to residents. In areas farther from the smelter, average concentrations are more than 10 times the Kazakh standard, averaging 60 mg/kg, with max values reaching 189 mg/kg.

Cr	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	771	10.86	838.32	100.52	40.3	94.68	1.43
	10 cm	209	9.77	352.1	109.59	33.55	103.83	1.44
	20 cm	54	54.13	162.8	107.35	25.59	103.94	1.3
	30 cm	8	52.84	111.11	84.64	22.12	81.97	1.29
	40 cm	21	45.86	124.63	102.95	21.19	100.31	1.28

Interpolated Total		**1063**	**9.77**	**838.32**	**102.58**	**38.19**	**96.88**	**1.42**
Non Interpolated Samples	surface	113	9.28	189.11	60.39	34.91	50.65	1.89
	10 cm	1	15.38	15.38	15.38	#NUM!	15.38	1
Not Interpolated Total		**114**	**9.28**	**189.11**	**59.99**	**35.01**	**50.12**	**1.9**
Grand Total		**1177**	**9.28**	**838.32**	**98.45**	**39.92**	**90.89**	**1.55**

Table 5. In situ *soil chromium (Cr) results by depth for the interpolated area (closer proximity to smelter) and the cluster sampling area (farther from smelter) in mg/kg (ppm). Concentrations obtained with handheld XRF. Surface XRF tests include 0-3 cm (after organic debris and rocks were removed, if needed), 10 cm tests include 4-10 cm, 20 cm tests include 11-20 cm, 30 cm tests include 21-30 cm, and 40 cm tests include 31-40 cm. The Kazakh and U.S. standards for Cr in soils are 6 mg/kg and 70 mg/kg, respectively.*

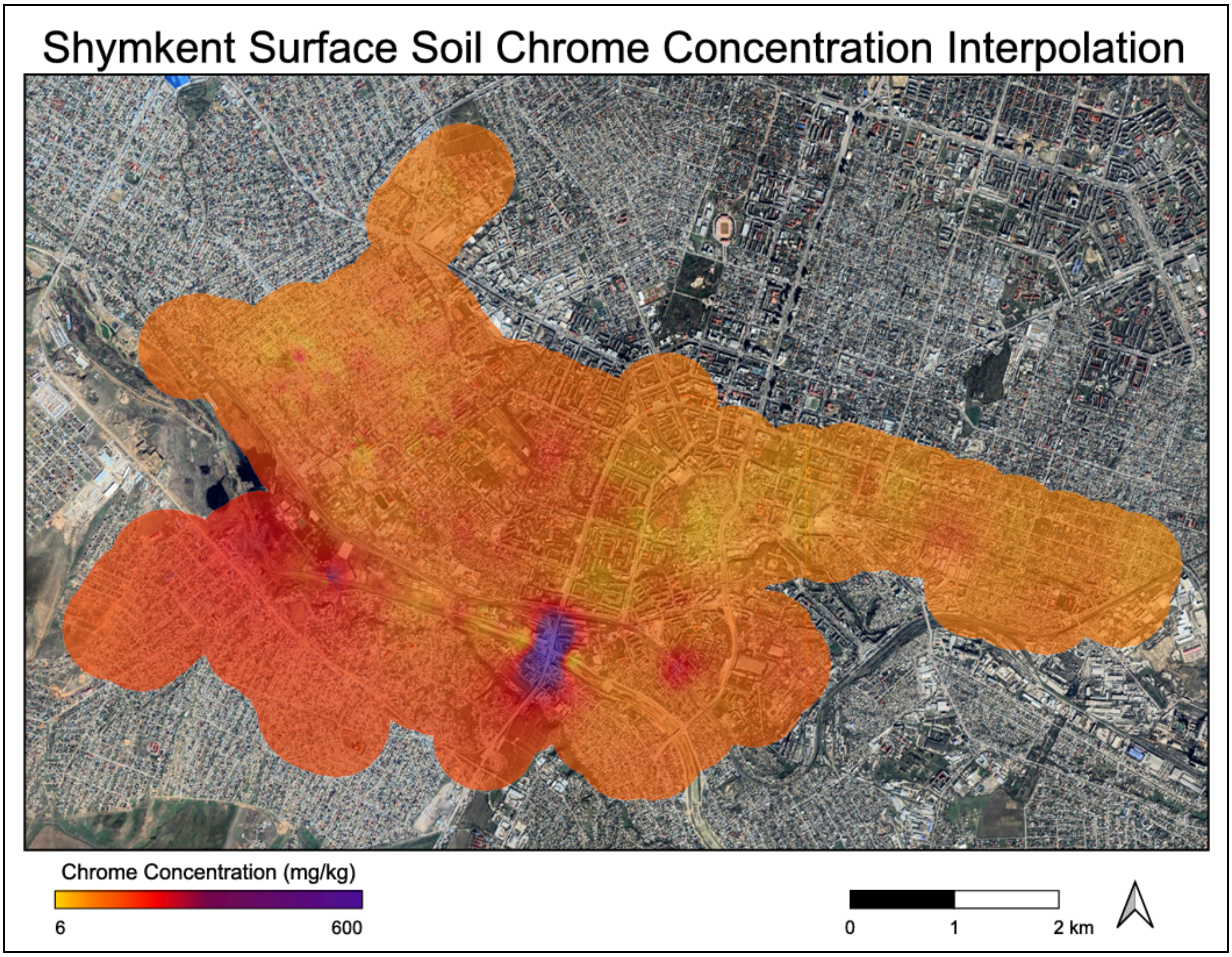

Figure 4. Interpolation of surface chromium concentrations.

Human Health Risks

Severe soil contamination in Shymkent is putting residents, especially children, at risk of long-term and irreversible health issues. The effects of chronic exposure may be invisible at the individual level, as most health effects are subclinical and detectable only through population-level health studies. This makes the total health burden easy to underestimate and difficult to recognize without environmental and biomonitoring data.

Lead (Pb)

- No safe level of exposure, particularly for children whose developing brains and nervous systems are highly sensitive. The levels seen in Shymkent soils are putting an entire generation of children at risk for developmental delays, chronic health conditions, and other burdens.
- Chronic, low-level lead exposure is associated with reduced IQ, attention deficits, learning difficulties, behavioral problems, and impaired executive function. This has cascading effects throughout a family, community, and country.
- The effects of lead exposure are permanent and cumulative. The damages may occur without obvious symptoms.
- At the population level, even modest shifts in average blood lead levels translate to measurable reductions in educational attainment, economic productivity, and increased burden of cardiovascular and renal disease later in life.

Arsenic (As)

- Chronic exposure to inorganic arsenic is linked to skin lesions, cardiovascular disease, diabetes, and multiple cancers, including cancer of the skin, bladder, and lungs.
- Long-term exposure affects neurodevelopment in children, including decreased cognitive performance and memory deficits, similar to the impacts of lead exposure
- Impacts of chronic arsenic exposure accumulate over years or decades, with no early-warning symptoms in most cases.
- Population-level burdens include increased mortality from cancer and cardiovascular disease, and reduced quality of life from chronic health conditions.

Hexavalent Chromium (Cr VI)

- Hexavalent chromium (Cr VI) is highly toxic and a known human carcinogen. We do not have information on the form of chromium in Shymkent soils, only the total chromium values. Trivalent chromium (Cr III) is far less toxic than Cr VI.
- Chronic Cr VI exposure, especially via ingestion or inhalation of dust, can cause stomach and intestinal damage, anemia, and elevated cancer risk, particularly lung and stomach cancers.

