PURE EARTH

LEAD IN CONSUMER GOODS:

A 25-COUNTRY ANALYSIS OF LEAD (PB) LEVELS IN 5,000+ PRODUCTS AND FOODS

Acknowledgements

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Personnel

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Executive Summary

The scale of childhood lead poisoning is staggering, and due to a lack of research in the most impacted countries, the sources of exposure affecting the majority of the world's children have been poorly understood. The 2020 report titled The Toxic Truth, by Pure Earth and UNICEF, revealed that an estimated 800 million children globally, or one in every three, have levels of lead in their blood that indicate lead poisoning. This prevalence suggests that children are continually exposed to lead in their daily lives. The vast majority of these children live in low- and middle-income countries, where research into exposure sources has been limited. Pure Earth's Rapid Market Screening program (RMS) aims to improve our understanding of these exposure sources and advance the ability of all actors to implement solutions.

What is the Rapid Market Screening program?

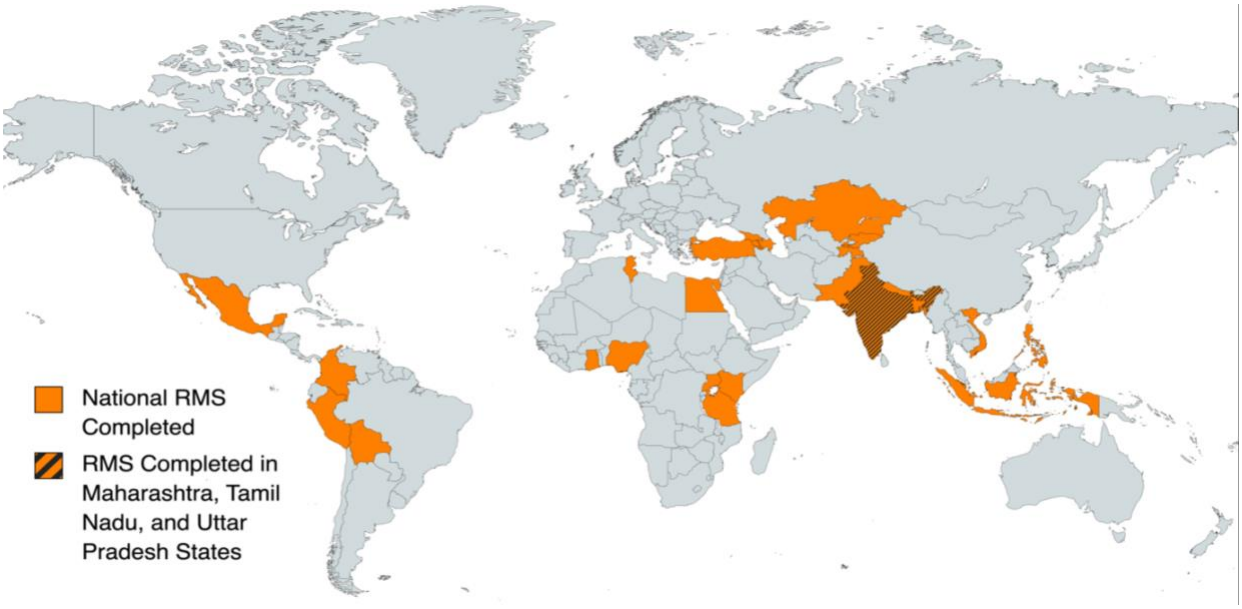
The RMS is a global assessment of lead (Pb) concentrations in more than 5,000 samples of consumer goods and foods from markets across 25 low- and middle-income countries.

What is new about this assessment and its findings?

While prior studies have identified lead in a variety of consumer goods, the geographic variations in lead exposure sources have been poorly understood. This assessment improves our understanding of which products are more likely to be contaminated, and how contamination levels vary across a diverse set of low- and middle-income countries.

Which countries were included?

The RMS was implemented in: Armenia; Azerbaijan; Bangladesh; Bolivia; Colombia; Egypt; Georgia; Ghana; the Indian states of Maharashtra, Tamil Nadu, and Uttar Pradesh; Indonesia; Kazakhstan; Kenya; Kyrgyzstan; Mexico; Nepal; Nigeria; Pakistan; Peru; the Philippines; Tajikistan; Tanzania; Tunisia; Türkiye; Uganda; and Vietnam.



What do “reference levels” and percentages mean in this report?

To contextualize the concentrations of lead found in various products, Pure Earth compared measured lead levels to “reference levels” for each product type. These reference levels come from existing public health guidelines and regulatory standards from United Nations agencies, the European Union, and the United States. Note that a lead concentration below a reference level does not mean a product is safe. There is no safe level of lead in blood, and thus exposure at any level can be harmful.

How should the RMS results be used?

Pure Earth recommends the RMS data be used to identify possible trends and products that warrant further attention and assessment. The data should be viewed as suggestive, not conclusive or representative of all similar products in these countries.

Results by Product Type

Across 5,010 samples from 25 countries, the following percentages of samples exceeded the relevant reference levels for that specific product type:

Across all 5,010 samples: 18% exceeded relevant reference levels

Ceramic foodware: 45% of 310 samples exceeded reference levels

Metallic foodware: 52% of 518 samples exceeded reference levels

Plastic foodware: 12% of 364 samples exceeded reference levels

Cosmetics: 12% of 815 samples exceeded reference levels

Toys: 13% of 781 samples exceeded reference levels

Paints intended for large surfaces: 41% of 437 samples exceeded reference levels

Paints for art, crafts, & special uses: 11% of 70 samples exceeded reference levels

Spices: 2% of 1085 samples exceeded reference levels

Sweets: 3% of 111 samples exceeded reference levels

Staple dry food (grains, flours, legumes): 1% of 362 samples exceeded reference levels

Traditional and herbal medicines: 4% of 54 samples exceeded reference levels

Results by Country (organized by regional groups)

The table below is organized by country and shows percentages of samples of each product and food category that exceeded the relevant reference level.

Region	Country	Ceramic foodware	Metallic foodware	Plastic foodware	Cosmetics	Toys	Paint - large surfaces	Paint - crafts/art	Spices	Sweets	Staple dry foods	Herbal/trad medicine
Caucasus	Armenia	36%	11%	6%	7%	3%	0%	0%*	4%	NA	11%	NA
Caucasus	Azerbaijan	100%	63%	60%*	10%	69%	100%	NA	0%*	NA	NA	NA
Caucasus	Georgia	48%	16%	0%*	0%	3%	50%*	7%	0%	NA	0%*	NA
C. Asia	Kazakhstan	NA	NA	NA	0%*	33%*	NA	NA	0%	NA	0%*	NA
C. Asia	Kyrgyzstan	44%	19%	13%	15%	6%	33%	NA	0%	NA	0%	NA
C. Asia	Tajikistan	100%*	NA	NA	0%*	0%*	NA	NA	60%*	NA	0%*	NA
S. S. Africa	Ghana	18%	55%	0%	7%	14%	0%*	0%*	0%	NA	0%	NA
S. S. Africa	Kenya	62%	53%	25%	6%	3%	36%	NA	0%	NA	0%	NA
S. S. Africa	Nigeria	29%	66%	4%	18%	16%	76%	NA	0%	NA	0%	NA
S. S. Africa	Tanzania	67%*	35%	4%	3%	10%	7%	NA	2%	3%	0%	NA
S. S. Africa	Uganda	8%	73%	20%	2%	0%	16%	NA	0%	NA	6%	100%*
L. America	Bolivia	60%	54%	14%	46%	6%	0%*	NA	0%	0%*	0%	NA
L. America	Colombia	50%	40%	24%	10%	12%	31%	11%	2%	0%	0%	0%
L. America	Mexico	67%	25%	8%	7%	22%	93%	NA	3%	4%	0%	0%*
L. America	Peru	42%	69%	17%	9%	2%	10%	0%	2%	NA	0%	0%*
MENA	Egypt	50%	55%	13%	42%	4%	0%*	NA	2%	NA	0%*	0%
MENA	Tunisia	56%	12%	4%	11%	4%	50%	NA	0%	NA	0%	17%
MENA	Türkiye	53%	67%	19%	100%*	29%	70%	NA	25%*	NA	NA	NA
S. Asia	Bangladesh	44%	59%	9%	6%	13%	0%*	50%*	7%	NA	17%	NA
S. Asia	Maharashtra, India	71%	63%	19%	3%	21%	19%	17%	0%	NA	0%	0%*
S. Asia	Tamil Nadu, India	50%	70%	14%	9%	23%	57%	NA	0%	NA	0%	NA
S. Asia	Uttar Pradesh, India	0%	65%	0%	2%	24%	42%	NA	12%	NA	0%*	0%*
S. Asia	Nepal	9%	100%	12%	0%	0%	0%	NA	0%	NA	0%	0%
S. Asia	Pakistan	20%*	75%	8%	30%	13%	35%	NA	9%	0%	0%	NA
SE Asia	Indonesia	NA	60%	NA	33%	10%	97%	NA	0%	NA	0%	NA
SE Asia	Philippines	13%	24%	0%	13%	6%	16%	0%*	0%	NA	2%	0%*
SE Asia	Vietnam	29%	56%	0%	23%	7%	59%	50%	3%	NA	0%	0%*

***** Results from 5 or fewer samples

Key recommendations from Pure Earth

1. **Blood lead level testing.** Few low- and middle-income countries conduct large surveys or ongoing monitoring of children's blood lead levels. The result is that we have little visibility into the prevalence, severity, and geographic distribution of lead poisoning for most countries. This is one of the largest impediments to solutions. Governments and their development partners should explore and invest in ways to generate primary data on children's blood lead levels so resources can be allocated appropriately, and so progress can be measured. The importance of blood lead level surveillance testing is highlighted by the identification of widespread lead exposure sources in low- and middle income-countries as part of the RMS.

2. **Home-Based Source Assessments.** Blood lead level surveys should be conducted in conjunction with in-home source analyses to establish connections between contaminated products and actual incidents of lead poisoning. During home-based source assessments, investigators asses a variety of products and environmental media in and around the homes of children with elevated blood lead levels. This combination of blood lead level testing with in-home source analysis can point to correlations between elevated blood lead levels and the presence of contaminated products like those highlighted in the RMS to help identify potentially significant local contributors to lead poisoning.

3. **Research into foodware leachability and use.** The high prevalence and wide geographic distribution of contaminated metallic and ceramic foodware was a surprise to Pure Earth's team. However, total lead levels in foodware, as measured in the RMS, provide only limited insights into the potential dangers from use. Total lead levels cannot yet tell us concretely what lead dose a person is likely to receive from each use of a pot or pan. While Pure Earth is conducting ongoing leachate testing of more than 100 aluminum pots to help answer these questions, field research is also needed to determine if lead contaminated foodware is used in settings where high concentrations of children could be exposed (e.g., schools, daycares, hospitals) and if the food prepared in such foodware is being contaminated. If contaminated foodware is used in settings with high concentrations of children and the food prepared in that foodware is becoming contaminated, interventions to replace contaminated foodware at these locations could be highly impactful at a relatively low cost.

   Given the extraordinary prevalence of contaminated metal foodware, research is needed to determine if there are ways to reduce the leachability of lead from metallic pots during or after production through the introduction of an additive, coating, or other means.

4. **Establishing recommended limits for total lead in foodware.** The RMS team did not find public health guidelines or regulatory standards for total lead concentrations in foodware from which to set reference levels. Instead, the RMS team created the reference level of 100 parts per million for foodware based on

guidelines for other products and on Pure Earth's ongoing research into foodware leachability. While some countries have limits for leachable lead in foodware, assessing the leachability of lead in a product generally requires a lab, which makes screening expensive and time consuming. Instead of establishing leachability limits, regulators should consider setting a maximum allowable concentration for total lead at the lowest achievable level. If exceptions are needed, regulations should force producers to demonstrate that products exceeding the allowable level would not leach lead into food under any condition.

5. **Track cosmetics to production sources.** There is a need to track commonly contaminated cosmetics to their production facilities and then work with governments and producers to eliminate lead use. Contaminated eyeliners, for example, can be bought through e-commerce retailers worldwide. Efforts to eliminate lead in such products could have global impacts.

6. **Enact and enforce lead paint laws.** All governments should enact and enforce regulations limiting lead in paint and consider guidance provided in the UNEP Model Law And Guidance for Regulating Lead Paint developed by the Global Alliance to Eliminate Lead Paint. Additionally, countries and their development partners should invest in monitoring and enforcement capacities to ensure strict regulatory compliance, taking into consideration the UNEP Lead Paint Law Compliance and Enforcement Guidance.

7. **Replicate programs to eradicate spice adulteration.** Successful efforts to stop the adulteration of spices with lead-based pigments in Bangladesh and Georgia should be adapted to other countries with similar challenges, particularly Northern India and Pakistan, where recent assessments suggest a pattern of adulteration.

Program Overview

The Rapid Market Screening program (RMS) aims to enhance our collective understanding of contaminated consumer products and foods that contribute to lead poisoning in low- and middle-income countries (LMICs). In 2020, Pure Earth and UNICEF released The Toxic Truth report, revealing that an estimated 800 million children, or one in every three, have blood lead levels indicative of lead poisoning (>5 µg/dL). This prevalence suggests that children worldwide are exposed to lead in their daily lives, particularly those in LMICs, where lead poisoning prevalence is highest.

Lead exposures are well documented around unsound industrial operations that use lead, particularly near informal and substandard lead smelting and lead-acid battery recycling operations. However, these industrial pollution sources generally affect limited numbers of people, often hundreds or perhaps thousands, who live, work, learn, or play nearby. Such pollution sources cannot explain the large numbers of children with elevated blood lead levels seen around the world, most of whom do not live near contaminated industrial sites. The findings of the RMS suggest that common consumer goods, paints, and some foods often contain concentrations of lead above relevant public health guidelines or regulatory standards and may contribute substantially to the prevalence of childhood lead poisoning.

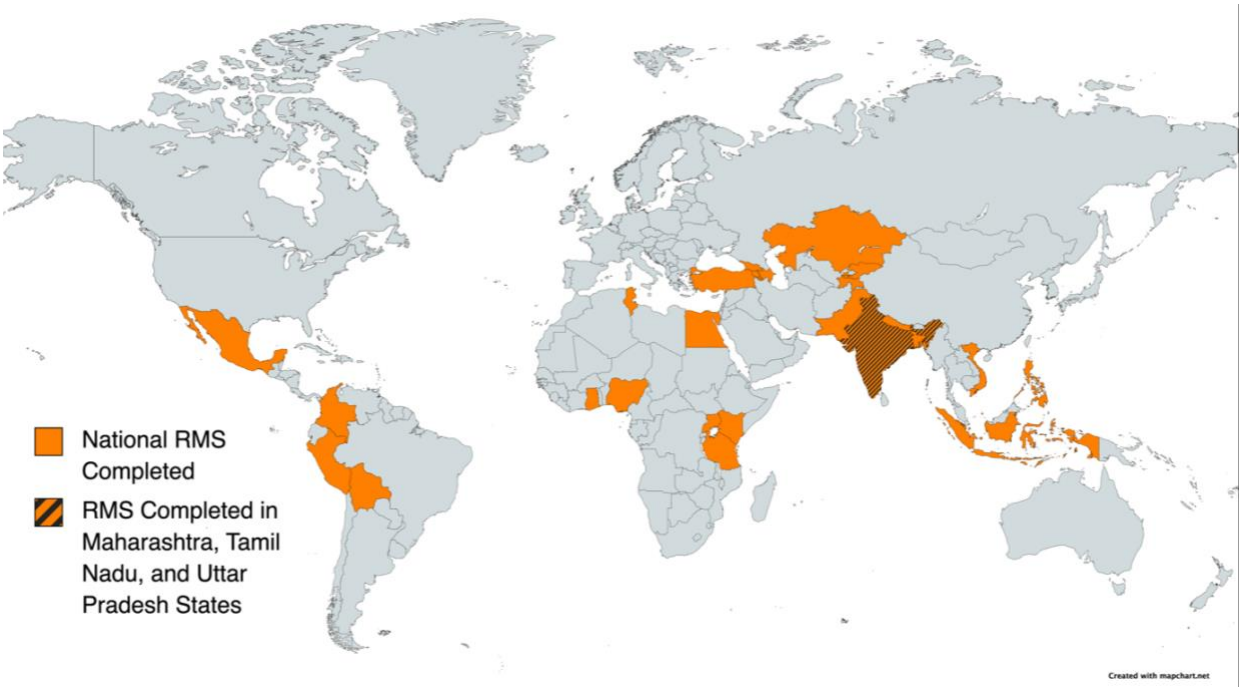
The sources of lead that contribute to lead poisoning vary by location, not only between countries, but also between provinces, cities, and even households. Prior studies of lead-contaminated goods have typically focused on a single product type in a single geographical region. The RMS provides a broader analysis of various goods from a geographically diverse set of 25 LMICs. By analyzing lead concentrations in over 5,000 consumer products and food samples from markets around the world, the RMS highlights lead sources that potentially affect large populations, exposing children and adults alike, often in their own kitchens.

This report highlights the primary findings from the RMS, as well as key observations and recommendations by Pure Earth. The results are presented first by product type (e.g., analytical results from all spice samples), and then by country (e.g., results for each product type sampled in Peru). The concentrations of lead found in the various product types are contextualized through comparisons with a “reference level” for each product type. These reference levels are from public health guidelines or recommended maximum levels published by United Nations (UN) agencies, or from regulatory standards from the European Union or United States, where available.

Product types analyzed through the RMS include ceramic foodware (cooking/serving pots and utensils), metallic foodware (predominantly aluminum), plastic foodware, cosmetics, toys, paints intended for large surfaces, paints intended for art and crafts, spices, sweets, staple dry foods, and herbal and traditional medicines.

The RMS was conducted in 25 countries, including India. However, given India’s large size and diversity, the RMS team decided to implement the RMS in three geographically diverse Indian states and to approach each state as if it were an independent country in

terms of how the RMS protocol was applied. In the end, the RMS was conducted in 27 study locations, including: Armenia; Azerbaijan; Bangladesh; Bolivia; Colombia; Egypt; Georgia; Ghana; the Indian states of Maharashtra, Tamil Nadu, and Uttar Pradesh; Indonesia; Kazakhstan; Kenya; Kyrgyzstan; Mexico; Nepal; Nigeria; Pakistan; Peru; the Philippines; Tajikistan; Tanzania; Tunisia; Türkiye; Uganda; and Vietnam.



Countries in which the RMS program was conducted.

The RMS was implemented between 2021 and 2023 and was supported by generous grants from Open Philanthropy, GiveWell, and the Effective Altruism Global Health and Development Fund.

Using This Report and Data

Pure Earth suggests readers pay special attention to the report sections titled Methodology, Study Limitations, and Decisions Made for This Report, and to the accompanying annexes, as each of these contains important information regarding the findings, how they are communicated, and how they should be understood and used. Pure Earth recommends that the RMS findings be viewed as suggestive of national and regional trends, not as conclusive or representative of all similar products in these countries. Where the RMS suggests a pattern

RMS findings should be viewed as suggestive of possible trends, not as conclusive or representative of all similar products in these countries.

of contamination within a product class, Pure Earth recommends that such findings be substantiated through more robust and targeted surveys or monitoring programs.

Pure Earth is committed to transparency and collaboration as core values. As part of our commitment to those values, we plan to release the full RMS dataset containing all sample information and measured lead concentrations so that stakeholders can use the data in different ways to identify trends, draw their own conclusions, and to advance solutions. However, as we also aim to publish RMS findings in a peer-reviewed journal, the release of the full dataset may occur after such publication due to publishing requirements of journals. When the full dataset becomes available, we will post it on a dedicated RMS page on Pure Earth's website.

Notable Findings and Recommendations

The RMS data suggest a variety of trends that Pure Earth finds particularly notable, and which could inform follow-up programs and policies to further identify and mitigate lead exposure sources. The following findings and recommendations are organized by product type, and include an "observation" (data that stood out), a "comment" (an explanation or discussion to add context), and a "recommendation" based on the observation. The "reference levels" cited for each product type are used to provide context regarding how the measured lead concentrations in products correspond to available public health guidelines or regulatory standards. Reference levels are discussed in greater detail in the section titled Decisions Made for This Report.

Metallic Foodware

Observation: Out of 518 samples of metallic foodware (mostly aluminum), 52% had lead concentrations exceeding the reference level of 100 ppm. All study locations had samples that exceeded the reference level by at least 2X. In 17 locations, the median sample exceeded the reference level. In 9 locations, the maximum value exceeded 10,000 ppm, or 1% lead.

Comment: As with ceramic foodware, the RMS results suggest that lead is common in metallic foodware across all regions. Most samples in the metallic foodware category were made primarily of aluminum, although this category also included some items made from brass, copper and iron alloys. Pure Earth is currently conducting leaching tests on over 100 aluminum foodware samples to better understand the relationship between total lead levels and the amount of lead that leaches through use (see the "Leachate Testing of Aluminum Cookware" section of this report). Early results indicate that exposures from this source could be substantial. Pure Earth will publish a subsequent report specifically detailing the findings of leaching tests.

Recommendation: Beyond Pure Earth's ongoing leaching tests, more research is needed into correlations between total lead level that can be measured by XRF and leachable lead that comes out during food preparation.

Recommendation: Instead of establishing regulations that set a maximum value of leachable lead, regulators should consider setting a maximum allowable concentration for total lead at the lowest achievable level. If exceptions are needed, regulations should force producers to demonstrate that products exceeding the allowable level would not leach lead into food under any condition.

Recommendation: There is an immediate need to understand if metallic pots used to prepare food in schools, hospitals, and other locations with high concentrations of children contribute to lead poisoning. If so, this would represent an urgent but also a highly concentrated and solvable problem. Interventions to replace contaminated foodware in schools and other locations with safe alternatives could have large impacts at low cost.

Recommendation: Additional research is needed to determine if there are ways to reduce the leachability of lead from pots through the introduction of an additive, coating, or other means.

Ceramic Foodware

Observation: RMS results suggest that elevated lead levels in ceramic coatings (glazes and paints) are widespread. Out of 310 samples of ceramic foodware, 45% had lead concentrations exceeding the reference level of 100 parts per million (ppm). In 11 locations, the median sample exceeded the reference level, suggesting that contaminated items are common. In 25 of the study locations (all but Pakistan and Uttar Pradesh State, India), the maximum lead level was more than 10 times the reference level.

Comment: The RMS has revealed a higher prevalence and geographic distribution of lead in ceramic foodware than the Pure Earth team expected. The lead that was found was in the exterior glaze or decorative paint, not in the clay itself. Challenges regarding the use of lead-based glazes have been well-documented in Mexico, and have been identified elsewhere, but the RMS shows a fairly uniform geographic distribution of contaminated items. This does not necessarily mean that these pieces all contribute to exposure equally. As with all forms of foodware, a high lead concentration on exterior surfaces does not tell us how much lead is leaching into food. The type of glaze, temperature in which it is fired, types of food prepared or served, and ways in which the item is used can all affect leachability and thus exposure. Readers should note that ceramics with high concentrations of lead were not limited to handmade, artisanal, or traditional pieces, but included mass-produced pieces that may have been imported to the country where they were purchased.

Recommendation: Research into the relationship between XRF values and leachable lead per use is needed to better understand the contribution of ceramics to lead poisoning. Additionally, research into alternative glazes and production processes is needed to facilitate a transition to lead-free products.

Recommendation: Governments should establish appropriate regulations and enforcement capacities to prevent the manufacture and sale of ceramic foodware that is prone to leaching lead into food.

Recommendation: Governments and civil society groups should collaborate to help ceramic producers transition to lead-free production. Ongoing programs in Mexico may serve as a model.

Plastic Foodware

Observation: Concentrations of lead in plastic foodware were generally much lower than in ceramic or metal foodware. Out of 364 samples, 12% had concentrations of lead exceeding the reference level.

Comment: Without a better understanding of potential doses per use through leaching tests, we remain unsure about risks associated with the lead concentrations that we have observed.

Recommendation: Research is needed to better understand the relationship between total lead concentrations in plastic foodware and lead doses per use.

Cosmetics

Observation: Out of 815 cosmetics samples, 12% exceeded the reference level of 2 ppm. A variety of cosmetic products were collected and divided into subcategories. Notably, elevated lead levels were identified across nearly all subcategories. The geographic distribution of contaminated cosmetics was also wide, with elevated lead levels found in 21 countries.

The two items with the highest lead concentrations were both eyeliners, known as kajal or kohl, from Pakistan. Lab results from these two products showed lead concentrations of 290,000 and 320,000 (equivalent to 29 and 32% lead, respectively). The item with the third highest concentration of lead (128,400 ppm) was a face paint intended specifically for children. Among the samples with elevated lead levels, the most common item was nail polish (29 items), which had a maximum lead concentration of 6,751 ppm, followed by lipstick (15 items, maximum lead concentration of 42,350 ppm), and eyeshadow (13 items, maximum lead concentration of 974 ppm). Finally, lead levels above the reference level were also found in face powder, mascara, liquid foundation/concealer, and hair products.

Comment: There have been a variety of studies showing elevated lead levels in certain traditional eyeliners and religious powders, but the RMS shows that contamination in cosmetics is broader than these product types.

Recommendation: There is a need to track commonly contaminated products to their production facilities and then work with governments, producers, and other stakeholders to eliminate lead contamination. Contaminated eyeliners, for example, can be bought

through e-commerce retailers, and efforts to eliminate lead in such products could have global impacts.

Toys

Observation: Out of 781 toy samples, 13% had lead levels exceeding the reference level of 100 ppm. Samples from Azerbaijan stand out as outliers, with 69% of 26 toy samples exceeding the relevant reference level.

Comment: While a lower percentage of toy samples exceeded the relevant reference level than some other product categories, the fact that toys are used by children may increase the risk of exposure, as children tend to put toys in their mouths.

Recommendation: Due to children's extreme vulnerability to lead poisoning and their tendency to put toys in their mouth, the safety of toys should be a top priority for regulators. We recommend that all countries enact and enforce strict limits on lead concentrations in toys and that LMIC governments work with development partners to ensure they have the capacity to monitor items and enforce regulations.

Paints

Observation: Out of a total of 437 samples of paint that the RMS Investigators categorized as "intended for large surfaces," 41% of samples showed lead levels exceeding the reference level of 90 ppm. Out of 70 samples of paint categorized as "intended for crafts, art, and other specialty uses," 11% showed lead levels exceeding 90 ppm. Among 102 paint samples that could not be confidently classified into one of the two categories above, 47% showed lead concentrations exceeding 90 ppm. More than half of the study locations (14 of 27) had maximum lead concentrations exceeding 10,000 ppm, while 10 locations had samples exceeding 20,000 ppm.

Comment: As of March 2023, 48% of countries in the world had legally binding controls on lead concentrations in paints. Many of these have adopted regulations based on a model law establishing a maximum lead concentration of 90 ppm. However, many of the paint samples analyzed through the RMS that exceeded 90 ppm were collected from countries that have a 90ppm regulatory limit. For example, 8 of the countries and Indian States that have such regulations had more than 10% of paint samples exceed 90 ppm. This suggests a considerable enforcement gap in these locations.

Recommendation: All governments should enact and enforce regulations limiting lead in paint and consider guidance provided in the UNEP Model Law And Guidance for Regulating Lead Paint developed by the Global Alliance to Eliminate Lead Paint. Additionally, countries and their development partners should invest in monitoring and enforcement capacities to ensure strict regulatory compliance, taking into consideration the UNEP Lead Paint Law Compliance and Enforcement Guidance.

Spices

Observation: Out of 1084 spice samples, 2% exceeded the reference level of 2 ppm. A high prevalence of elevated lead levels was found in spices from Uttar Pradesh State, India, and from Pakistan, with 12% and 9% of samples exceeding the relevant reference levels, respectively.

Comment: Lead contamination of certain varieties of spices from South Asia has been documented in the past, particularly in Bangladesh, where researchers from Stanford University and the Bangladesh health research institute, icddr,b, have documented producers adulterating turmeric with pigments containing lead chromate to improve the color of the product. More recent assessments have shown that spice contamination exists across South Asia. While RMS samples from Nepal did not reveal elevated lead levels, the RMS results suggest that both Pakistan and Northern India may have substantial challenges regarding spice contamination. Other countries are likely to have similar problems but were not reviewed as a part of the RMS. These countries include other Central Asia countries, as well as those in the Middle East and Northern Africa. Note that there was some uncertainty within the RMS Quality Control Team regarding lead levels in spice samples from Pakistan, as is discussed in the Quality Control section.

Recommendation: Pure Earth recommends further testing to confirm lead levels in spices in Pakistan and across Northern India. Given the enormous populations potentially at risk, Pure Earth recommends interventions in Pakistan (if warranted by additional testing) and Northern India to monitor lead levels in spices; track contaminated spices back to production facilities; educate producers and consumers regarding relevant risks, regulations, and measures to reduce risk; and assist relevant agencies to ensure they have the resources and capacities to enforce regulations and update them if necessary.

Observation: The RMS did not reveal significant spice contamination in Bangladesh or Georgia, where interventions to reduce spice adulteration have been implemented. Maximum lead concentrations identified through the RMS were 4 ppm in Bangladesh and “non-detect” in Georgia.

Comment: This finding is notable as both Bangladesh and Georgia have had well researched and publicized issues in the past regarding spice adulteration with lead chromate to enhance color. In Bangladesh, producers were adulterating turmeric in this way, while in Georgia, producers were adulterating spices containing yellow marigold flowers (also known as Georgian saffron or kviteli kvavili). Importantly, in both Bangladesh and Georgia, civil society groups collaborated with government regulators to implement activities to halt such adulteration. The low levels of lead found in Bangladesh and Georgia through the RMS are supported by other recent spice sampling programs that also documented steep declines in lead levels after the recent interventions to stop adulteration. These findings suggest that these interventions may have succeeded, or at least contributed to recent declines.

Recommendation: Recent programs aimed at stopping spice adulteration with lead-based pigments in Bangladesh and Georgia should be studied and adapted to other

countries with similar challenges, particularly Northern India and Pakistan, where recent assessments suggest a high prevalence of contaminated spices.

Observation: The RMS results suggest the presence of lead-contaminated spices in Tajikistan.

Comment: Unfortunately, a quality control issue regarding one of the XRF analyzers used in Central Asia resulted in Pure Earth rejecting field XRF results from spices analyzed in Kazakhstan and Tajikistan. However, a subset of Tajik spice samples analyzed in an accredited laboratory in the US revealed highly elevated lead levels in 3 out of 5 samples. The three samples that exceeded the reference level were all turmeric purchased from three different markets, with laboratory lead levels ranging from 66 to 320 ppm. However, field XRF results from Kyrgyzstan and a selection of 8 samples from Kazakhstan that were tested with a validated XRF, as well as a subset tested in a lab, did not reveal elevated lead levels. This suggests that Kazakhstan and Kyrgyzstan may not share supply chains with Tajikistan.

Recommendation: A national spice testing program is needed in Tajikistan focused on spice varieties that have been shown to have lead contamination, particularly turmeric.

Sweets

Observation: The RMS did not reveal significant contamination of sweets.

Staple Dry Foods

Observation: Out of 364 samples of staple dry foods, the RMS revealed only occasional contamination. Among the countries where contamination was detected, Bangladesh had 17% of samples exceeding the reference level, Armenia had 11%, Uganda had 6%, and the Philippines had 2%. The maximum observed concentration was 17 ppm.

Herbal/Traditional Medicines

Observation: Only two of the 54 traditional medicine samples exceeded the reference level of 10 ppm, representing 4% of samples.

Comment: This sample size is likely too small to draw conclusions. Other studies have shown considerable lead contamination among medicines from the rasa shastra branch of Ayurveda, from Chinese medicines known as Ba-baw-san, from a digestive aid used in Thailand and Myanmar known as Daw Tway, and from Greta and Azarcon (also known as alarcon, coral, luiga, maria luisa, or rueda) which are Hispanic traditional medicines.

General Recommendations:

Blood lead level testing. Few low- and middle-income countries conduct large surveys or ongoing monitoring of children's blood lead levels. The result is that we have little visibility into the prevalence, severity, and geographic distribution of lead poisoning for most countries. This is one of the largest impediments to solutions. Governments and their development partners should explore and invest in ways to generate primary data on children's blood lead levels so resources can be allocated appropriately, and so progress can be measured. The importance of blood lead level surveillance is highlighted by the identification of lead exposure sources in low- and middle income-countries through the RMS.

Home-Based Source Assessments. Blood lead level surveys should be conducted in conjunction with in-home analyses of potential exposure sources to establish connections between contaminated products and actual incidents of lead poisoning. During home-based source assessments, investigators asses a variety of products and environmental media in and around the homes of children with elevated blood lead levels. This combination of blood lead level testing with in-home source analysis can point to correlations between elevated blood lead levels and the presence of specific products and help identify potentially significant local contributors to lead poisoning.

Regulatory enforcement. Many of the RMS countries have regulations limiting lead levels in consumer goods and foods (e.g., paints, spices), but the RMS results suggest that enforcement is lacking. Governments and their development partners should assess where there are enforcement gaps and invest in additional monitoring and enforcement capacities.

Methodology

The RMS aims to answer the following questions:

1. What concentrations of lead exist among product types that previous studies have identified as containing lead in the RMS countries?
2. What concentrations of lead exist among *other* common consumer products and foods that have not been previously identified as containing lead in the RMS countries, but have been found to contain lead in *other* countries?
3. Within each product type sampled, what is the statistical distribution of lead concentrations across the samples, and how do distributions vary by country?
4. How do the concentrations of lead in each product type compare to available regulatory standards or health guidelines?
5. What product types in each study location stand out as potentially significant contributors to lead poisoning and therefore warrant more attention and analysis?
6. What other observations, trends, lessons, and recommendations can be drawn from both the results *and* the implementation of the RMS that could help Pure Earth and other actors design and carry out more effective and efficient lead poisoning research and mitigation programs?