- Some evidence suggests Cr VI exposure in children can impair growth and development, though research is more limited than for lead and arsenic.
- Population-level health impacts emerge over decades, with cancer incidence and chronic gastrointestinal disorders as major contributors.

Vulnerable groups

For all metals, children are at heightened risk because they:

- Ingest more soil and dust relative to body weight.
- Have developing organ systems that are more susceptible to damage.
- Absorb certain metals more efficiently than adults.
- Are exposed during critical neurodevelopmental windows, leading to lifelong consequences.

Because exposures that occur in utero can be especially damaging to the fetus, women of childbearing age are also an important vulnerable group. Even when no child in the community shows overt symptoms, population-wide exposure can alter developmental trajectories, resulting in measurable deficits in learning, productivity, and long-term health outcomes. The majority of health impacts from these contaminants are invisible in routine clinical care – no rash, no fever, no dramatic onset – yet they are still profoundly damaging. The true burden is reflected in population impacts: higher rates of chronic disease, lower educational performance, reduced earning potential, and shortened life expectancy.

Exposure Pathways

The severe soil contamination present in Shymkent presents multiple exposure risks. The most significant direct exposure risk is incidental ingestion of soils and dusts with elevated levels of lead and other heavy metals. While inhalation exposures may be a concern, the primary risk is incidental ingestion of contaminated soils and dusts, especially by young children. The contamination of vegetables grown in residential gardens is also a concern, though the PEH team was unable to sample these areas to better understand the potential risk.

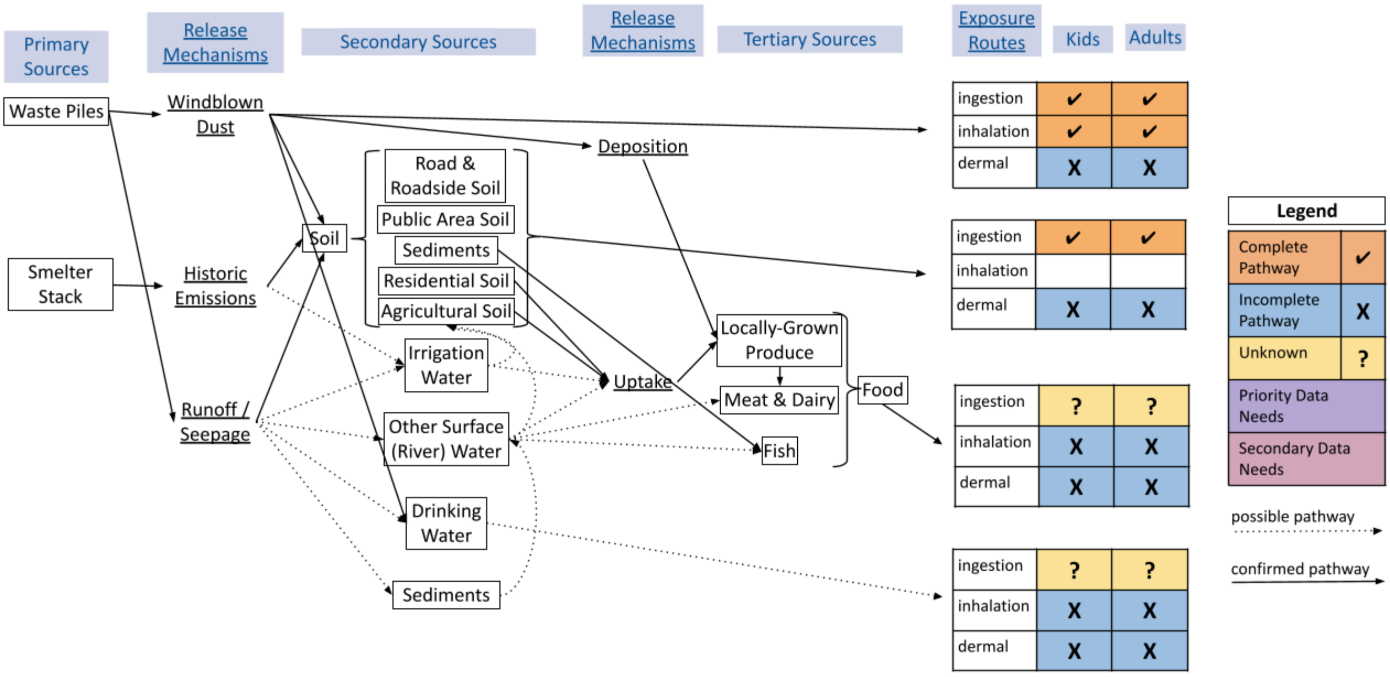

Figure 5. Conceptual Site Model for human exposure to heavy metals in Shymkent.

Data Gaps

The 2025 assessment provides valuable evidence of widespread soil lead contamination in Shymkent. However, some important gaps in understanding remain. These gaps limit the precision of our understanding of total risk and may influence the components of the associated intervention.

Extent of contamination: The geographic reach of contamination remains uncertain, as the sampling teams were not able to find areas with soil lead levels below Kazakh standards. Extensive testing will eventually be required in order to determine which areas of the city, if any, are not impacted by historic smelting activities.

Single-family residential areas: The sampling team did not have access to private residences. Therefore, we do not have a clear picture of risks in these homes, including soil contamination, risks to homegrown produce, household dusts, or any 'take-home' exposures from family members who may be exposed when working in industrial areas.

Assessment of all media: our 2025 work focused on assessing the extent of lead contamination in soil because that is often the source of exposure that contributes most to risk in sites with industrial sources of contamination. However, we have not assessed local foods, drinking water, household dusts, garden vegetable soils, or air emissions from the smelter site where some amount of processing may be ongoing. Some of these sources may contribute to elevated exposure levels, and inclusion of testing should be considered in the larger intervention program. Referring to the conceptual site model in Figure 5 may be useful in understanding the interaction of various sources and how humans can be exposed to them.

- **Garden soils:** there is no data on contamination levels in household gardens where residents may grow a significant portion of their family's caloric intake. This could represent a significant pathway, especially for certain root crops.
- **Drinking water:** no testing has been conducted on surface water, ground water, or drinking water. Most likely, the contribution of contaminated water to elevated blood lead levels will be much less than the contribution of contaminated soils. However, water testing and provision of safe drinking water should be included as part of a comprehensive lead health intervention program.
- **Consumer products:** Based on limited testing of a small number of products, lead glazed ceramics and lead-based paints may be an exposure source for some families. Other consumer products, such as recycled metal cookware, cosmetics, and toys may also be significant factors. Similar to water, testing and education about product safety should be included as part of a comprehensive lead health intervention program.

Smelter activity and management of existing wastes: The extent of activities at the smelter site is unknown. There are employees at the site, and there appears to be some amount of activity, but it is not known if there is any reprocessing of wastes or ores occurring. Additionally, we do not know how wastes are managed on site, as they may be a source of windblown dusts into the residential areas.

Cleanup criteria: Kazakhstan does not, to our understanding, have pre-defined soil cleanup criteria for heavy metal contamination of residential or public spaces. It is difficult to determine the threshold or action levels that may be used for cleanup activities, and this will impact the environmental cleanup. These need to be discussed and evaluated by project partners.

Recent biomonitoring data: data from different neighborhoods, age groups, ethnic groups, and other cross sections of the city would enable us to better understand factors influencing exposure and uptake of lead.

Possible Risk Reduction Approaches

The existing data gaps should not prevent immediate action to address the severe lead exposures in Shymkent. These can be addressed while simultaneously developing interventions to reduce children's exposures.

The following are draft recommendations. These should be carefully considered by government stakeholders and can be revised to align with government priorities, while still addressing exposures. Stakeholders may find it helpful to review resources pulled together by UNICEF on preventing childhood lead poisoning. This includes 4 of 12 topic-specific toolkits that are published, with the remaining expected to be completed by the end of 2026.

Coordinated Response

The effects of lead poisoning are felt in the health, economic, and education sectors, but the solution to the issue is deeply rooted in the regulatory and environmental sectors. It is essential that stakeholders from across these agencies are involved in developing and implementing coordinated response activities. Establishing a formal coordination mechanism that brings together health, environment, housing, and social services sectors to synchronize efforts across monitoring, prevention, and remediation. Including non-governmental stakeholders, academic partners, industry representatives, and community leaders from schools and religious institutions is also important for generating community support for the project. This may be best accomplished by creating a local task force that includes affected families, local agencies, NGOs, and environmental experts. This model improves trust, shapes a better understanding of risk and more effective interventions, and ensures inclusive remediation planning.

The United Nations Children's Emergency Fund (UNICEF), with support from a variety of global stakeholders, has developed a toolkit for a whole-of-government approach to developing strategies to address lead poisoning and a toolkit for developing a country strategy and action plan for addressing lead exposures. Aspects of this framework may be helpful to partners moving forward in Shymkent. Other UNICEF lead prevention tools that will be published later in 2025 may also be helpful to PEH project partners as the program develops.

The most appropriate intervention will be developed at the local level. Informal and formal leaders in Shymkent are best positioned to determine how to adapt proven intervention options to work within the local context. However, financial support needs to be identified to develop, implement, and sustain long-term activities. This requires federal financial support at the national level, as well as possible additional support from international donors. Funding is needed to advance laboratory capacity for environmental and blood lead monitoring, secure engineering expertise for remedial design, train health and environmental technicians, and engage grassroots leaders in community outreach.

Several examples of programs to address childhood lead poisoning can be adapted for use in Shymkent. TIFO and EHPMI have extensive experience supporting in-country stakeholders to develop and implement projects that are rigorous, practical, and effective. PEH Partners can be relied upon to help select and refine the intervention, train laboratory staff and case managers, design surveillance systems and adapt international guidelines, facilitate data analysis and quality assurance, and guide remediation protocols and assessment of additional sources of exposure.

Conduct Environmental Remediation

The best solution for addressing lead poisoning is to stop exposures. The contaminated soils in

Shymkent pose an immediate and direct risk to children who live near and play on those soils. The lead-contaminated soils should be removed and replaced with backfill that is certified to meet Kazakh soil MPCs. This approach has been employed at heavy-metal-contaminated sites worldwide, including in smelter-contaminated communities.

Remediation will require engineered design documents for each site to be addressed, along with plans for removing, transporting, disposing of, and managing contaminated soil. Health and safety plans need to be developed to ensure crews are not exposed to unsafe levels of heavy metals. All of these site control documents must meet Kazakh standards, and protocols will need to be approved by local authorities.

In addition to addressing residential contamination, processing wastes at the smelter site needs to be properly managed. This includes ensuring wastes are either properly disposed of in appropriate waste facilities or managed on site to prevent wind-blown dust from continuing to expose populations.

Provision of “clean” play areas for children is one way to dramatically reduce soil exposures for a large number of children. Tackling playgrounds in residential and/or school facilities enables young children to spend time in areas without risk of heavy metal exposure. This is an approach that has been suggested by other groups that are familiar with Shymkent.

Comprehensive Source Mapping

It is likely that residents of Shymkent are exposed to secondary sources of lead exposure. While the contaminated soil almost certainly poses the most significant risk and contributes to most of the heavy metal exposures, lead in consumer products, such as paint or ceramics, may contribute to lead poisoning. Comprehensive testing should be conducted to identify and prioritize these secondary sources, including water, paint, cookware, and other non-industrial sources. The toolkit on assessing lead exposures in resource constrained settings may be helpful in guiding the approach to furthering environmental soil testing, and secondary source testing.

Piloting Interventions

We recommend planning and implementing a pilot program that includes some combination of the interventions described above. For example, project partners could develop plans to assess BLLs in one residential area (e.g., an apartment block), remediate public area soils (e.g., playground soils) in that neighborhood, and engage residents in health education outreach. The program would be implemented by local authorities, supported at the national level, and rely on guidance from PEH technical experts. The approach enables all partners to make adjustments to planned activities on a smaller scale, gain expertise, and better understand the local context and needs before expanding activities to a larger scale. The pilot program can be replicated at other parts of the city and expanded to larger areas as expertise is established. Taking this approach will enable partners to better understand associated costs, address unexpected challenges that arise, and better plan for city-wide interventions.

Table 6 (below) lists estimated removal volumes in 5 playgrounds assessed in 2025. The location of these playgrounds is shown in Figure 6. Engineering drawings would need to be developed, relevant authorities engaged, and full cost estimates provided. These playgrounds would be a convenient place to begin the pilot remediation, monitoring, and health education efforts. It would provide relief from exposures for children and families in these neighborhoods, and enable project partners to gain valuable experience and plan for larger scale work in the city.

Playground	Estimated Removal Volume (m3)	Playground Street Location
1	950	Chapaeva St (West)
2	1,145	Chapaeva St (East)
3	811	Gagarina St
4	759	Chekhova St
5	1,320	Respublika Ave

Table 6. Volumes of the soil that needs to be removed during remediation from the five assessed playgrounds in Shymkent. Volume was calculated by multiplying the total surface area of each playground by forty centimeters. No samples were taken at depths greater than 40 centimeters. Areas in playgrounds that are currently covered by cement or artificial surfaces were not excluded from the total removal volumes. These volumes are estimates.

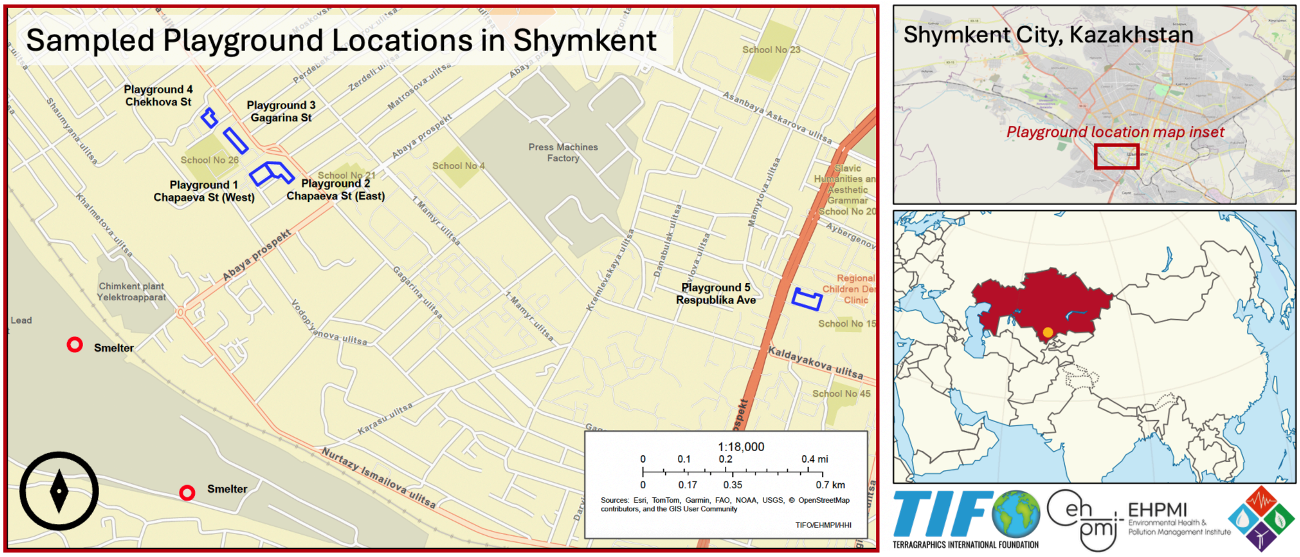

Figure 6. Location of 5 playgrounds characterized during 2025 sampling effort, indicated in blue outline in the main map. The location of the playgrounds in the city is shown in the upper right inset, and the location of Shymkent is shown in the bottom right inset.