Country Selection

The factors that influenced the selection of RMS countries included: a desire to include 25 LMICs; a desire for geographic diversity; a focus on countries with a high prevalence and/or severity of childhood lead poisoning according to existing studies or estimates; existing Pure Earth or partner capacity to implement the program; safety; cost; ability to import analytical equipment, and other feasibility factors.

Due to the high prevalence and severity of childhood lead poisoning in India, and the country's unusual size and diversity, the RMS was implemented in three Indian states as if they were independent countries. This means that rather than visiting markets in three or four cities across all of India, as was done in other countries, the RMS Investigators visited markets in three cities in each of Maharashtra, Tamil Nadu, and Uttar Pradesh. The results from each state are reported separately.

Product Selection

The types of products sampled through the RMS were selected following a series of desk assessments that reviewed literature on lead concentrations in a variety of products in LMICs. In selecting product types to analyze, Pure Earth desired a degree of uniformity across all RMS countries, but also flexibility based on local contexts. We wanted to ensure that we could generate additional data on product types that were shown to contain lead in prior studies, but also potentially identify contaminated products that had not yet been previously identified as containing lead. Ultimately, 11 product types were selected for analysis: ceramic foodware, metal foodware, plastic foodware, cosmetics, toys, paints intended for large surfaces, paints for art and crafts, spices, sweets, staple dry foods, and traditional and herbal medicines. To allow flexibility and account for local behaviors and contexts, the RMS Investigators were permitted to exclude and add certain product types upon consultation with the RMS program managers.

Desk Assessments

Before purchasing and analyzing any products, RMS Investigators in each country and Indian state completed a desk assessment to review previous research on lead poisoning and contamination in local products and foods.

Local Market Selection

RMS Investigators in each country selected three or four geographically diverse cities, and in each city, selected, when possible, at least one wholesale bazaar and one retail market from which to purchase items. Within each market, RMS Investigators interviewed and purchased from at least two vendors. The names and locations of markets and individual vendors are attached to each sample log in the RMS database.

Data Collection and Product Testing

An RMS Protocol was developed by Pure Earth staff with external expert review prior to implementation (available as Annex A on Pure Earth's RMS web page). The Protocol

describes the information to collect about each market, vendor, and item, and includes standardized analytical approaches for each product type. The primary analytical tools used for the RMS were portable X-ray fluorescence analyzers (XRF). The protocol outlined how to prepare each item for testing and specified the number of XRF readings required for each item. In every country except Bangladesh, samples were analyzed with a Thermo Scientific Niton XL3T XRF, using the "Test All" mode, which is designed for consumer goods. In Bangladesh, an Olympus Vanta Series C was used in "Soil" mode. All data collected by the RMS Investigators was entered into a central database using the platform SurveyCTO. Subsets of samples from each country were sent to Pure Earth's Headquarters in New York for confirmatory analysis, as discussed in the Quality Control section.

Study Limitations

Hazard Assessment, Not Source Apportionment

The RMS is a hazard identification and assessment program. While it is the largest and most diverse study of lead contamination in consumer goods from LMICs that Pure Earth is aware of, it is not designed to apportion exposures by product types. The data cannot, for example, be used to conclude that product X is responsible for Y% of lead poisoning in country Z. The RMS does not assess the frequency of product use, the likely lead dose from each use, the actual prevalence and severity of lead poisoning among local populations, exposures to other lead sources such as environmental media, or other data necessary for a full source apportionment analysis. We recommend the data be used to identify possible trends and highlight products that warrant further investigation and attention.

Analytical Limitations

RMS field data were generated using portable XRFs. The XRF is a valuable screening device for this type of program because once an XRF is procured, analysis is instant, free, and relatively consistent with laboratory results. In all but one country, the same Thermo Scientific Niton XL3T model of XRF was used, and samples were analyzed in the same "Test All" mode designated for consumer goods. RMS Investigators were instructed to regularly confirm the accuracy of the XRFs against the provided "standard" samples with known lead concentrations.

The use of XRFs avoided reliance on the availability of suitable and reliable local laboratories, which can vary considerably in LMICs. Even where reliable labs exist, the cost per sample can be prohibitive for a large screening program. Furthermore, relying primarily on lab analysis may have resulted in products being analyzed with different methods, equipment, and quality assurance protocols.

While XRFs are well suited for screening programs, they have limitations. The XRF is not able to detect as low of a concentration of lead as certain lab techniques. The Thermo Scientific Niton XL3T does not have one single detection limit. Rather, the limit

depends on the material being analyzed, and even varies from sample to sample within a product type. For example, the detection limit is often ~2 to 3 ppm for spices, but ~50 ppm for metal foodware. The XRF's detection limit is important to consider in relation to the reference levels used in this report (discussed below). For some products like spices and cosmetics, the limit of detection is very close to the reference level (2 ppm), meaning that the XRF may not detect lead even if lab analysis would reveal a concentration above the reference level. The consistency and accuracy of the XRFs compared with confirmatory lab testing is discussed in greater detail in the Quality Control section.

Sample Sizes

The RMS budget and timeline allowed for ~150 to 300 samples to be analyzed per country. Generally, Pure Earth analyzed 10 to 50 samples of each product type in each study location. Given the small sample sizes, the results should be considered suggestive only. Pure Earth suggests readers avoid drawing conclusions from cases where samples sizes are very small.

Product Origins

Some products purchased for the RMS may have been imported into the RMS country rather than produced locally. This fact may not affect the product's impact on local users, but may affect the design of intervention programs.

No Environmental Data

The RMS focuses on consumer products and foods, and does not include environmental media such as soil, water, air, or household dust which often contribute to lead poisoning. Pure Earth implements a separate program called the Toxic Sites Identification Program that identifies and assesses locations contaminated by chemical pollution, including lead, and stores that information in a publicly available database.

Decisions Made for This Report

Reference Levels

To provide context to the concentrations of lead found in the various products, Pure Earth selected a “reference level” for each product type. These reference levels serve as thresholds indicating where UN agencies or particularly well-resourced regulatory authorities have established public health guidance, a level of concern, or a regulatory limit for lead in each product class. Although countries often have unique standards for lead concentrations in different products, Pure Earth has included a uniform reference level for each product type to facilitate comparisons across countries.

The inclusion of uniform reference levels is not a suggestion that any one guidance value or regulatory standard is superior to any other, or that concentrations below the reference levels are safe. Rather, the reference levels used here are simply an attempt to contextualize concentrations and highlight particularly concerning results. We selected existing regulatory standards and guidance values promulgated by UN agencies, the European Union, and the United States, prioritized in that order.

Pure Earth could not identify existing reference levels for total lead in foodware (items used to cook, serve, consume, and store food). While standards for leachable lead from foodware exist, field testing of leachable lead in foodware was not possible. Pure Earth has engaged in a substantial effort to test the degree to which lead leaches from metallic foodware (mostly aluminum) with a variety of lead concentrations under various cooking scenarios. This effort and some of the initial findings are discussed in greater detail in the Leachate Testing of Aluminum Cookware section.

This report uses a reference level of 100 ppm for all types of foodware. Readers should note that this level is not based on an existing regulatory standard, and that lead doses per use likely vary between categories of foodware, and indeed between individual products. The lead dose per use is likely also affected by the type of food prepared, the method and duration of cooking, and other contextual factors.

In the absence of any available standards for total lead content for these categories of foodware, we used the US Consumer Product Safety Commission total lead standard for “children’s products” (also used in this report for the category of toys). At this stage, we were only able to conduct leaching tests on metal foodware, but the results of such tests support the use of 100 ppm as a conservative threshold below which the concentration of lead in leachate is generally below the WHO drinking water standard of 10 ppb (17 out of 18 pots tested). Please see the “Leachate Testing of Aluminum Cookware” section of this report for more detailed information.

Reference Levels and measured lead levels in this report are expressed in parts per million of lead (ppm), which is equivalent to milligrams per kilogram (mg/kg). The following reference levels are used in this report:

- Ceramic foodware: 100 ppm*
- Metal foodware: 100 ppm*
- Plastic foodware: 100pmm*
- Cosmetics: 2 ppm (EU/Germany)**
- Toys: 100 ppm (US)***
- Paint: 90 ppm (UNEP)
- Spices: 2 ppm (EU)****
- Sweets: 0.1 ppm (US)
- Staple Dry Foods: 0.2 ppm (FAO)
- Herbal/traditional medicines: 10 ppm (WHO)

* As explained in the text above Pure Earth applied 100 pm as reference level for foodware
**EU regulations state that cosmetics cannot contain heavy metals. They provide exceptions for unavoidable concentrations but do not define these. The German Office of Consumer Protection and Food Safety states that for most cosmetics, levels above 2 ppm are avoidable.
*** The EU has a toy standard, but it is a "migration" standard that measures lead leaching from products during an acid bath and is not applicable to XRF measurements of total lead.
**** The EU has several regulatory levels that apply to various spice types. 2 ppm is the highest.

Note that for items where multiple XRF readings were taken, the highest reading was used in the analyses presented in this report.

No Averages/Means

A significant portion of the XRF results were "non-detect," indicating a lead concentration below the XRF's lower detection limit. Including "non-detect" readings in calculations to create an average requires the use of a substitute value (e.g., the level of detection divided by the square root of 2). With a high percentage of "non-detect" readings, such a substitution can skew the results. However, "non-detect" readings can be used in the reporting of minimum, median, maximum, and quartile values, which are included in this report.

Classifying Products

RMS Investigators analyzed some items that could reasonably be placed into multiple categories. In such cases, the Quality Control team categorized items based on what they believed was the dominant usage globally, and then applied that category to all identical items from all countries. For example, turmeric is categorized as a spice in all countries, even though some people may use it primarily for medicinal properties. The major implication for classifying an item as either a spice or a medicine is the reference level, which is 2 ppm for spices, but 10 ppm for medicines, meaning the same item may appear to pose a greater risk if it is classified as a spice than if classified as a medicine.

The Quality Control team used the classification system used by FAO's CODEX Committee on Spices and Culinary Herbs, which identifies seven types of spices: dried

fruits and berries, dried roots, rhizomes and bulbs, dried seeds, dried floral parts, dried bark, dried leaves, and herbs. The team also included spice or seasoning mixtures with components from these categories. Any food additives that did not fall into one of these categories, was categorized as “other foods.”

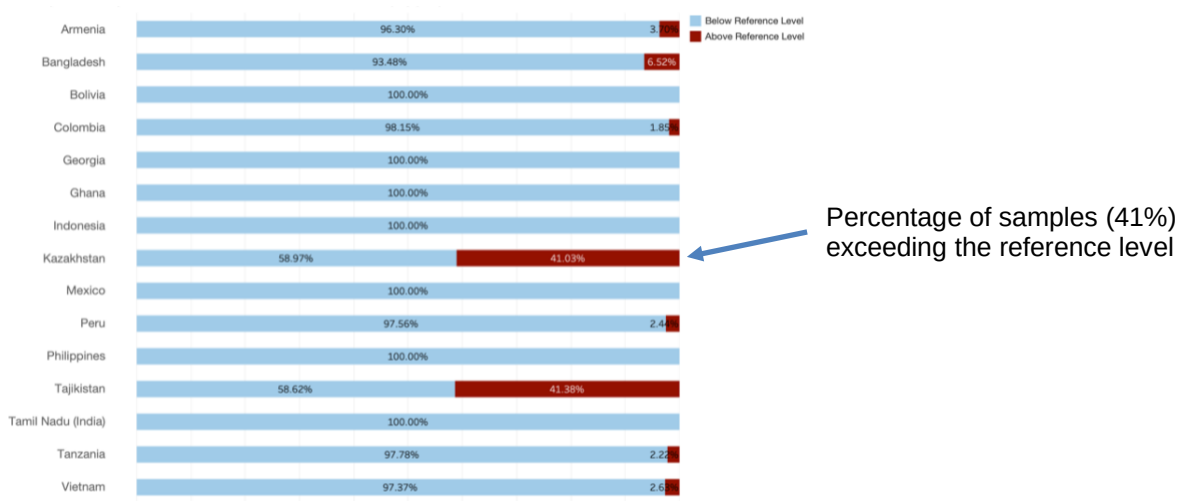
Not all Samples Reported

Pure Earth analyzed more than 5,000 individual samples through the RMS, but not all samples are reflected in this summary report. Most samples that are not included here were excluded because they did not fit neatly into the 11 product categories presented here. Other samples were expunged for quality control concerns. Pure Earth aims to release the full dataset after publishing the RMS results in a peer-reviewed journal.

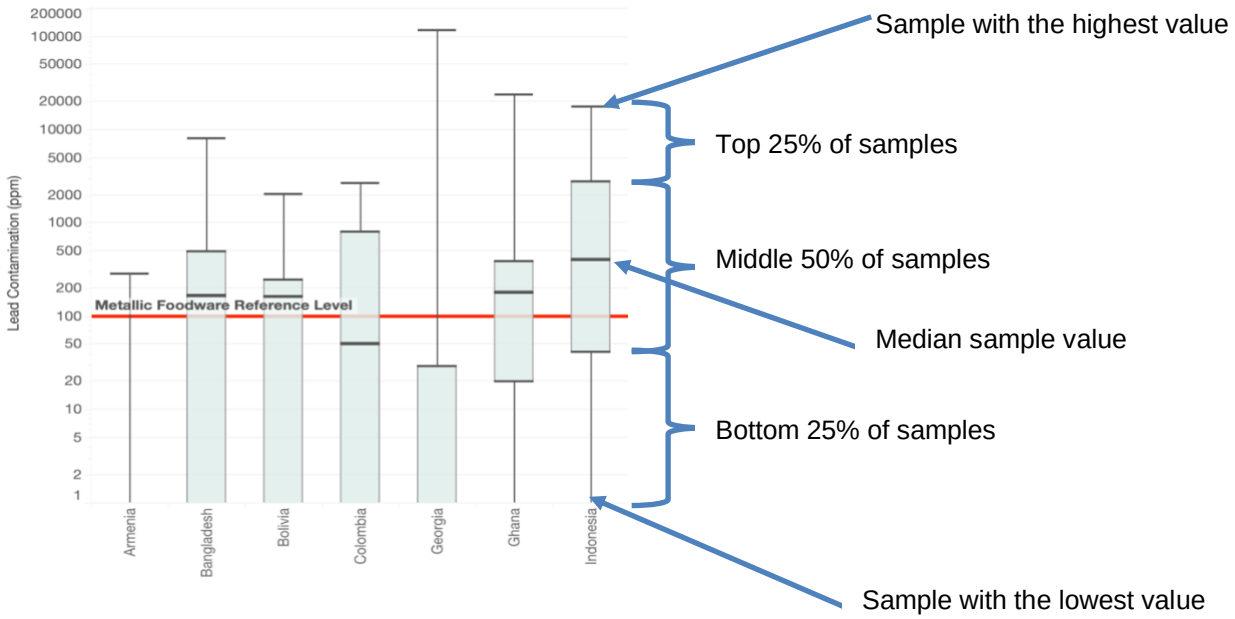
Chart Types and How to Interpret Them

The following types of charts are used to help communicate RMS findings:

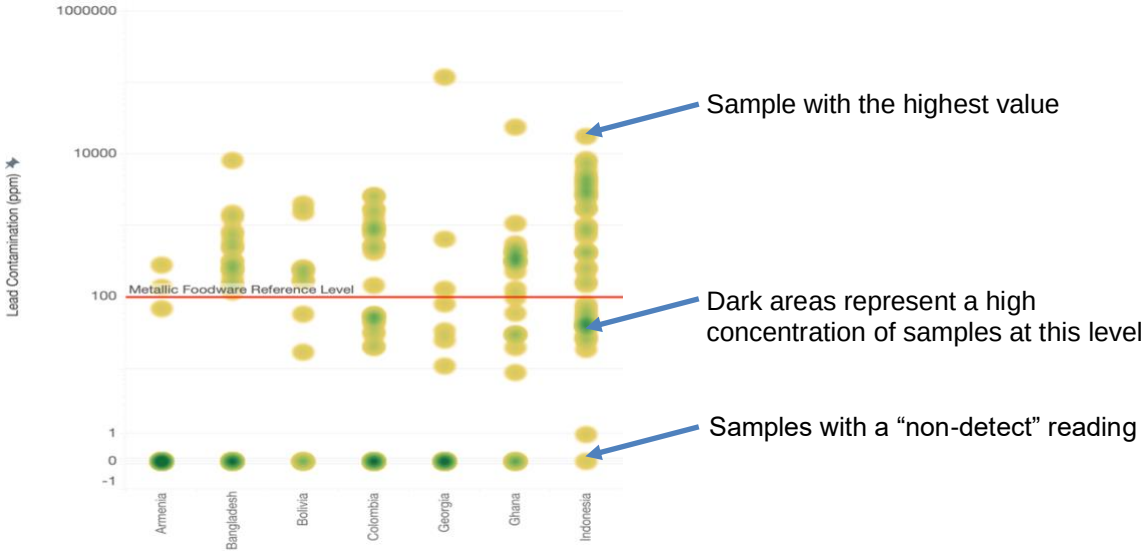
1. This chart type shows the percent of samples with lead concentrations below the reference level in blue and above the reference in red.