Proposed Medical Monitoring Program

There are two ways to identify lead exposures. Environmental sampling is an effective, low-cost, and reliable method for assessing the risk of lead poisoning. The assessment completed by PEH project partners in 2025 provides an excellent example of this approach. A complementary way to assess lead exposure is to implement blood lead level (BLL) monitoring, which provides an integrated metric of past and current exposures across all sources. There are several options for how this is approached, and the most appropriate plan should be determined by local authorities.

Just as there is no safe level of lead exposure, there is no safe level of lead in blood. In the US, the CDC has determined a reference value of 3.5 micrograms of lead per deciliter of whole blood (µg/dL) to be the level at which follow-up is recommended for US children. This value represents the upper 2.5% of US children aged 1-5 years with the highest BLLs, or put simply, those children with more lead in their blood than most US children. The World Health Organization (WHO) cites a BLL of 5 µg/dL as the level requiring intervention to identify and reduce exposure sources. As there are few LMICs with robust, nationally representative blood lead data from which to develop a reference value based on the US CDC criteria, in the absence of a national policy on BLL action levels, the WHO value of 5 µg/dL is likely the most appropriate reference value to use.

Blood lead testing can be performed using a point-of-care device and capillary (finger prick) testing, or with laboratory analysis of venous blood samples. Capillary blood sampling, involving a finger prick for children, is relatively easy and quick, creates minimal pain for children, and is minimally invasive. It also does not necessarily require trained nurses or phlebotomists to conduct the sampling. It also enables the immediate reporting of results to participants, which simplifies report-back logistics. However, capillary blood sampling is more likely to be contaminated by environmental lead sources and may give false positives. Another disadvantage of capillary blood collection is that it can sometimes rupture blood cells, producing inaccurate results. Venous sampling is the standard method for obtaining blood and requires a trained medical professional (physician, nurse, or phlebotomist) to obtain the sample. Because this method is invasive, it can be stressful for children, caregivers, and health workers, and therefore risks higher non-participation rates in surveys. The approach requires anticoagulant, refrigeration, and freezing, and is more expensive than the point-of-care capillary testing. Ultimately, the most appropriate BLL testing approach depends on the available resources and other considerations.

BLL testing has many advantages: it captures the actual absorbed dose into the body, can be compared to health-based reference values for lead that have associated intervention thresholds, and compels stakeholders to take action. It can also track trends over time, demonstrating the efficacy of interventions and identifying exposures that were missed by environmental monitoring. There are also some important challenges to consider. Many of these can be overcome with adequate planning and coordination, but are important to highlight nonetheless:

- Determining the goal of biomonitoring
    - A good BLL assessment needs a well-designed and planned approach. If the goal is medical monitoring and follow-up, a case-management strategy will need to be developed. If the goal is to establish an understanding of population BLLs in the community, the study needs to be carefully designed to be representative.
- Ethical and legal obligations
    - BLL testing results often require follow-up, treatment, or the offer of an intervention to reduce the subject’s exposure. This means that exposure sources must be known.
    - Programs must be ready to respond; collecting data without the capacity for action can be unethical.
    - Prior and informed consent must be obtained, which can be especially difficult when working with parents of young children who may participate in the testing program.
    - Data confidentiality must be maintained to protect study participants.
- Costs and logistics
    - Sample collection, analysis, and interpretation can be expensive and require specialized training and laboratory capacity.
    - Cold chain and timely transportation may be necessary.
- Community trust and potential stigma
    - Miscommunication, whether individual or community-wide, can cause fear, stigma, or blame, especially if results are not explained in context.

A follow-up exposure source investigation protocol must be in place prior to implementing the BLL testing program. This includes plans for comprehensive environmental histories and on-site assessments to identify exposure sources for children and families who have been impacted. Health advisors can be trained to engage families, provide education, conduct home visits, and ensure follow-up until safe BLLs are reached through intervention implementation.

Preparatory stage

The first step is to model probable lead concentrations in the blood of children of different age groups using predictive models. This can be done by international experts in cooperation with the Shymkent City Health Department. The model will be based on the collected data on lead contamination of the city.

The second step is to develop an official medical monitoring program approved by the Ministry of Health. The program must identify the age groups of children, number of children tested, and priority areas. The program will provide for the procedures of the approval from the ethics committee to conduct blood lead level monitoring.

Organization of blood lead testing

Organize a primary screening study of blood lead levels of children using the LeadCare system or another approved selected equipment in accordance with the developed Medical Monitoring Program. All children aged 1 to 12 years living in the contaminated zone are recommended to undergo annual screening testing for lead in the blood. Such testing can be carried out in kindergartens and schools, or in clinics. Direct collection of blood samples from children can be carried out in preschool (school) educational institutions with the participation of specially trained medical personnel or at city polyclinics by order of the Shymkent Health Department with mandatory signed voluntary informed consent from legal representatives. To confirm the detected elevated or to clarify the questionable results of lead concentrations in the capillary blood of children, conduct a venous blood sampling in city hospitals.

In-depth health examination

All children with high blood lead levels should be examined as part of an in-depth medical examination in specified city hospitals polyclinics by order of the Shymkent City Health Department and undergo subsequent dynamic monitoring by a local pediatrician and specialists in order to monitor and identify potential health problems associated with lead exposure.

Data analysis and interpretation

The collected blood lead data should be stored in a database that will allow access of health professionals to perform analytical and statistical processing of the results and comparing medical monitoring data with predictive models. The data should be analysed to identify a possible correlation between elevated blood lead levels and the prevalence of diseases in children (anemia, developmental delays, behavioral disorders, etc.).

Working with children with high BLLs

Each family with children with high BLL should receive counselling about sources of exposure of children to lead and ways to mitigate lead health risks. The families will receive recommendations on hygiene and nutrition, and limiting contact with sources of pollution.

A home based assessment of residences should be conducted in order to identify the source of lead exposure. The assessments will include sampling different environmental media, conversations with the child's parents or guardians, a questionnaire and inspection. Such work should be done by groups of trained investigators assigned by the Department of Sanitary and Epidemiological Supervision of Shymkent and the Department of Environmental Protection of Shymkent. The protocol for home based assessment should be approved by the Ministry of Health. Proposed protocol is presented in the appendix.

It will be important to train health care workers in the reduction of health risks associated with toxic environmental pollutants, including prevention and treatment. Faculty from medical schools, colleges and training centers will conduct classes for students on the developed training courses. As a result, health care workers working in the contaminated area will be able to provide up-to-date recommendations to patients on the treatment of lead poisoning, paying attention to symptoms characteristic of chronic lead exposure.

Medical Monitoring Program Activities			
	Type of work	**Term**	**Funding estimate USD/year**
1.	Blood lead screening for children in kindergartens and schools; Repeat screening of children from the "risk group" (kindergartens №. ...; schools №. ...)	2025- Kindergartens № … School № … Kindergartens and schools in the "risk group" (kindergartens № …, schools № …)	15000
2.	Data analysis	Annually, based on screening results	2000
3.	Compiling a database of tested children, with additional information for children with elevated blood lead levels; Interviewing parents and identifying the routes of lead exposure for each child.	Annually based on screening results	6000

Medical Monitoring Program Activities			
	Type of work	**Term**	**Funding estimate USD/year**
4.	Treatment of children with lead poisoning	Annually, based on screening results	6000
5.	Conducting additional examinations and tests with the involvement of specialists for children with lead levels in the blood that exceed the maximum permissible concentration (from 30 mcg/dl, or from 20 mcg/dl at the request of the parents)	Annually, based on screening results	2000
Total for medical and environmental work			*31000*

Proposed Education and Awareness Program

The goal of an awareness program is to ensure that residents, schools, and local leaders understand exposure occurs, who is most at-risk, and what practical actions can reduce it in daily life. **It's important to note that an awareness program, when implemented correctly, can reduce some exposures, but it is insufficient as a stand-alone intervention.**

A well-designed education and awareness program should combine clear, accessible messaging with community participation. Materials should be developed in both Kazakh and Russian and reflect local customs, daily routines, and housing conditions. Activities might include community meetings, school-based learning modules, informational leaflets, short videos, and social media messaging. Trusted community members—teachers, healthcare providers, and local leaders—can play a key role in delivering and reinforcing messages about handwashing, household cleaning to reduce dust, and safe play areas for children. UNICEF's toolkit on communication to prevent and address lead poisoning may be a helpful resource for stakeholders in developing the program.

The program could also include capacity building for healthcare workers and local authorities to recognize, prevent, and respond to lead exposure. Training sessions might cover the health impacts of lead, how to identify at-risk groups, and how to communicate effectively with families about exposure prevention. Partnerships with local media can help sustain awareness campaigns and provide timely information about remediation activities or new findings.

This education and awareness initiative must be paired with other interventions to reduce exposure, such as environmental remediation or regulation of lead in consumer products. The program can serve as a foundation for long-term public health improvements and support broader environmental remediation efforts across the region.

Educational events help raise awareness among parents and teachers about the sources of lead and ways to prevent it, thereby reducing blood lead levels in children. These events are consistent with state health and environmental safety programs and promote a responsible public attitude toward children's health.

Based on research into lead contamination, these recommendations have been developed to raise public awareness about the sources of lead, its exposure pathways, and preventative measures.

Target audience:

- Parents of preschool- and school-aged children.
- Pregnant and lactating women.
- Kindergarten teachers and school teachers.
- Primary care workers (pediatricians, general practitioners).
- Residents of areas with a high risk of lead contamination (e.g., areas adjacent to industrial facilities).

Communicating about the risks and health effects of lead exposure in children.

- A detailed explanation of the negative impact of lead on the development of the nervous system, intelligence, behavior, hearing, and other organs and systems of children.
- Emphasizing the particular vulnerability of children to lead exposure due to their metabolic characteristics and increased absorption of lead in the gastrointestinal tract.
- A description of possible symptoms of lead poisoning in children (ranging from mild to severe).

Identification of sources of lead in the environment and everyday life.

Water: Information about the potential for lead contamination of tap water from old lead pipes. Recommendations for using water filters or drinking bottled water, especially for preparing baby formula. Water testing in various areas of the city.

Soil: Explaining the potential for lead contamination of soil near industrial facilities, busy roads, and older buildings with lead-based paint. Recommendations for arranging playgrounds away from potential sources of contamination and for regular wet cleaning of indoor spaces.

Air: Information about lead contamination of air from industrial emissions and waste incineration. Recommendations for limiting children's time outdoors near busy roads and industrial areas.

Household Items:

Toys: Caution against using old or uncertified toys, especially those made in China, which may contain lead paint.

Tableware: Information about the potential risk of using ceramic tableware with damaged glaze, which may contain lead.

Paint: Explain the dangers of using old paint on walls and furniture, especially in older homes. Recommendations for removing old paint while taking precautions (wearing masks and gloves, wet cleaning).

Food: Information about the possibility of lead contamination of food products from soil, water, or air. Recommendations for thoroughly washing fruits and vegetables, especially those grown near roads and industrial plants. Limit the consumption of foods produced in areas with high levels of lead contamination (if any).

Awareness and Education Activities			
	Actions	**Term**	**Funding estimate, USD/year**
1.	Citizen consultations on issues and problems related to lead risk	All year round	20,000
2.	Distribution of visual information, printed materials, release of information through the media	Annually	
3.	Dissemination of information and environmental education of the population through the activities of libraries and museums	Annually with at least one event per year	
4.	Educational program for children attending preschools and schools and their parents (parent meetings, meetings for teachers and educators); For high school students in grades 7–11 – lessons, competitions, and quizzes; For children in grades 1–6 – interactive performances, game activities, competitions, and quizzes; For children in kindergartens – interactive performances, indoor and outdoor game activities	Continuous	
5.	Installation of warning signs and information banners in areas with hazardous levels of pollution	2026-2027	
6.	Equipping kindergartens and schools with information stands, reminders, signs and stickers on doors and walls (above sinks in canteens, at the entrance to the premises)	2026-2027	
Total for health education activities			**20,000**

Next Steps

Next steps and priority action items will be discussed during stakeholder meetings in the fall and winter of 2025 and 2026.

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APPENDIX A: Photographs

Available here: https://docs.google.com/document/d/1ENkDHAJKeiY_b3CvnxbLiLqjYp3btKQ885fe1KoiZKI/edit?usp=sharing

APPENDIX B: Tables

As	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Playground 1	surface	116	3.965	265.4	36.13	42.05	25.37	2.17
	10 cm	25	3.705	241.43	49.17	62.45	26.08	3.1
	20 cm	10	11.1	193.83	65.48	49.9	52.31	2
	30 cm	6	15.04	86.81	39.13	27.32	32.61	1.8
	40 cm	3	12.71	56.68	28.16	24.73	22.16	1.95
Playground 1 Total		160	3.705	265.4	39.97	45.91	26.84	2.34
Playground 2	surface	82	3.975	245.12	58.83	54.02	40.12	2.42
	10 cm	41	5.885	262.94	71.83	54.28	52.68	2.37
	20 cm	16	6.51	97.07	42.54	28.17	32.41	2.25
	40 cm	4	9.515	76.5	33.45	29.62	25.26	2.11
Playground 2 Total		143	3.975	262.94	60.02	51.88	41.81	2.42

Playground 3	surface	62	2.895	264.5	28.23	39.54	18.19	2.38
	10 cm	30	2.495	214.54	37.9	45.84	22.11	2.8
	20 cm	7	8.96	168.96	43.93	58.03	25.26	2.63
	30 cm	1	7.875	7.875	7.88	#NUM!	7.88	1
	40 cm	6	8.33	38.55	21.29	12.56	18.08	1.8
Playground 3 Total		106	2.495	264.5	31.42	41.57	19.48	2.5
Playground 4	surface	79	4.065	342.11	69.7	66.43	47.61	2.43
	10 cm	39	2.875	188.03	75.76	48.42	56.98	2.44
	20 cm	8	10.4	67.65	30.13	17.8	26.12	1.71
	40 cm	4	9.13	44.37	26.88	15.54	22.89	1.83
Playground 4 Total		130	2.875	342.11	67.77	59.53	47.34	2.44
Playground 5	surface	32	10.14	95.49	26.6	15.24	23.91	1.55
	10 cm	16	5.67	33.88	20.75	6.91	19.36	1.51