2. The “box and whisker” plots reveal where each quartile of samples (bottom 25%, 25-50%, 50-75%, and top 25%) sits compared to the reference level. Readers should note that the Y axis uses a logarithmic scale rather than a linear scale, meaning that as you move up the Y axis, the incremental change in values between each horizontal line increases dramatically.



3. The final chart type shows the distribution of individual sampling results through color intensity. The darker the color, the higher the concentration of results at that lead level. Readers should again note the logarithmic scale on the Y axis.



Findings by Product Type

Out of a total of 5,010 product samples from 25 countries, 916 samples had concentrations of lead exceeding the relevant reference level based on XRF readings, representing 18% of all samples. As shown in the table below, metallic foodware, ceramic foodware, and paints most frequently exceeded the relevant reference levels.

Summary of Sample Distribution by Product Category

Product Category	Total # of Samples	Min Value (ppm)	25th% (ppm)	Median (ppm)	75th% (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	310	ND	30	72	3665	397100	45
Metallic foodware	518	ND	ND	124	754	119500	52
Plastic foodware	364	ND	ND	ND	ND	3289	12
Cosmetics	815	ND	ND	ND	ND	1000000	12
Toys	781	ND	ND	ND	13	97300	13
Paint - large surface	437	ND	ND	1	1518	807309	41
Paint - craft/art	70	ND	ND	ND	ND	93500	11
Paint - unclassified	102	ND	ND	10	3400	79000	47
Spices	1084	ND	ND	ND	ND	622	2
Sweets	111	ND	ND	ND	ND	5	3
Staple Dry Foods	364	ND	ND	ND	ND	17	1
Herbal/Trad Medicines	54	ND	ND	ND	ND	31	4

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Ceramic Foodware

One of the most interesting RMS findings is the high prevalence and wide geographic distribution of ceramic foodware with elevated lead levels. Out of 310 ceramic foodware samples analyzed across the 27 study locations, 45% had lead concentrations exceeding the reference level of 100 ppm.

The lead found in ceramics samples is generally not in the clay itself, but in the glaze or paint coating. Many of the ceramic samples analyzed in the RMS had heterogeneous coatings, with multiple colors or differences between interior and exterior coating. Investigators were asked to take at least 3 readings per item, prioritizing measurements in the inside of the item where food or drink would come in contact. As with all categories, the highest lead reading was used where we had multiple readings for the same item.

The use of lead-based glazes has been well documented in Mexico and several other Latin American countries, but the RMS reveals that contamination is highly prevalent across all regions. That is not to say that all regions have the same exposure risks. The leachability of lead from ceramics coatings is influenced by the type of glaze and the conditions under which it is fired and used. Certain lead-based glazes fired under comparably low temperatures in wood-burning kilns in Mexico, for example, have been shown to be highly leachable in the presence of hot or acidic foods and are believed to

contribute substantially to lead exposures. Other glazes that contain lead but are fired at higher temperatures may leach less and thus contribute less to exposure. Additionally, ceramic products that contain lead, but which do not contact hot or acidic foods may leach less. The leachability of lead from various ceramic glazes produced and used under different conditions is an area that requires further research.

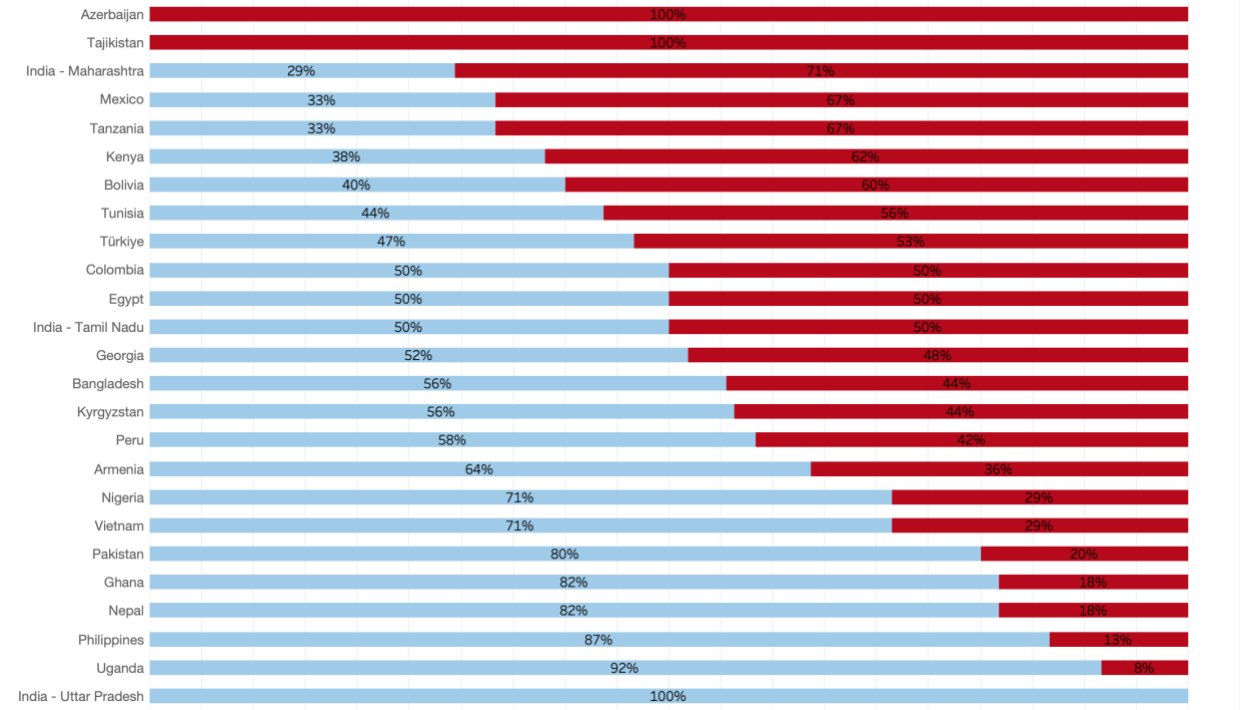
Summary of Ceramic Foodware Results by Country

Country name	# of Samples	Min Value (ppm)	Median Value (ppm)	Maximum Value (ppm)	% Above Reference
Armenia	11	ND	58	9280	36
Azerbaijan	13	312	774	11400	100
Bangladesh	9	ND	22	4636	44
Bolivia	10	35	131853	397100	60
Colombia	18	ND	237	29100	50
Egypt	10	ND	158	50600	50
Georgia	27	ND	76	13200	48
Ghana	11	30	50	6570	18
India - Maharashtra	17	ND	1910	80000	71
India - Tamil Nadu	8	ND	75	5230	50
India - Uttar Pradesh	6	ND	20	80	0
Kenya	21	ND	4210	91000	62
Kyrgyzstan	16	ND	73	240500	44
Mexico	6	ND	19215	65700	67
Nepal	11	ND	ND	9220	18
Nigeria	21	20	40	46000	29
Pakistan	5	ND	69	103	20
Peru	12	ND	65	18600	42
Philippines	15	ND	35	1159	13

Tajikistan	3	100700	133400	266000	100
Tanzania	3	20	7780	22300	67
Tunisia	16	ND	251	68600	56
Türkiye	15	ND	119	14300	53
Uganda	12	17	23	6092	8
Vietnam	14	ND	59	19789	29

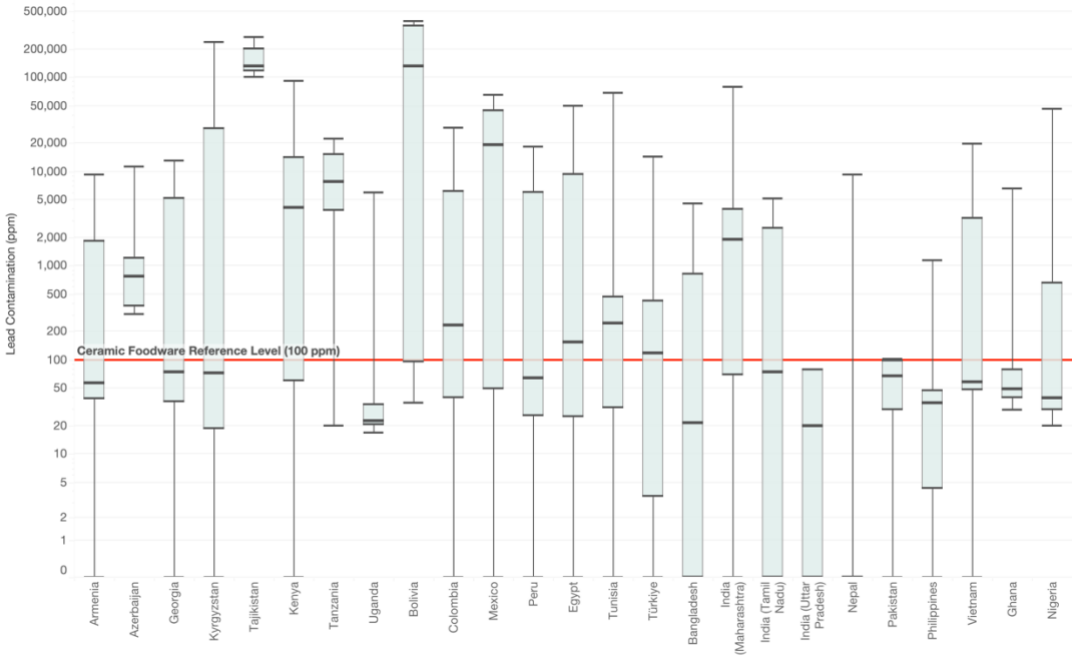
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage Of Ceramic Samples Below and Above the Reference Level by Country



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Small sample size in Tajikistan and Tanzania.

Distribution of Ceramic Foodware Sampling Results by Quartile



Distribution of Ceramic Foodware Sampling Results by Individual Samples

Metallic Foodware

Out of 518 samples of metallic foodware, 52% exceeded the reference level of 100 ppm. Previous studies have highlighted elevated lead levels in metallic foodware made in LMICs, particularly in inexpensive aluminum foodware. These pots are generally light, inexpensive, and have good conductivity, which helps conserve fuel usage. Some of this foodware is believed to be made from mixed recycled metals from engine parts, radiators, aluminum cans, and construction materials.[1] Among Pure Earth's recommendations is the need to further identify lead sources contributing to contamination in recycled metals.

This study analyzed a wide variety of foodware items and materials. Samples included both small-batch, informally produced items, as well as large-scale, commercially produced items. Of the items in the metallic foodware category that were found to be above the reference level, 69% were pots and pans, 17% were vessels for food or water not intended to be exposed to direct heat, and 14% were cooking utensils.

Across all item types, 57% of the items found to be above the reference level were reported to be made of, or labeled as aluminum or aluminum alloys. For 35% of the items, we were not able to determine the metal composition based on the item description or label. None of the other metal types—including brass, copper, and iron alloys—exceeded 5% of the total number of items found to be above the reference level.

Readers should note that the total lead content in foodware samples does not reflect leachable lead. To improve our understanding of potential doses of lead per use, Pure Earth is conducting leachability testing of more than 100 aluminum foodware samples. A description of this program and the early findings is included in this section below the following tables and charts.

Summary of Metallic Foodware Results by Country

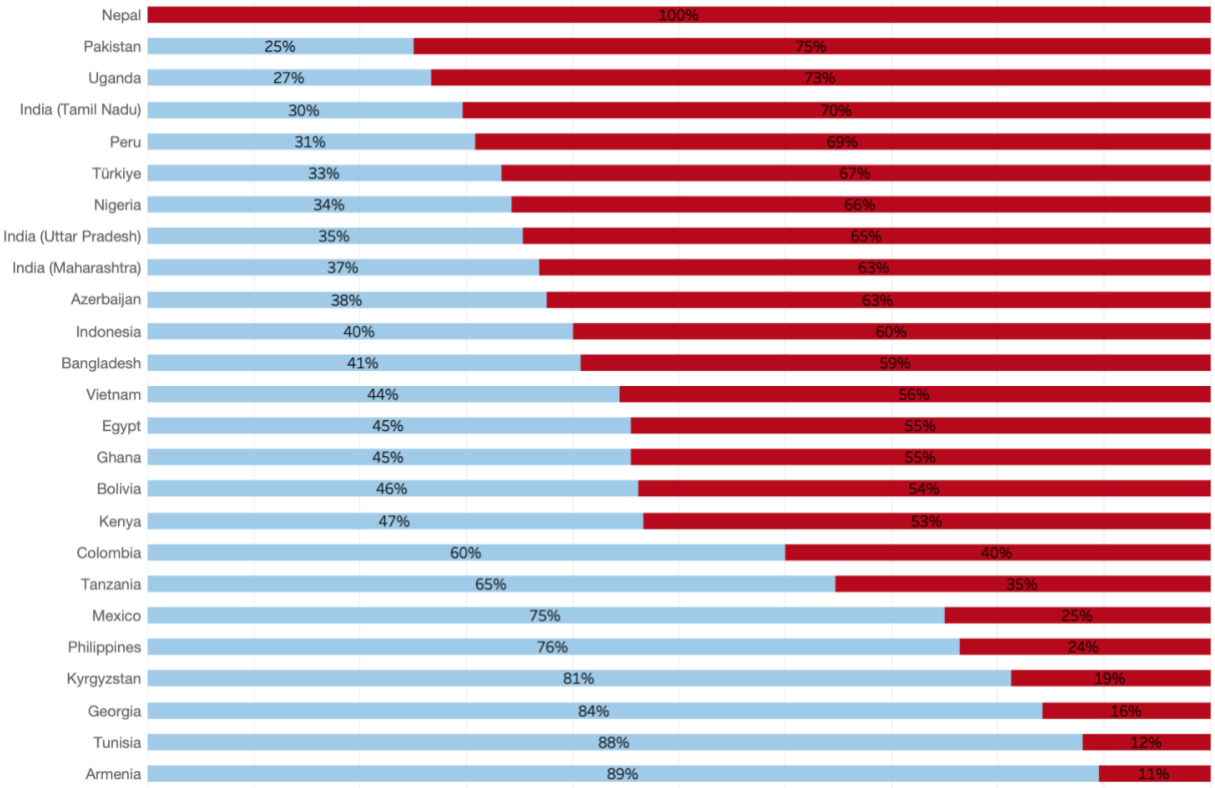
Country name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	19	ND	ND	287	11
Azerbaijan	16	ND	178	2342	63
Bangladesh	27	ND	186	8186	59
Bolivia	13	ND	164	2049	54
Colombia	35	ND	51	2679	40

[1] Weidenhamer JD, Kobunski PA, Kuepouo G, Corbin RW, Gottesfeld P. Lead exposure from aluminum cookware in Cameroon. Sci Total Environ. 2014 Oct 15;496:339-347.