	20 cm	2	18.79	19.6	19.2	0.57	19.19	1.02
	40 cm	2	12.03	19.6	15.82	5.35	15.36	1.28
Playground 5 Total		52	5.67	95.49	24.1	12.92	21.85	1.54
Grand Total		591	2.495	342.11	48.01	50.51	31.39	2.5

Cr	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Playground 1	Surface	116	10.86	216.04	110.48	25.76	106.28	1.38
	10 cm	25	9.77	208.47	102.5	32.68	94.38	1.66
	20 cm	10	54.43	133.29	86.17	31.95	81.19	1.41
	30 cm	6	52.84	109.15	79.42	22.52	76.79	1.3
	40 cm	3	45.86	102.9	73.75	28.54	69.94	1.39
Playground 1 Total		**160**	**9.77**	**216.04**	**105.86**	**28.51**	**100.55**	**1.45**
Playground 2	Surface	82	55.26	145.39	111.32	17.4	109.81	1.19
	10 cm	41	28.04	352.1	119.56	45.29	113.05	1.4
	20 cm	16	84.24	158.78	115.69	17.29	114.51	1.15
	40 cm	4	67.95	102.72	92.71	16.63	91.43	1.19
Playground 2 Total		**143**	**28.04**	**352.1**	**113.65**	**28.53**	**110.68**	**1.26**
Playground 3	Surface	62	70.28	151.04	106.16	16.49	104.93	1.16
	10 cm	30	31.2	143.16	106.7	24.29	103.08	1.34
	20 cm	7	100.08	139.56	115.02	12.93	114.43	1.11
	30 cm	1	111.11	111.11	NA	NA	NA	NA
	40 cm	6	89.45	122.01	113	12.33	112.37	1.11
Playground 3 Total		**106**	**31.2**	**151.04**	**107.33**	**18.56**	**105.47**	**1.22**

Cr	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Playground 4	Surface	79	44.62	299.57	108.73	29.27	105.45	1.28
	10 cm	39	58.27	146.1	118.4	20.26	116.3	1.22
	20 cm	8	75.2	133.39	111.6	18.89	110.04	1.19
	40 cm	4	78.65	123.17	107.66	19.99	106.09	1.19
Playground 4 Total		**130**	**44.62**	**299.57**	**111.77**	**26.21**	**108.9**	**1.26**
Playground 5	surface	32	75.81	145.14	114.41	17.84	113.02	1.17
	10 cm	16	87.47	139.05	112.9	14.85	111.97	1.14
	20 cm	2	102.7	124.63	113.67	15.51	113.13	1.1
	40 cm	2	122.44	124.63	123.54	1.55	123.53	1.01
Playground 5 Total		**52**	**75.81**	**145.14**	**114.27**	**16.34**	**113.08**	**1.16**
Grand Total		**591**	**9.77**	**352.1**	**110.05**	**25.71**	**106.73**	**1.31**

Pb	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Playground 1	Surface	116	16.2	3584.65	375.79	642.11	153.04	3.77
	10 cm	25	20.21	3827.28	705.49	1020.72	257.11	4.71
	20 cm	10	23.66	2287.92	876.04	684.94	569.02	3.31
	30 cm	6	114.61	1213.71	510.28	399.71	391.28	2.12
	40 cm	3	87.4	597.65	295.15	268	218.75	2.2
Playground 1 Total		**160**	**16.2**	**3827.28**	**462.1**	**717**	**187.87**	**4**
Playground 2	Surface	82	35.71	3962.31	800.2	866.75	422.94	3.5
	10 cm	41	17.47	2590.31	906.04	675.53	596.96	3.09
	20 cm	16	32.19	1686.67	678.27	484.6	491.6	2.56
	40 cm	4	460.95	967.9	666.68	221.57	640.94	1.32
Playground 2 Total		**143**	**17.47**	**3962.31**	**813.17**	**766.92**	**480.34**	**3.25**
Playground 3	Surface	62	10.43	3436.32	293.29	599.5	95.76	4.06
	10 cm	30	13.3	2211.26	451.59	632.44	150.82	5.16
	20 cm	7	64.23	1556.04	510.43	503.92	333.15	2.65
	30 cm	1	347.66	347.66	347.66	#NUM!	347.66	1
	40 cm	6	247.81	734.15	558.42	177.55	527.8	1.44
Playground 3 Total		**106**	**10.43**	**3436.32**	**367.95**	**586.51**	**131.83**	**4.44**

Pb	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Playground 4	Surface	79	56.91	3222.49	741.6	647.65	528.34	2.35
	10 cm	39	21.57	4633.71	1082.05	1000.2	696.67	2.97
	20 cm	8	33.12	423.12	215.17	157.28	156.5	2.39
	40 cm	4	164.4	661.97	411.1	232.57	356.29	1.75
Playground 4 Total		**130**	**21.57**	**4633.71**	**801.17**	**776.5**	**526.22**	**2.68**
Playground 5	Surface	32	16.06	726.74	230.41	171.48	172.03	2.31
	10 cm	16	41.7	449.63	165.59	132.74	121.92	2.2
	20 cm	2	33.47	114.96	74.22	57.62	62.03	1.85
	40 cm	2	34.73	114.96	74.85	56.73	63.19	1.82
Playground 5 Total		**52**	**16.06**	**726.74**	**198.47**	**159.27**	**143.16**	**2.35**
Grand Total		**591**	**10.43**	**4633.71**	**581.55**	**723.86**	**270.97**	**3.93**

Cu	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	828	7.5	6743.67	116.68	353.08	71.88	2.19
	10 cm	209	9.23	964.51	94.65	102.71	68.83	2.15
	20 cm	54	24.64	745.79	114.29	147.43	78.65	2.1
	30 cm	8	31.27	62.96	50.06	11.2	48.86	1.25
	40 cm	21	28.26	122.01	67.23	27.72	61.99	1.5
Interpolated Total		**1120**	**7.5**	**6743.67**	**111.05**	**308.67**	**71.21**	**2.16**
Non Interpolated Samples	Surface	113	8.82	120.38	40.9	23.18	34.9	1.79
	10 cm	1	34.51	34.51	34.51	NA	NA	NA
Non Interpolated Total		**114**	**8.82**	**120.38**	**40.84**	**23.08**	**34.89**	**1.78**
Grand Total		**1234**	**7.5**	**6743.67**	**104.56**	**294.84**	**66.67**	**2.19**

Ni	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	828	7.89	231.02	40.08	26.47	32.17	1.96
	10 cm	209	9.85	113.68	43.37	25.22	35.69	1.92
	20 cm	54	13.4	146.37	51.9	30.35	42.61	1.95
	30 cm	8	14.66	72.9	47.73	26.82	38.75	2.03
	40 cm	21	15.02	92.68	52.61	25.51	45.37	1.8
Interpolated Total		**1120**	**7.89**	**231.02**	**41.55**	**26.57**	**33.51**	**1.96**
Non Interpolated Samples	Surface	113	11.8	122.01	37.93	25.83	30.59	1.91
	10 cm	1	96.56	96.56	NA	NA	NA	NA
Non Interpolated Total		**114**	**11.8**	**122.01**	**38.44**	**26.3**	**30.9**	**1.92**
Grand Total		**1234**	**7.89**	**231.02**	**41.27**	**26.55**	**33.26**	**1.96**

S	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	771	100.78	13899.15	691.95	955.57	488.58	2.11
	10 cm	209	68.82	26789.76	565.42	1848.15	367.8	1.97
	20 cm	54	148.22	6712.26	577.68	910.67	400.88	2.04
	30 cm	8	165.57	1179.72	538.95	355.9	436.71	1.95
	40 cm	21	173.74	1078.07	391.74	219.03	349.36	1.58
Interpolated Total		**1063**	**68.82**	**26789.76**	**654.18**	**1174.1**	**454.02**	**2.09**
Non Interpolated Samples	Surface	113	82.4	3002.97	680.38	551.22	519.96	2.06
	10 cm	1	431.06	431.06	NA	NA	NA	NA
Non Interpolated Total		**114**	**82.4**	**3002.97**	**678.19**	**549.27**	**519.11**	**2.06**
Grand Total		**1177**	**68.82**	**26789.76**	**656.51**	**1128.68**	**459.95**	**2.09**

Sb	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev

Interpolated Samples	Surface	389	4.45	365.28	21.72	27.81	15.18	2.22
	10 cm	150	5.25	140.77	28.99	18.12	24.26	1.88
	20 cm	51	6.46	94.82	29.06	17.08	24.17	1.91
	30 cm	8	14.11	53.37	36.58	13.54	33.8	1.53
	40 cm	18	5.85	41.18	18.26	10	15.39	1.86
Interpolated Total		**616**	**4.45**	**365.28**	**24.19**	**24.71**	**17.88**	**2.17**
Non Interpolated Samples	Surface	5	6.16	34.22	20.41	12.48	16.54	2.01
Grand Total		**621**	**4.45**	**365.28**	**24.16**	**24.63**	**17.87**	**2.17**

Zn	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev
Interpolated Samples	Surface	828	23.81	47561.55	636.12	2238.56	349.59	2.4
	10 cm	209	60.57	4285.92	464	495.91	324.68	2.25
	20 cm	54	84.74	8824.23	672.98	1199.47	415.71	2.37
	30 cm	8	106.78	457.36	251.74	123.31	226.19	1.6
	40 cm	21	104.35	1132.98	372.05	295.61	292.82	1.94
Interpolated Total		**1120**	**23.81**	**47561.55**	**598.08**	**1955.9**	**345.47**	**2.36**
Non Interpolated Samples	Surface	113	40.95	1358.35	191.86	166.85	155.19	1.84
	10 cm	1	111.94	111.94	NA	NA	NA	NA
Not Interpolated Total		**114**	**40.95**	**1358.35**	**191.16**	**166.28**	**154.74**	**1.84**
Grand Total		**1234**	**23.81**	**47561.55**	**560.49**	**1867.69**	**320.76**	**2.39**

Zr	Depth	Count	Min	Max	Average	StdDev	Geomean	GeoStdDev

Interpolated Samples	Surface	828	29.26	235.76	135.24	37.32	129.31	1.37
	10 cm	209	47.21	226.37	145.85	32.61	141.45	1.3
	20 cm	54	33.52	192.7	143.66	35.78	137.04	1.42
	30 cm	8	82.43	170.82	142.17	34.83	137.57	1.31
	40 cm	21	61.45	198.41	155.55	37.06	149.78	1.35
Interpolated Total		**1120**	**29.26**	**235.76**	**138.05**	**36.67**	**132.28**	**1.36**
Non Interpolated Samples	Surface	113	59.84	221.06	134.13	35.47	128.83	1.35
	10 cm	1	182.3	182.3	NA	NA	NA	NA
Non Interpolated Total		**114**	**59.84**	**221.06**	**134.55**	**35.6**	**129.22**	**1.35**
Grand Total		**1234**	**29.26**	**235.76**	**137.73**	**36.57**	**132**	**1.36**

APPENDIX C: Home Based Assessment

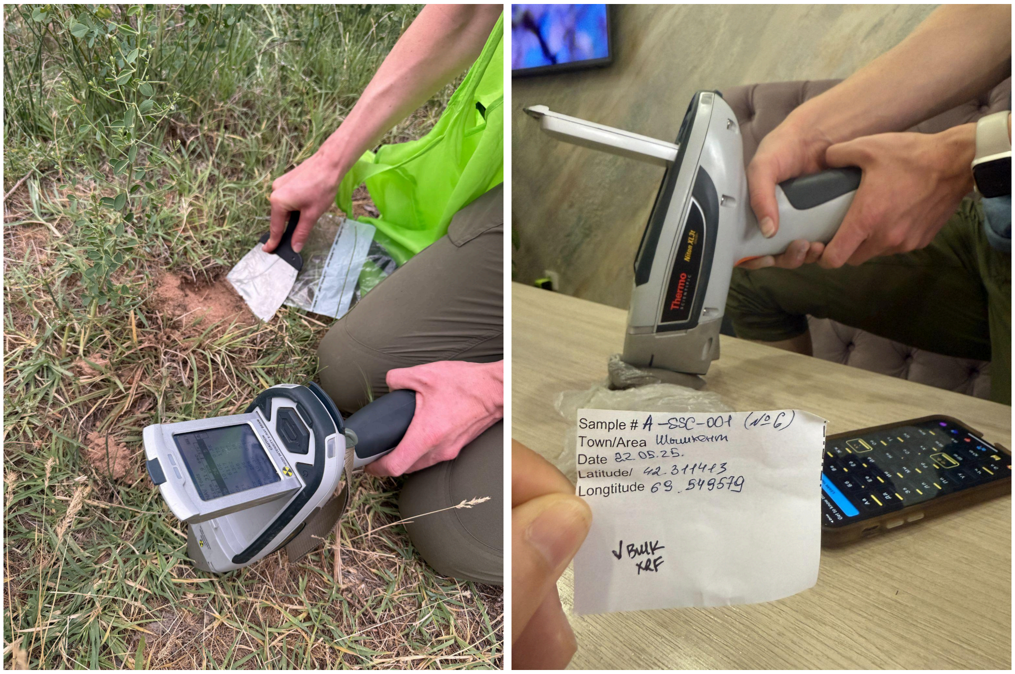
May 22

Team A (left) and team B (right) taking XRF samples in Shymkent neighborhoods.

Example of shallow soil samples that have been bagged and labeled.

May 23

PEH team member C. Bartrem collecting a sediment sample along the Badam river near the industrial smelter. Sediment was bagged and labeled.



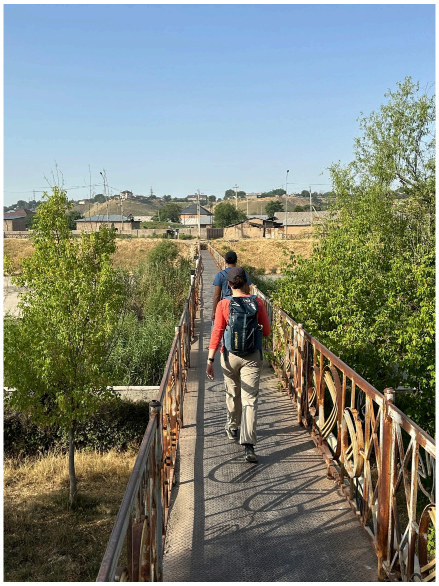
Examples of the XRF being used *in situ* (left) and *ex situ* (right). *In situ* tests occurred in the field and recorded soil heavy metal concentrations in position. The top layer of organic material was removed to prevent interference and ensure accurate results. *Ex situ* (bagged) samples were tested with the XRF before and after sieving to compare XRF results to laboratory results.