Egypt	11	ND	180	1086	55
Georgia	19	ND	ND	119500	16
Ghana	22	ND	181	24100	55
India - Maharashtra	19	ND	720	6590	63
India - Tamil Nadu	27	ND	870	13900	70
India - Uttar Pradesh	17	ND	850	74600	65
Indonesia	45	ND	410	18100	60
Kenya	15	21	130	3600	53
Kyrgyzstan	16	ND	8	494	19
Mexico	16	ND	30	900	25
Nepal	11	170	750	3960	100
Nigeria	35	ND	410	1000	66
Pakistan	28	ND	3238	7858	75
Peru	26	ND	217	90400	69
Philippines	17	ND	26	1253	24
Tanzania	17	ND	30	15100	35
Tunisia	25	ND	ND	26600	12
Türkiye	9	ND	171	903	67
Uganda	15	ND	303	1564	73
Vietnam	18	ND	269	13080	56

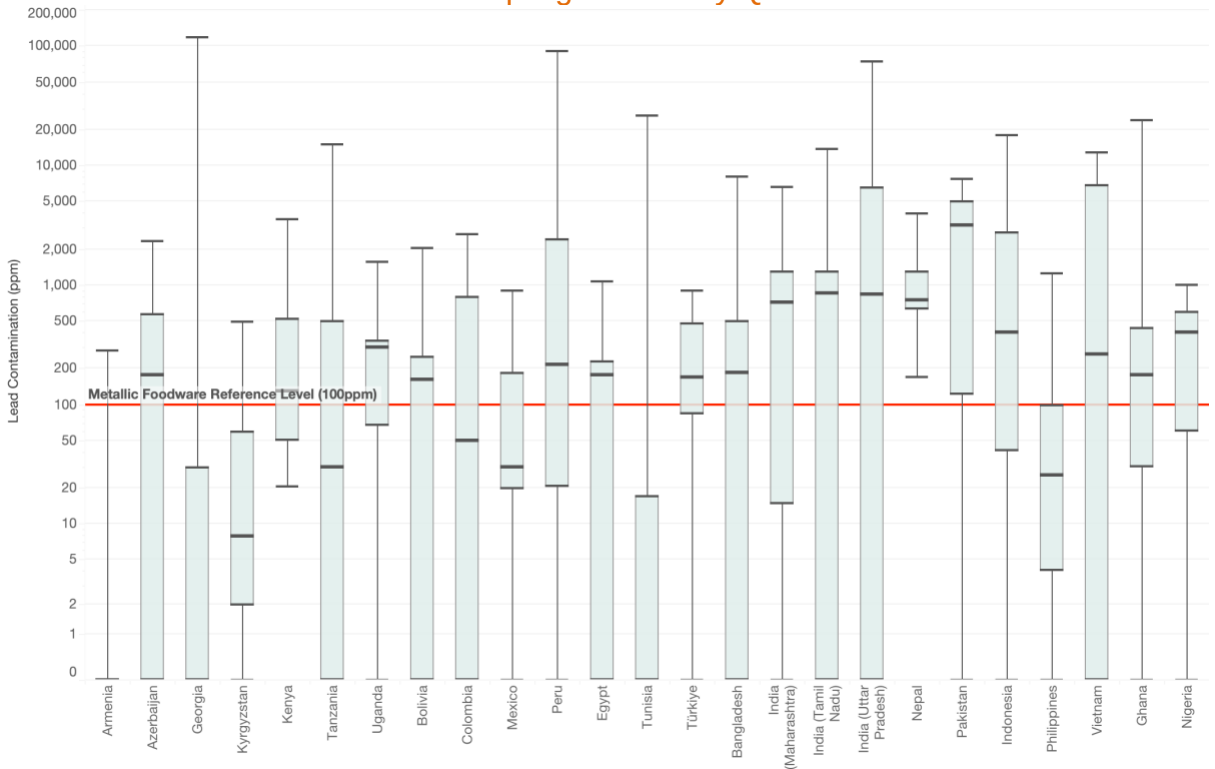
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage Of Metallic Foodware Samples Below and Above the Reference Level by Country

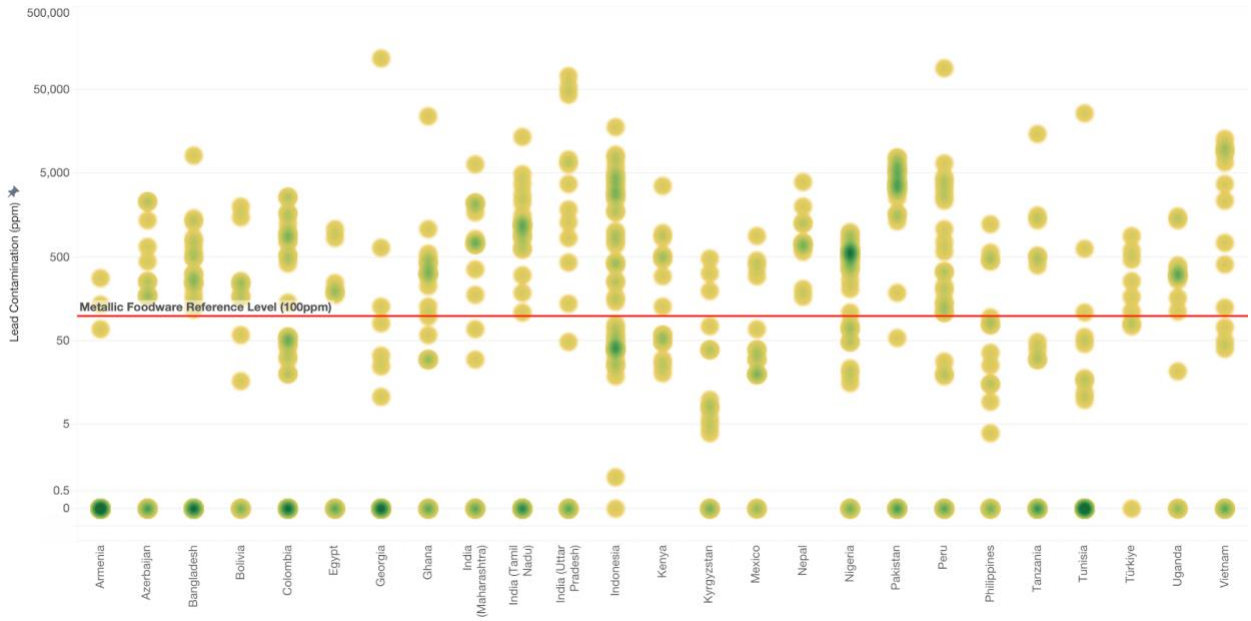


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Distribution of Metal Foodware Sampling Results by Quartile



Distribution of Metal Foodware Sampling Results by Individual Samples



Leachate Testing of Aluminum Cookware

As noted above, Pure Earth has analyzed a subset of 92 aluminum cookware samples, collected through the RMS, in a commercial research laboratory to model conditions that may occur when using the pots for cooking. This research is ongoing and the full results will ultimately be shared in a subsequent publication. However, the preliminary findings are notable and help shed light on the possible contribution of contaminated aluminum cookware to elevated blood lead levels.

The objectives of this research are:

- Evaluate the potential for aluminum pots to be a source of lead exposure;
- Evaluate the relationship between lead levels measured by XRF to lead concentrations that may be released during cooking; and
- Refine a testing protocol that is practical and reproducible.

Pots were selected for leachate testing from 23 of the RMS countries. The pots varied in shape, size, and finish from country to country. Some examples are shown below:

Examples of Aluminum Pots Tested in the Leach Study

There is no standard method for testing aluminum pots for lead release during cooking. The method used by Pure Earth is similar to those used by other researchers. The method models cooking acidic food for an extended period to leach or solubilize lead from the interior surface of a pot. In these studies, acidic water (i.e., 4% solution of acetic acid), termed leachate, is used to model acidic food. The method involves:

- Filling the pot with a 4% solution of acetic acid
- Bringing the pot to a boil and boiling, covered, for 2 hours
- Collecting the sample while hot, then processing the sample to dissolve lead compounds that may have formed particles in the leachate
- Analyzing the leachate for lead and aluminum using standard US EPA methods[2]

Reference Level for Leachate

Pure Earth used a preliminary reference level of 10 ug/L (10 parts per billion) lead in the leachate to evaluate the potential for a pot to be a source of lead exposure. The reference level considers the following existing criteria for water and food:

- The US EPA action level for drinking water is 15 µg/L;
- The World Health Organization provisional guideline is 10 µg/L for drinking water; and,
- The US FDA Interim Reference Limit (IRL) is 2.2 µg/day in food for children. A daily serving of 250 ml or grams is a standard assumption; therefore 2.2 µg/day x day/250 ml x 250 ml/L = 8.8 µg/L, which is close to the 10 µg/L reference level.

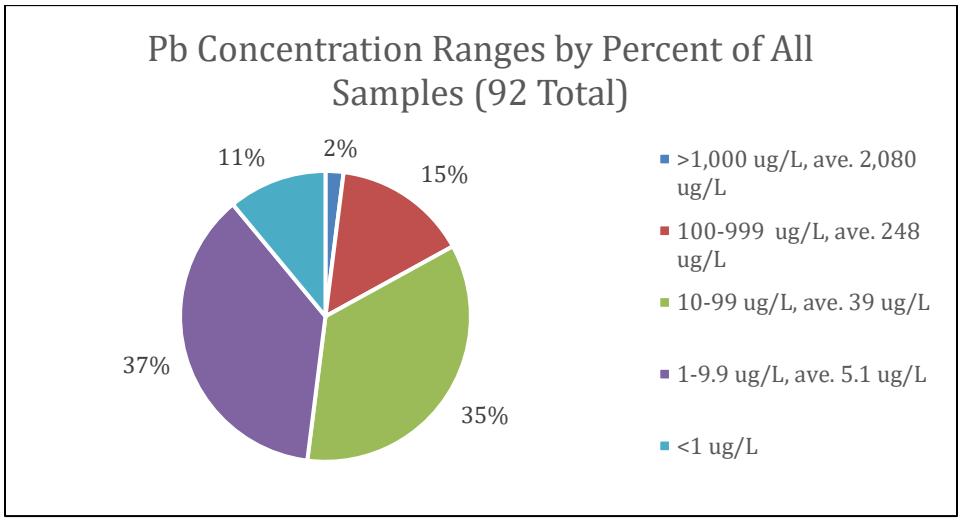
[2] US EPA SW-846 Method 6020 for lead (inductively coupled plasma-mass spectrometry or ICP-MS) and SW-846 Method 6010C for aluminum (inductively coupled plasma-atomic emission spectrometry or ICP-AES)

- In application, a child aged 0 to 7 years old ingesting 250 ml or grams of food every day, with a lead concentration equal to the 10 µg/L reference level, would result in an average blood lead level of 0.47 µg/dL. These calculations are derived from the US EPA's *Integrated Exposure Uptake Model for Lead in Children (IEUBK)*[3].

Lead Concentrations in Leachate

Of the 92 pots tested, 48 (52%) had lead concentrations in leachate exceeding the screening level of 10 ug/L. The average lead concentration in leachate was 98 ug/L, while the median concentration was 12 ug/L.

For those samples exceeding the 10 µg/L reference level, most were in the range of 10 to 99 ug/L and averaged 39 ug/L (35% of total pots), followed by pots with leachate concentrations ranging from 100 to 999 ug/L and averaging 248 ug/L (15% of total pots). A small number of pots leached lead at concentrations exceeding 1,000 ug/L, averaging 2,080 ug/L (2% of total pots). For pots where the 10 µg/L reference level was not exceeded, most were in the range of 1-9.9 ug/L, averaging 5.1 ug/L (37% of total pots). Lead was nondetectable in leachate for 11% of the pots.

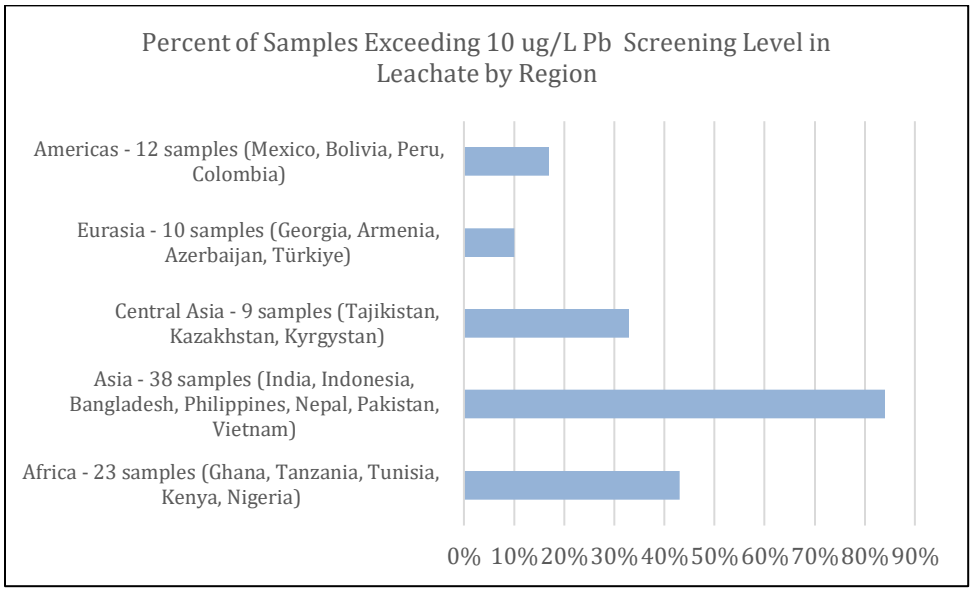


Regional and Country Variations

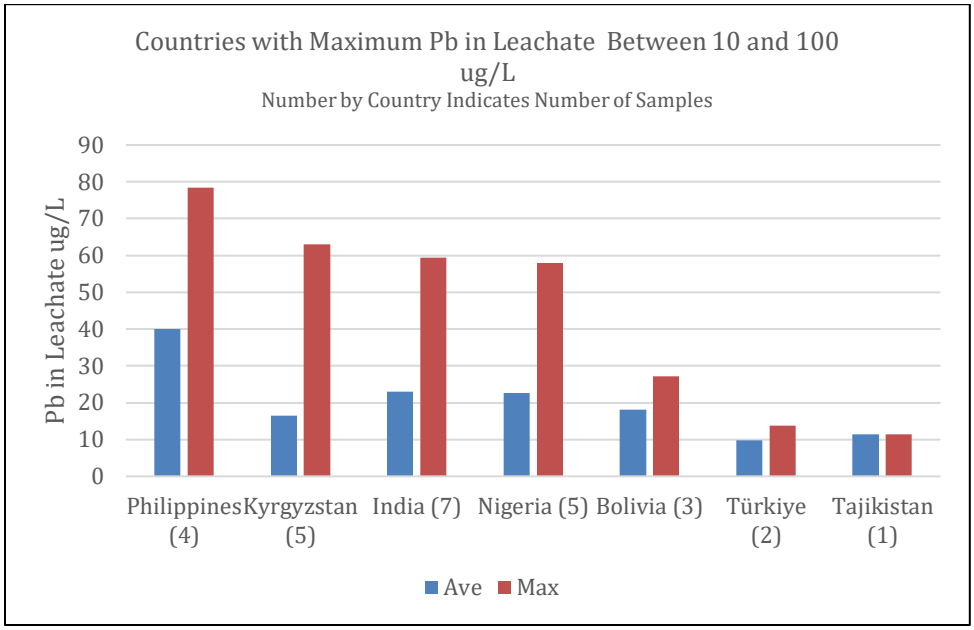
Lead concentrations in leachate and exceedances of the 10 µg/L reference level varied by geographic region and country. The numbers of samples collected and analyzed by country and region were not equal, which potentially skews the results, but the trends are worth noting. The majority of the pots analyzed in this study were collected in South Asia or Southeast Asia, including India, Indonesia, Bangladesh, the Philippines, Nepal, Pakistan, and Vietnam, and 84% of the pots from this region exceeded the screening level of 10 ug/L. A moderate number of samples were collected from Africa (Ghana, Nigeria, Tunisia, Kenya, Tanzania), and 43% of the samples exceeded the 10 µg/L reference level. The results are consistent with observations in these regions, where

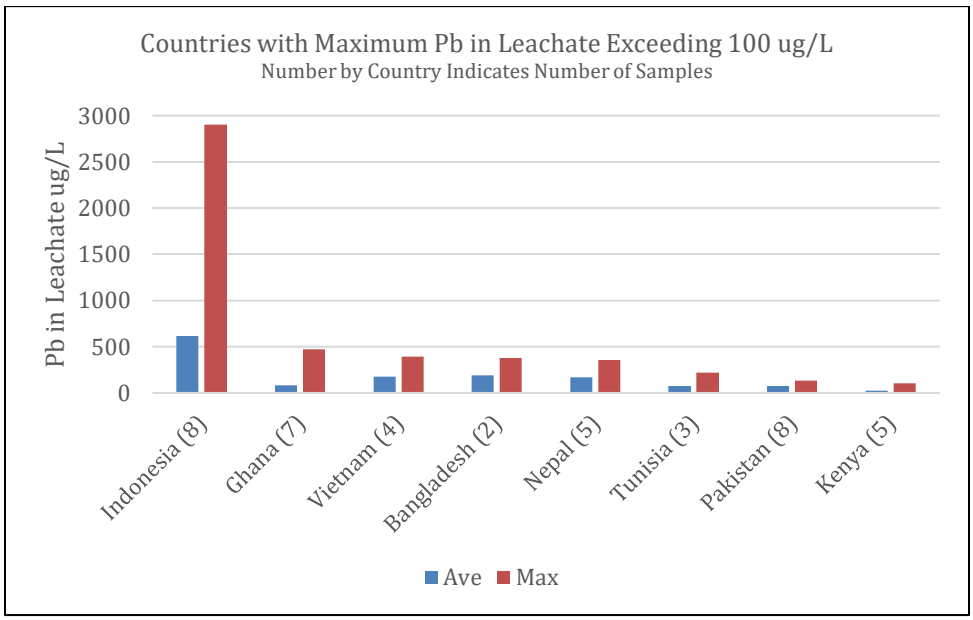
[3] INUK computations by Dr. Jack Caravanos, DrPH, CIH, Clinical Professor, NYU

many of the aluminum pots found in markets are made locally from a variety of scrap sources that could contain lead. Pots from Eurasia and the Americas had fewer exceedances or none at all, and had the appearance of being factory-made.