May 24

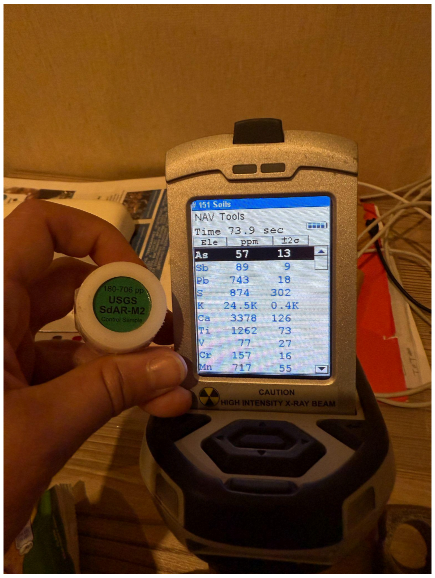
Sampling teams worked early in the morning and late at night to avoid exertion during the hottest parts of the day..

Example of using tools in the field to collect data at different soil depths. Sampling holes were measured to ensure accuracy of results.

May 25



Left: Sampling team traveling across the Badam river to get data from both sides of the banks. Right: Team planning the sampling approach for the day by looking at live maps showing areas sampled on the previous day.



```
# 151 Soils
NAV Tools
Time 73.9 sec
 Ele   ppm    ±2σ
 As     57     13
 Sb     89      9
 Pb    743     18
 S     874    302
 K   24.5K   0.4K
 Ca   3378    126
 Ti   1262     73
 V      77     27
 Cr    157     16
 Mn    717     55
```

Left: Standard reference materials (SRMs, shown here next to the XRF display) contain certified concentrations of heavy metals. These were tested by the XRF each day to ensure it was giving accurate results. Right: In addition to the detailed site assessments at five playgrounds, shallow soil tests were taken at other playgrounds in the city.

May 26

Ex situ soil samples were tested before and after sieving (bulk and sieved tests). Sieving involves shaking soil through a decontaminated 100 mesh (150 um) sieve which separates out fine soil particles. A large amount of soils is required to get enough sieved material for post-sieving analysis. PPE was worn during sieving.

May 27


Населенные пункты, где добывают ртуть, в Баткенской области, Кыргызстан

Исследование загрязнения и очистка почв

Casey (left) and Petr (right) presenting at the Southern Kazakhstan Medical Academcy on approaches for assessment and remediation of heavy metal contaminated sites from other countries.

May 28

Left: Casey explaining how to use the XRF to members of the Southern Kazakhstan Medical Academy. Right: Aidar relaying the depth of a hole that was dug for sampling to the team.

May 29

Left: Casey digging a hole to be sampled in a playground. Holes had to be large enough so that an XRF could reach the bottom to measure the soil concentrations. Right: The sampling team was frequently asked questions about the work by local residents and in this photo, are demonstrating the XRF to people living in a nearby apartment.

June 17

Left: Preparing surface, 3cm, and 10 cm holes for XRF analysis in a playground. Right: Soccer turf in a playground with damage to the artificial turf, exposing a large patch of contaminated soil.

Measuring depth of hand dug pits to ensure consistent depth samples.

June 18

Evidence of children digging in and playing with contaminated soil in a playground.

Left: The smelter site, visible from the park. Right: A 40 cm pit that was dug by hand for the detailed site assessment.

June 19

Left: Another example of prepped test pits at surface level, 3 cm, and 10 cm in a playground. Right: This is an example of canals that run through some parks. Older soil gets trapped inside, so the XRF was used to measure the concentration of this older soil.

Sampling on this day was done in playground 3.

June 20

Sampling on this day was done in playground 4.

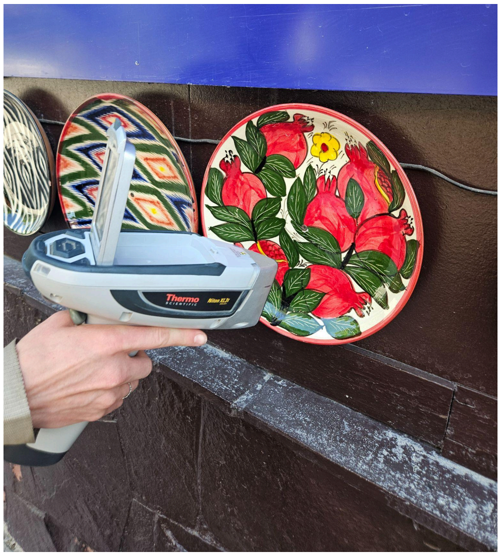
Left: Another example of prepped tests, this time prepping a 30 cm test. Right: A 40 cm test using a tool with markings at different depths to ensure accuracy.

June 21

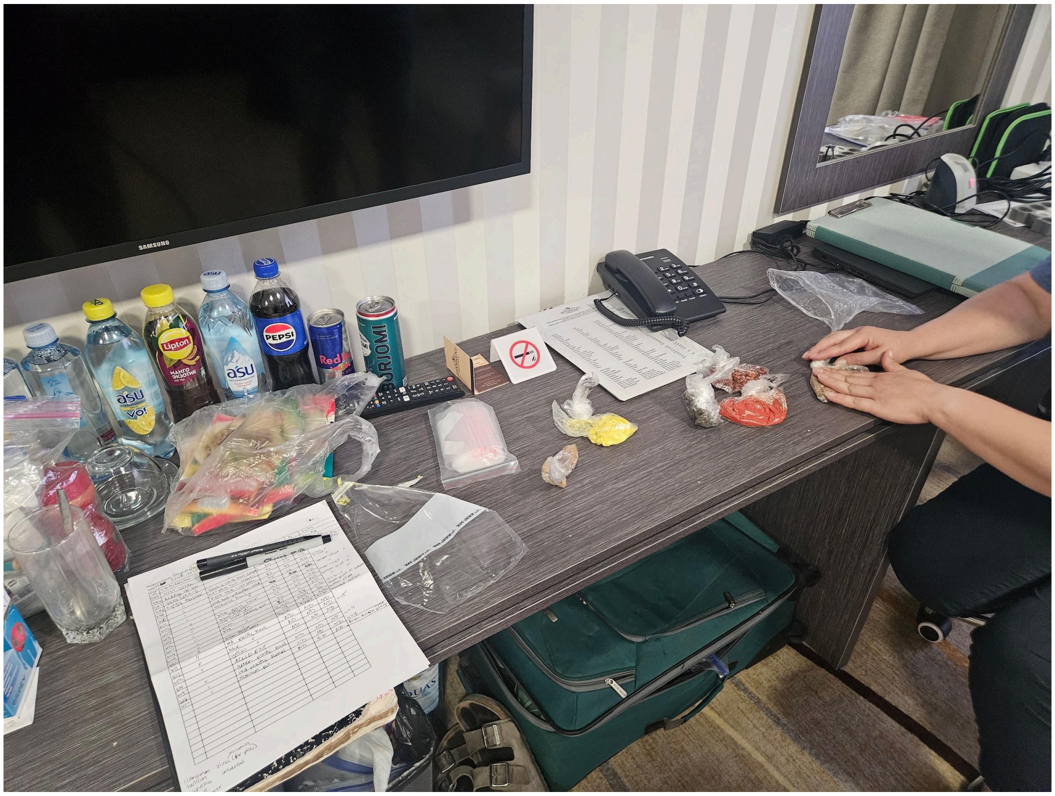
Samples from this day are from playground 5. The surface was contaminated at 3 cm, but deeper tests had much lower concentration. This layering of contamination is more typical of areas where soils haven’t been mixed by construction activities.

Smelter stack from the industrial site.

June 22



Left: Ornamental plates were tested by the XRF and were found to have high lead levels. This is likely in the glazing used to seal the pottery, but can also come from the use of lead-based paints. Right: A variety of spices were sampled from local vendors.



Bagging prepackaged consumer products to test with the XRF.