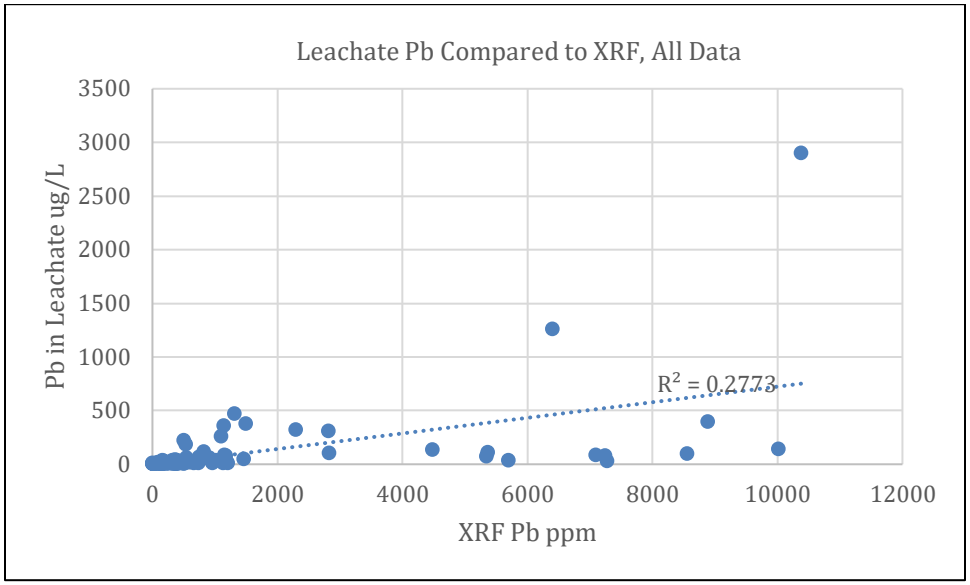
The graphs below show average and maximum lead concentrations in leachate by country, where maximum concentrations are (1) between 10 and 100 ug/L and (2) greater than 100 ug/L, respectively. Maximum and average leachate concentrations from pots from eight countries (Azerbaijan, Tanzania, Mexico, Kazakhstan, Colombia, Peru, Armenia, and Georgia) did not exceed the reference level of 10 ug/L. Average and maximum lead concentrations in leachate were in the range of 10 to 100 ug/L in pots from Kyrgyzstan, Nigeria, Türkiye, Tajikistan, Bolivia, India, and the Philippines; the remaining countries of Tunisia, Pakistan, Kenya, Ghana, Nepal, Vietnam, Bangladesh, and Indonesia exceeded 100 ug/L on average. The most pots per country (eight) were analyzed from Indonesia and Pakistan. Indonesia had the highest maximum lead concentration (2,900 ug/L) and average lead concentration (617 ug/L). Six of the eight pots tested from Indonesia exceeded the 10 µg/L reference level. All pots from Pakistan exceeded the 10 µg/L reference level, although at lower concentrations than Indonesia, with a maximum of 132 ug/L and an average of 74.2 ug/L.

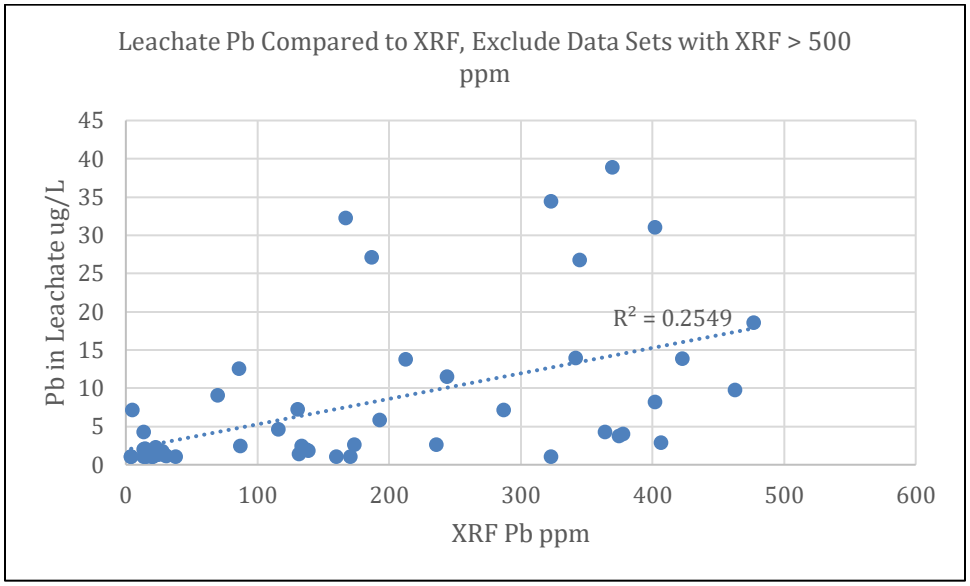




Comparison of XRF Readings to Lead Concentrations in Leachate

The XRF analyzer has been a useful screening tool for aluminum pots. XRF readings for lead in aluminum foodware ranged from nondetectable to greater than 10,000 ppm, with an average of 1,407 ppm and a median value of 402 ppm. When comparing lead in leachate to XRF readings for all pots, the correlation is low, with an R^2 coefficient of 0.28. When data at the lower end of the scale is plotted, looking at data pairs where the XRF readings are less than 500 ppm, the correlation is even lower, with an R^2 coefficient of 0.25.





There is not a strong linear correlation between leachable lead and total lead in the pots tested. Notably, total XRF lead below 100 ppm is a very good indicator that the pot would leach less than the 10 ug/L reference level. Of the 18 pots tested with less than 100 ppm total lead, only one pot, with total lead of 86 ppm, indicated a leachate concentration of 12.5 ug/L, exceeding the 10 ug/L reference level. Conversely, XRF readings of total lead greater than 100 ppm provides a working screening level of the potential for leaching above the reference level of 10 ug/L about 70% of the time. That is, in about 30% of the samples with XRF readings above 100 ppm, lead concentrations in leachate did not exceed 10 ug/L. We consider 100 ppm total lead in aluminum pots and pans to be a working screening level for pots leaching above or below the 10 ug/L reference level.

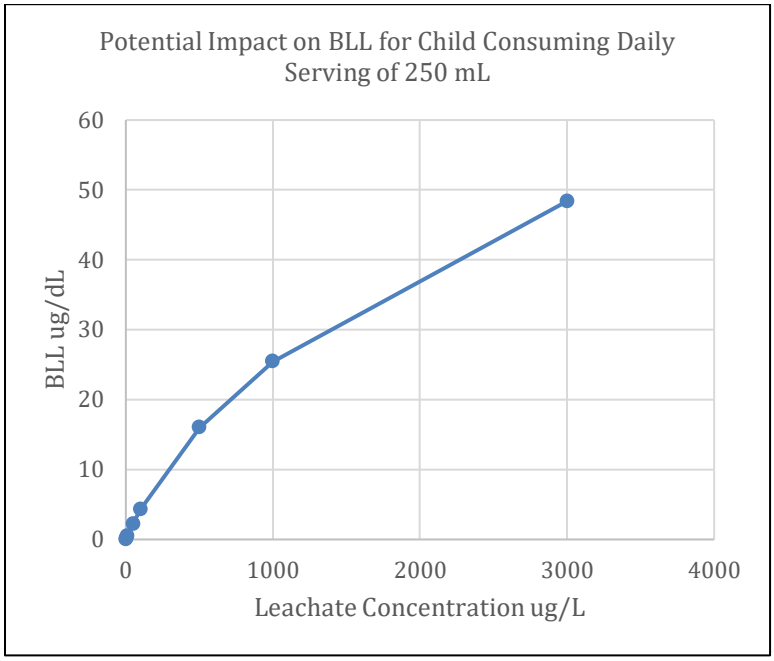
It is important to note that the actual amount leaching from any pot must be determined using representative leaching tests. The use of a 100 ppm total lead screening level to evaluate the potential for leaching is an estimate, particularly considering leaching data in the literature that has shown the potential to leach at total lead values below the 100 ppm threshold. It is also important to note that there are many factors affecting the amount of lead leaching from any particular pot, including temperature, contact time, leaching medium, pot coatings, condition and age of the pots, among other factors.

Potential for Lead Leached from Cooking Pots to Result in Elevated Blood Lead Levels

To evaluate the potential for aluminum pots to be a source of lead exposure, computations were made using US EPA's *Integrated Exposure Uptake Model for Lead in Children (IEUBK).* The assumptions in the model were that food consumed by the child would contain lead leached from the pot, and that a child would consume a daily 250-mL portion of food cooked in the pot.

The concentrations of lead in food in the model reflected the range of leachate concentrations observed during these tests, from 1 ug/L to 3,000 ug/L. The model assumed an uptake of 50% of the lead ingested. IEUBK generates data for different age ranges for children from 0 to 7 years (6-12 months, 12-24 months, etc.). For the purposes of this comparison, results across the age ranges from 0 to 7 years were averaged. The table of projected blood lead levels (BLLs) resulting from daily ingestion of food (leachate) containing lead in a range of concentrations is shown in the table and graph below. Importantly, a child aged 0 to 7 years old ingesting 250 ml or grams of food every day with a lead concentration equal to the 10 µg/L reference level would see an average increase in blood lead level of 0.47 µg/dL.

Leachate Concentration ug/L	Average BLL ug/dL for Child 0-7 years
1	0.03
5	0.23
10	0.47
50	2.24
80	3.45
100	4.27
500	16.04
1,000	25.47
3,000	48.39



The US Centers for Disease Control use a blood lead reference level 3.5 ug/dL as a threshold for recommending intervention in a child's environment to reduce lead exposure. Using data from the graph above, a food (or leachate in the lab setting) with a lead concentration of about 80 ug/L could result in a blood lead level above 3.5 ug/dL if food is consumed on a daily basis. In our studies, 21% of the pots tested produced a leachate of 80 ug/L or greater, indicating that there are circumstances under which aluminum pots could be a considerable contributor to elevated blood lead levels.

Plastic Foodware

Out of 364 plastic foodware samples, 12% showed lead levels exceeding the reference level of 100 ppm. RMS Investigators were asked to prioritize items used by children for food consumption and storage, particularly bowls and cups. Unlike ceramic and metallic foodware, for which many countries had samples with maximum concentrations above 10,000 ppm, all samples of plastic foodware were below 3,300 ppm.

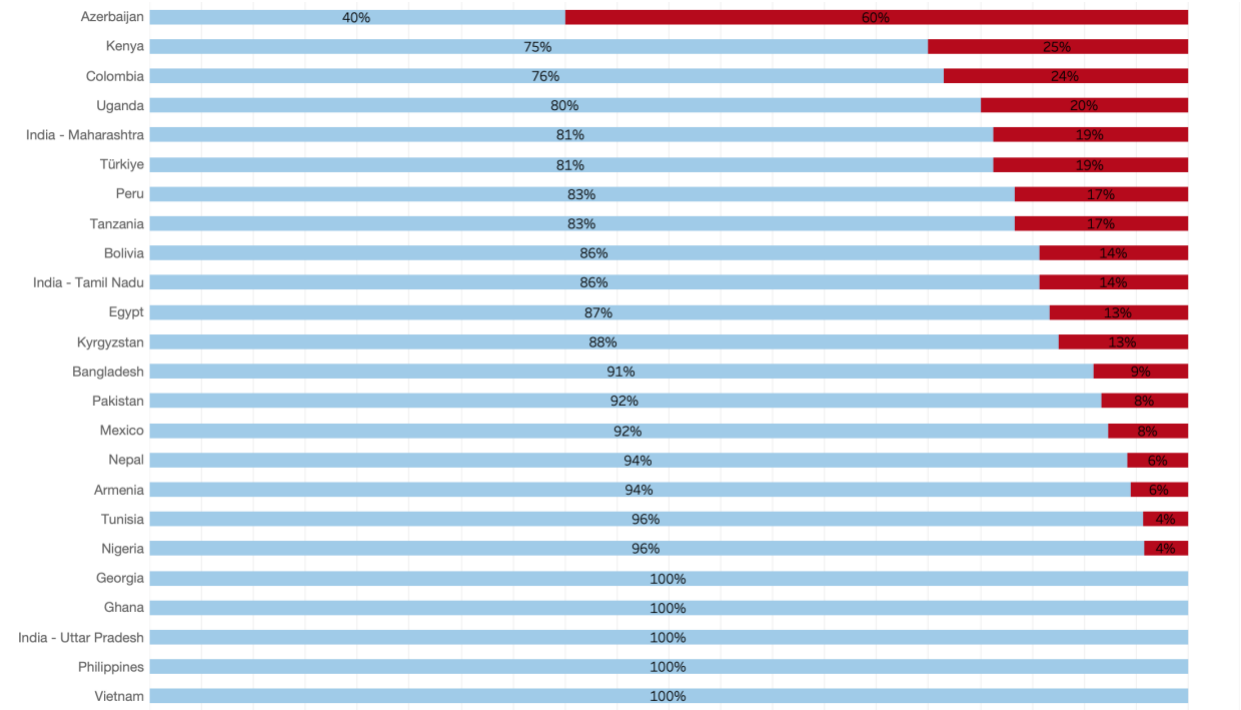
Summary of Plastic Foodware Results by Country

Country name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	18	ND	ND	478	6
Azerbaijan	5	ND	211	1196	60
Bangladesh	11	ND	ND	672	9
Bolivia	14	ND	ND	2073	14

Colombia	17	ND	ND	1687	24
Egypt	15	ND	ND	1121	13
Georgia	5	ND	ND	ND	0
Ghana	12	ND	ND	32	0
India - Maharashtra	16	ND	ND	437	19
India - Tamil Nadu	7	ND	ND	872	14
India - Uttar Pradesh	18	ND	ND	11	0
Kenya	12	ND	ND	2395	25
Kyrgyzstan	16	ND	ND	368	13
Mexico	13	ND	ND	853	8
Nepal	17	ND	ND	348	6
Nigeria	24	ND	ND	280	4
Pakistan	12	ND	ND	2419	8
Peru	18	ND	ND	1643	17
Philippines	14	ND	ND	ND	0
Tanzania	18	ND	ND	2791	17
Tunisia	23	ND	ND	3289	4
Türkiye	16	ND	ND	1281	19
Uganda	30	ND	ND	1032	20
Vietnam	13	ND	ND	9	0

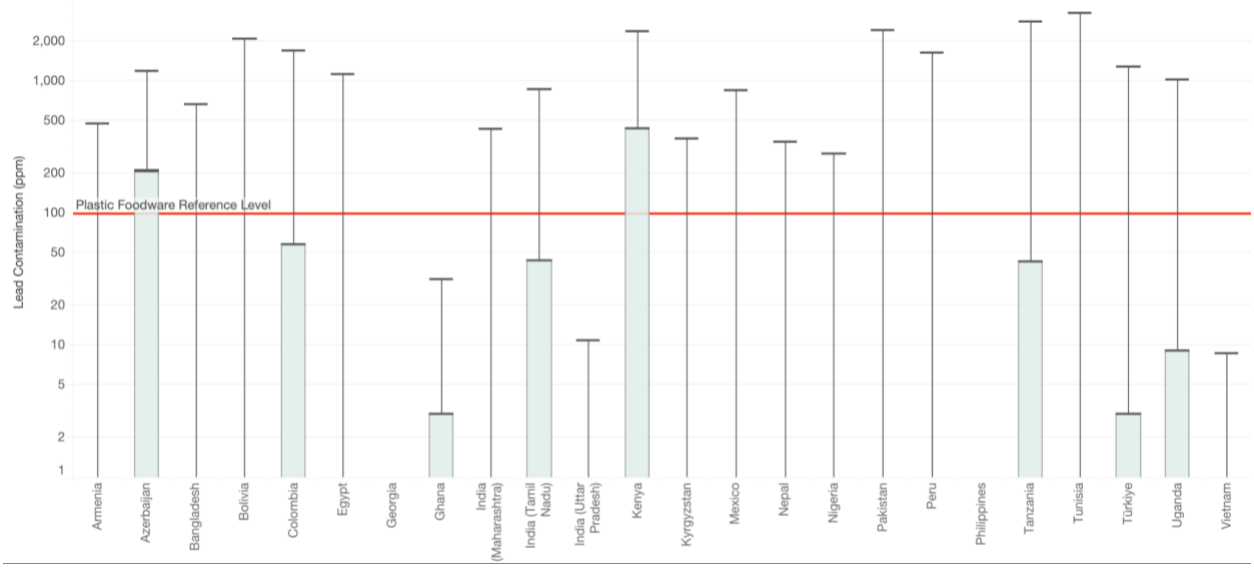
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage Of Plastic Foodware Samples Below and Above the Reference Level by Country

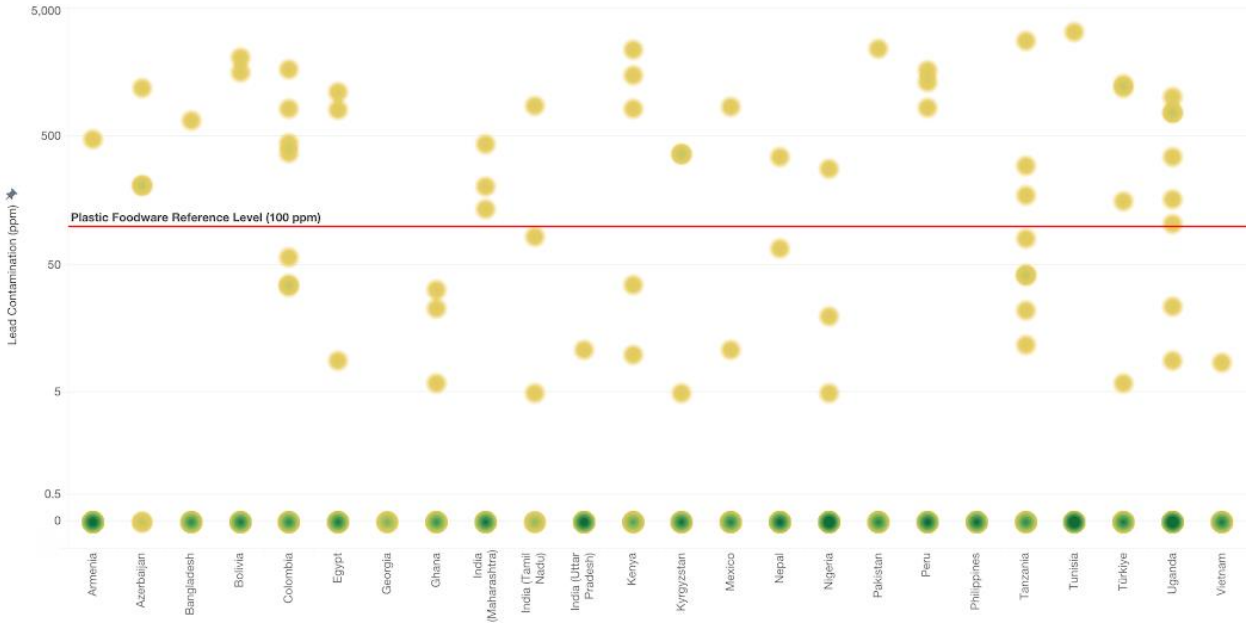


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Distribution of Plastic Foodware Sampling Results by Quartile



Distribution of Plastic Foodware Sampling Results by Individual Samples



Cosmetics

Out of 815 cosmetics samples, 12% had lead levels exceeding the reference level of 2 ppm.

A wide array of cosmetic products were collected and divided into subcategories. Notably, elevated lead levels were identified across nearly all of the subcategories. Furthermore, cosmetics with elevated lead levels were found in 21 of the 25 countries.

The two items with the highest lead concentration were both eyeliners, known as kajal or kohl, from Pakistan. These samples had concentrations of 637,600 ppm (64%) and 1,000,000 ppm (100%) lead as assessed by XRF, with lower but still significant concentration (29% and 32%) reported by confirmatory laboratory testing. In some cultures, kajal/kohl is applied to infants and children. Unfortunately, the item with the third highest lead concentration of lead (128,400 ppm) was face paint intended specifically for children.

Among the samples with elevated lead levels, the most common item was nail polish (29 items), which had a maximum lead concentration of 6,751 ppm, followed by lipstick (15 items, maximum lead concentration of 42,350 ppm), and eyeshadow (13 items, maximum lead concentration of 974 ppm). As noted above and in the Quality Control section, some deviations were observed between the XRF and lab-based measurements of lead concentration at the highest concentrations among the cosmetics. Nevertheless, at such extreme concentrations, the risk is still significant even with a wide margin of error.

In addition to kajal/kohl, elevated lead levels were found in other traditional products, including henna and kumkum (a red powder made of turmeric and other ingredients and used for social and religious purposes in India).

Finally, it is notable that lead levels above the reference level were also found in a variety of conventional cosmetics, such as nail polish, lipstick, and eyeshadow as previously described, as well as face powder, mascara, eyeliner, liquid foundation/concealer, and hair products.

Readers should note that the reference level is near the XRF's limit of detection for powders, and thus it is possible that some samples had a reading of "non-detect", but actually exceeded 2 ppm.

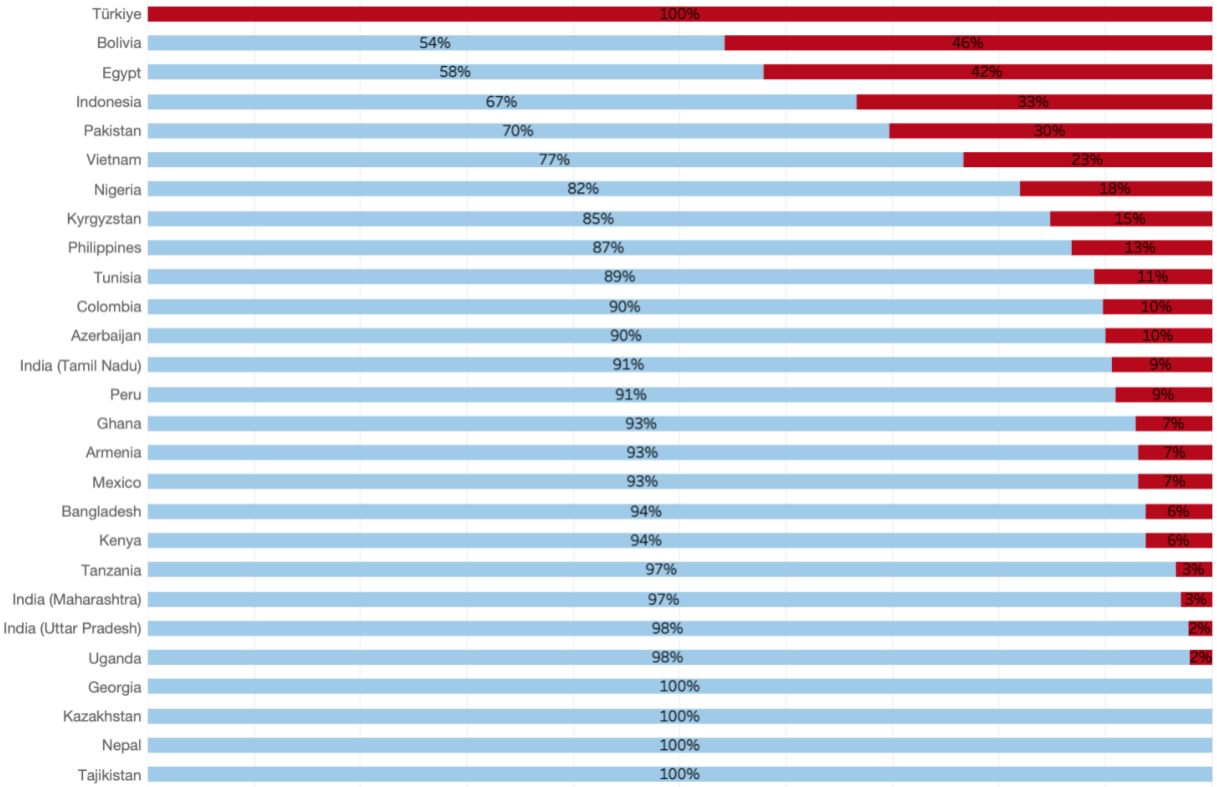
Summary of Cosmetics Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value 9ppm)	Max Value (ppm)	% Above Reference
Armenia	29	ND	ND	174	7
Azerbaijan	10	ND	ND	8	10
Bangladesh	32	ND	ND	186	6
Bolivia	24	ND	ND	693	46
Colombia	39	ND	ND	6751	10
Egypt	19	ND	ND	13700	42
Georgia	27	ND	ND	ND	0
Ghana	28	ND	ND	220	7
India - Maharashtra	69	ND	ND	60	3
India - Tamil Nadu	32	ND	ND	231	9
India - Uttar Pradesh	46	ND	ND	58	2
Indonesia	36	ND	ND	12	33
Kazakhstan	4	ND	ND	ND	0
Kenya	32	ND	ND	6	6
Kyrgyzstan	33	ND	ND	7	15
Mexico	29	ND	ND	50	7
Nepal	21	ND	ND	ND	0

Nigeria	50	ND	ND	1150	18
Pakistan	33	ND	ND	1000000	30
Peru	44	ND	ND	128400	9
Philippines	38	ND	ND	42350	13
Tajikistan	4	ND	ND	ND	0
Tanzania	30	ND	ND	52	3
Tunisia	27	ND	ND	712	11
Türkiye	1	121	121	121	100
Uganda	48	ND	ND	3	2
Vietnam	30	ND	ND	68	23

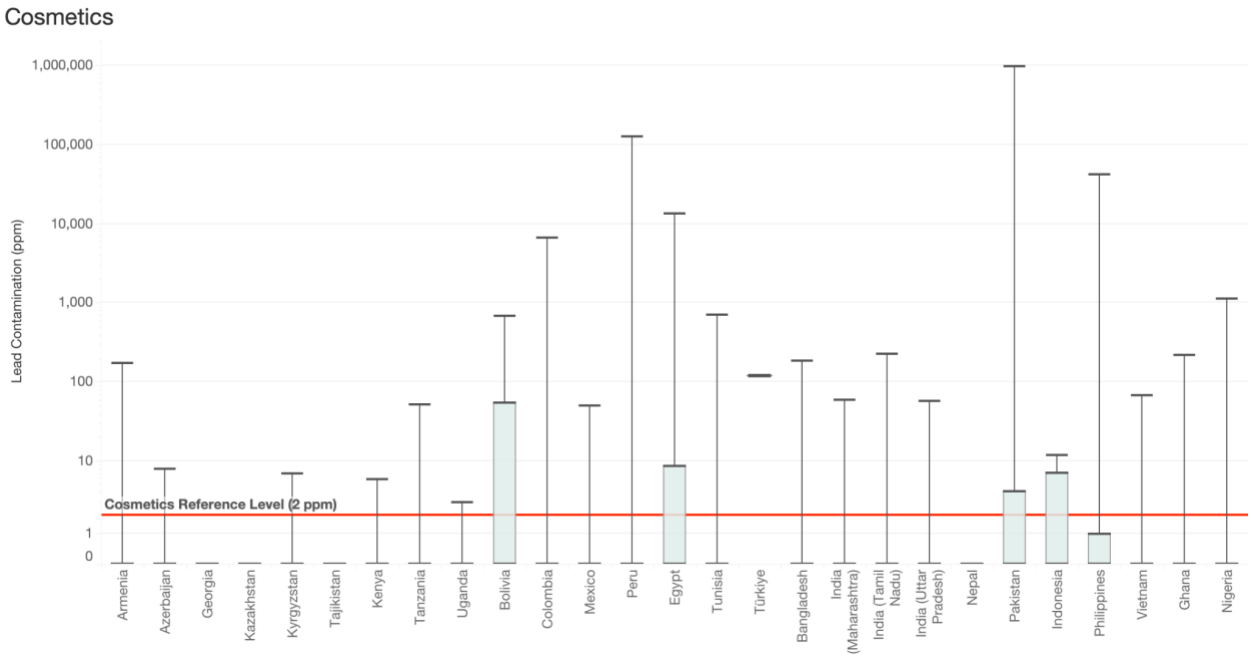
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage Of Cosmetics Samples Below and Above the Reference Level by Country

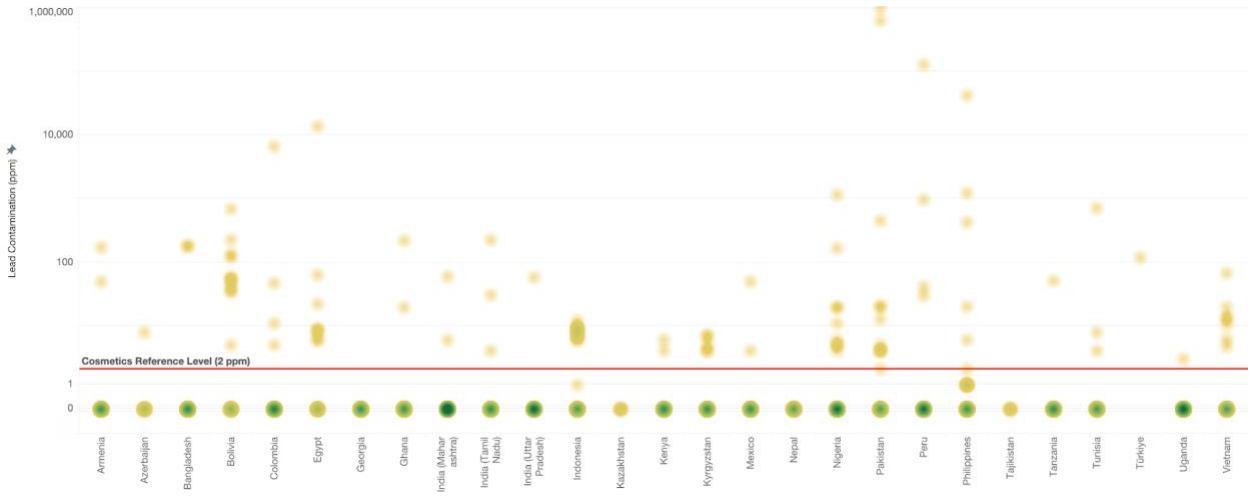


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Only one sample was analyzed from Türkiye.

Distribution of Cosmetics Sampling Results by Quartile



Distribution of Cosmetics Sampling Results (by Individual Samples)



Toys

Out of 781 toy samples, 13% had lead levels exceeding the reference level of 100 ppm. Azerbaijan stands out with 69% of 26 samples exceeding the reference level.

This category encompasses a variety of hard toys, composed primarily of plastic items, but also including metal, wood or other materials. Some of these items were also found to have paint or coatings on them. In addition to the variety at the category level, many toys were heterogeneous, made from a combination of materials. We found many toys to contain internal electronic or metallic parts, which were responsible for some of the highest lead readings observed by XRF. Such readings may not necessarily best reflect

the risk of that item, as the reference level relates to “accessible parts” to children. Also note that many of the toys collected and screened as part of the RMS were imported, which does not reduce the risk, but may influence interventions.

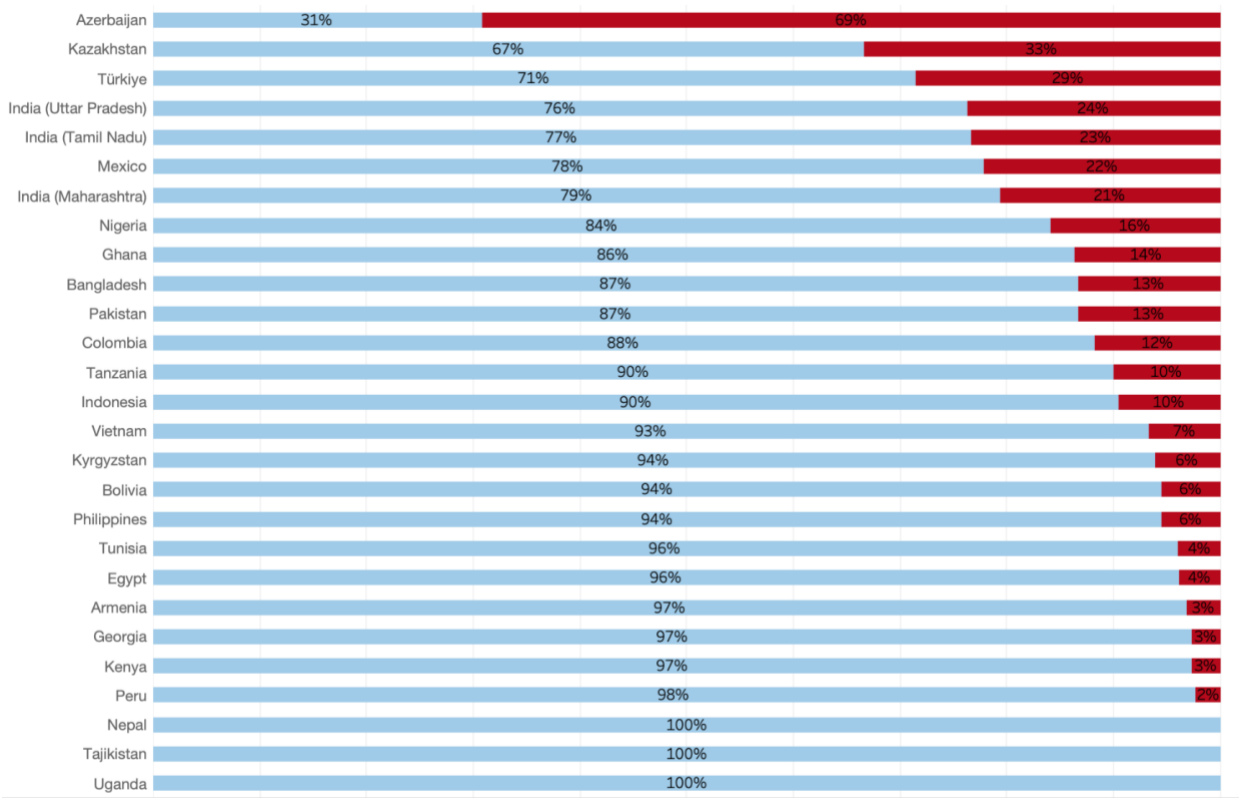
Summary of Toys Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	32	ND	ND	3125	3
Azerbaijan	26	ND	311	1175	69
Bangladesh	30	ND	ND	1814	13
Bolivia	18	ND	ND	1238	6
Colombia	34	ND	ND	455	12
Egypt	26	ND	ND	967	4
Georgia	38	ND	ND	376	3
Ghana	22	ND	ND	1533	14
India - Maharashtra	34	ND	ND	97300	21
India - Tamil Nadu	30	ND	ND	3250	23
India - Uttar Pradesh	38	ND	ND	4680	24
Indonesia	21	ND	ND	314	10
Kazakhstan	3	ND	ND	1138	33
Kenya	38	ND	ND	139	3
Kyrgyzstan	33	ND	ND	314	6
Mexico	27	ND	ND	1070	22
Nepal	10	ND	ND	ND	0
Nigeria	44	ND	ND	2292	16
Pakistan	30	ND	ND	1481	13

Peru	43	ND	ND	442	2
Philippines	36	ND	ND	2123	6
Tajikistan	5	ND	ND	34	0
Tanzania	30	ND	ND	698	10
Tunisia	25	ND	ND	176	4
Türkiye	49	ND	22	4336	29
Uganda	29	ND	ND	81	0
Vietnam	30	ND	ND	298	7

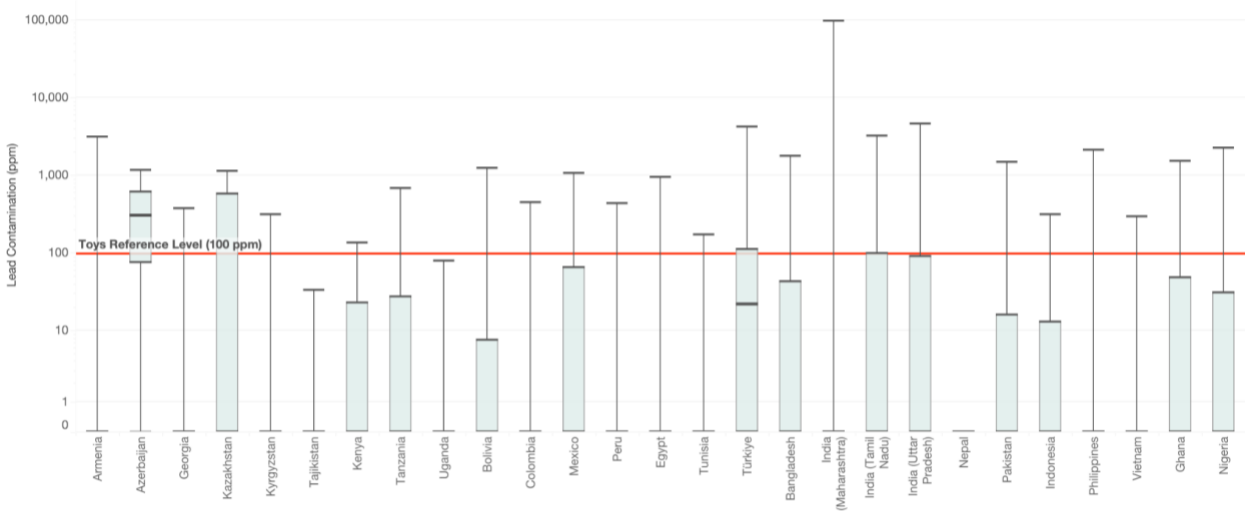
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage Of Toys Samples Below and Above the Reference Level by Country

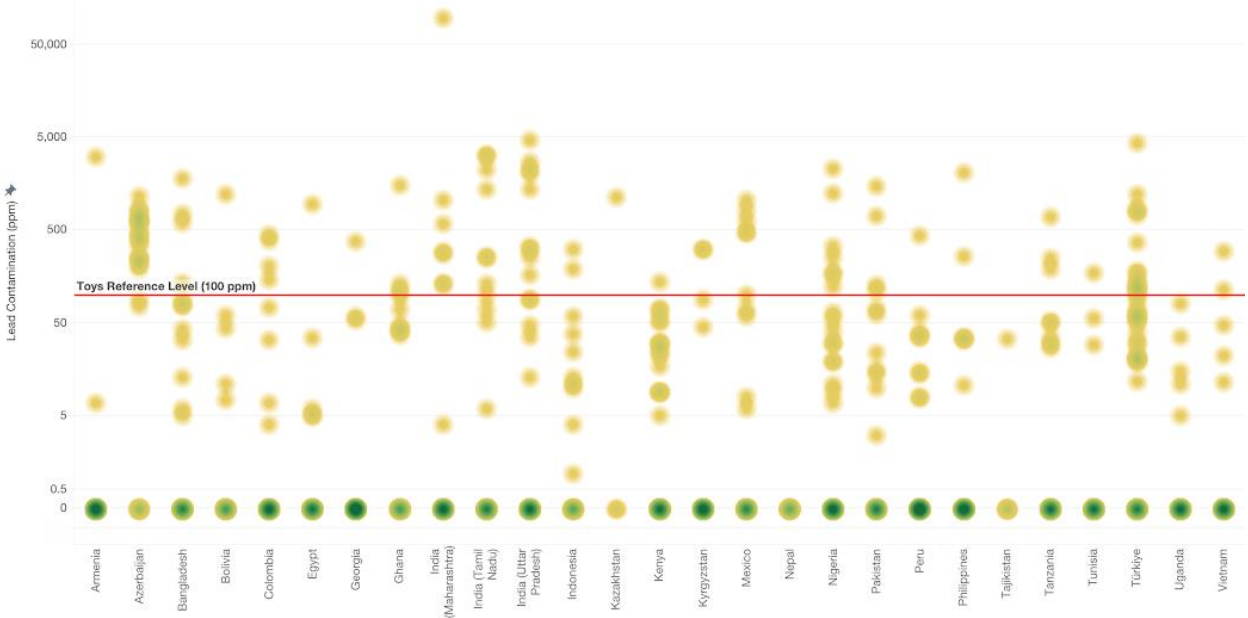


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Distribution of Results by Quartile



Distribution of Toy Sampling Results by Individual Samples



Paints Intended for Large Surfaces

Out of a total of 437 samples of paint intended for large surfaces, 41% showed lead levels exceeding the reference level of 90 ppm.

Pure Earth divided paint samples into two categories: paints intended for use on large surfaces, such as interior and exterior walls, and paints intended for crafts, art, and other specialty uses. This division was based on the recognition that exposure pathways may be different between wall paints, where exposure likely results from

chipping paint that becomes dust, and specialty paints, where exposure may be more directly related to the application of the paint or use of the painted product (e.g., a toddler getting art paints in the mouth or mouthing a painted toy).

For all paints, we use a reference level of 90 ppm. The data below is for paints intended for large surfaces. Note that we were not able to classify all paint samples into these two categories, and thus not all paint samples are represented in the following two sections. Among the 102 unclassified paint samples, 47% exceeded the reference level. We also note that the protocol for testing paint was amended during the RMS to specify testing only dried paint samples as opposed to allowing analysis of wet samples. The following tables and charts include results of both wet and dry analyses.

In the table below, countries with binding regulations limiting lead concentrations in paints are highlighted with orange text.

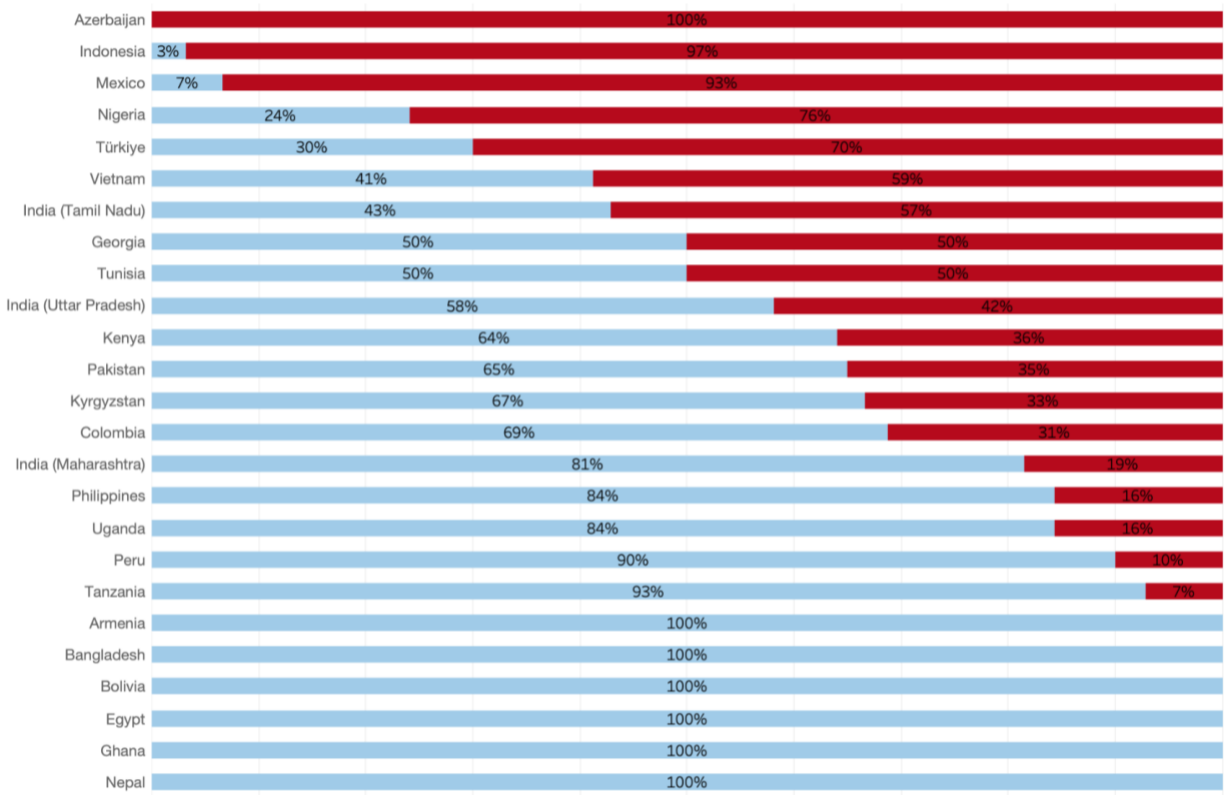
Summary of Results for Paint Intended for Large Surfaces by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	7	ND	ND	6	0
Azerbaijan	18	600	2603	12400	100
Bangladesh	2	ND	ND	ND	0
Bolivia	5	ND	ND	27	0
Colombia	16	ND	ND	66200	31
Egypt	3	ND	ND	ND	0
Georgia	4	ND	376	22600	50
Ghana	1	ND	ND	ND	0
India - Maharashtra	27	ND	ND	164000	19
India - Tamil Nadu	7	ND	2356	13400	57
India - Uttar Pradesh	31	ND	ND	33200	42
Indonesia	31	1	3142	51400	97
Kenya	25	ND	7	7788	36
Kyrgyzstan	33	ND	10	890	33

Mexico	15	3	53700	807309*	93
Nepal	20	ND	ND	ND	0
Nigeria	29	ND	494	20700	76
Pakistan	20	ND	ND	7370	35
Peru	10	ND	ND	2822	10
Philippines	32	ND	ND	41801	16
Tanzania	28	ND	ND	866	7
Tunisia	14	ND	286	72000	50
Türkiye	10	ND	3937	11200	70
Uganda	32	ND	ND	12600	16
Vietnam	17	ND	777	25505	59

Orange text indicates countries with legally binding regulations on lead concentrations in paint according to information submitted to the WHO Global Health Observatory. Note: information regarding relevant regulations was not available from this source for Bolivia or Indonesia.
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)
* This value is unusually high. We recorded four XRF readings in this range from four different paint samples from the same brand of paint purchased from a market in Mexico. We have confirmed that these are paint samples, not pigments, but the samples have not been subjected to confirmatory lab analysis.

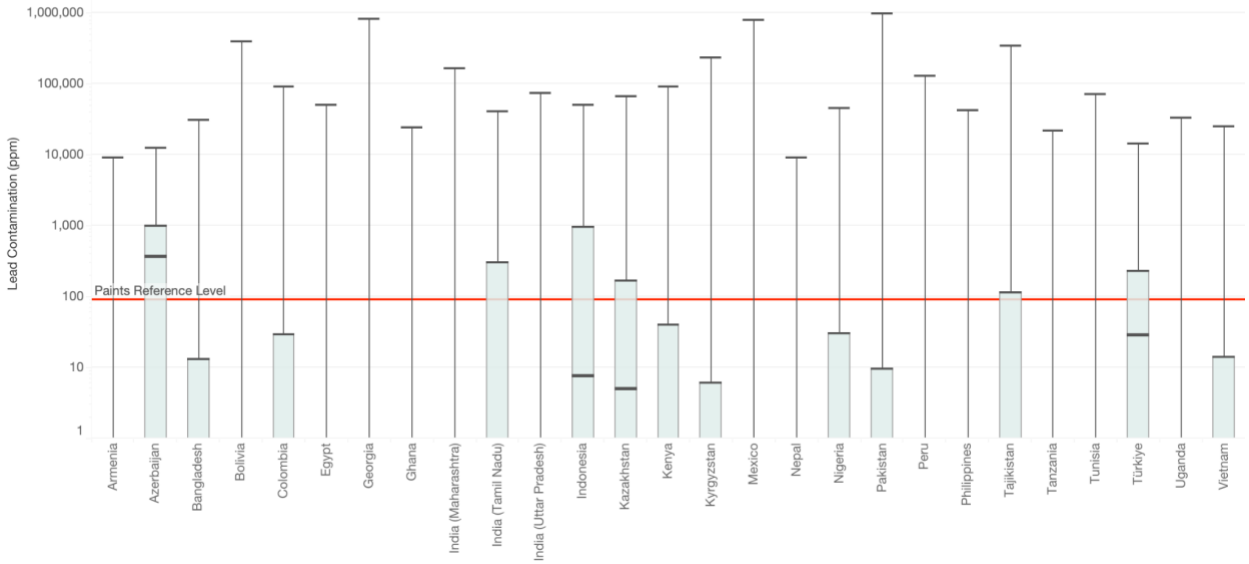
Percentage of Samples of Paints Intended for Large Surfaces That Are Below and Above the Reference Level by Country



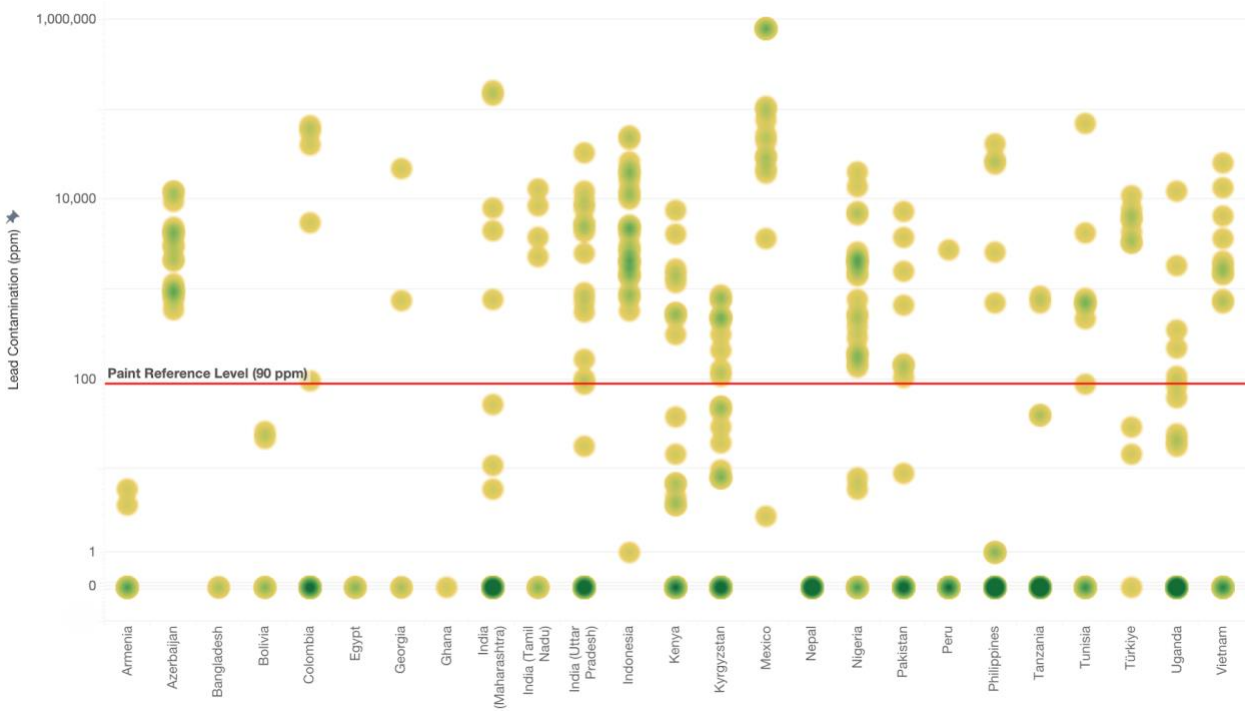
Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Fewer than 3 samples were analyzed from Ghana and Bangladesh.

Distribution of Results by Quartile

Paint (Large Surface)



Distribution of Results by Individual Samples



Paint Intended for Crafts, Art, and Specialty Uses

Out of a total of 70 samples of paint intended for crafts, art, and other specialty uses, 11% showed lead levels exceeding the reference level of 90 ppm. In the table below, countries with binding regulations limiting lead concentrations in paints are highlighted with orange text.

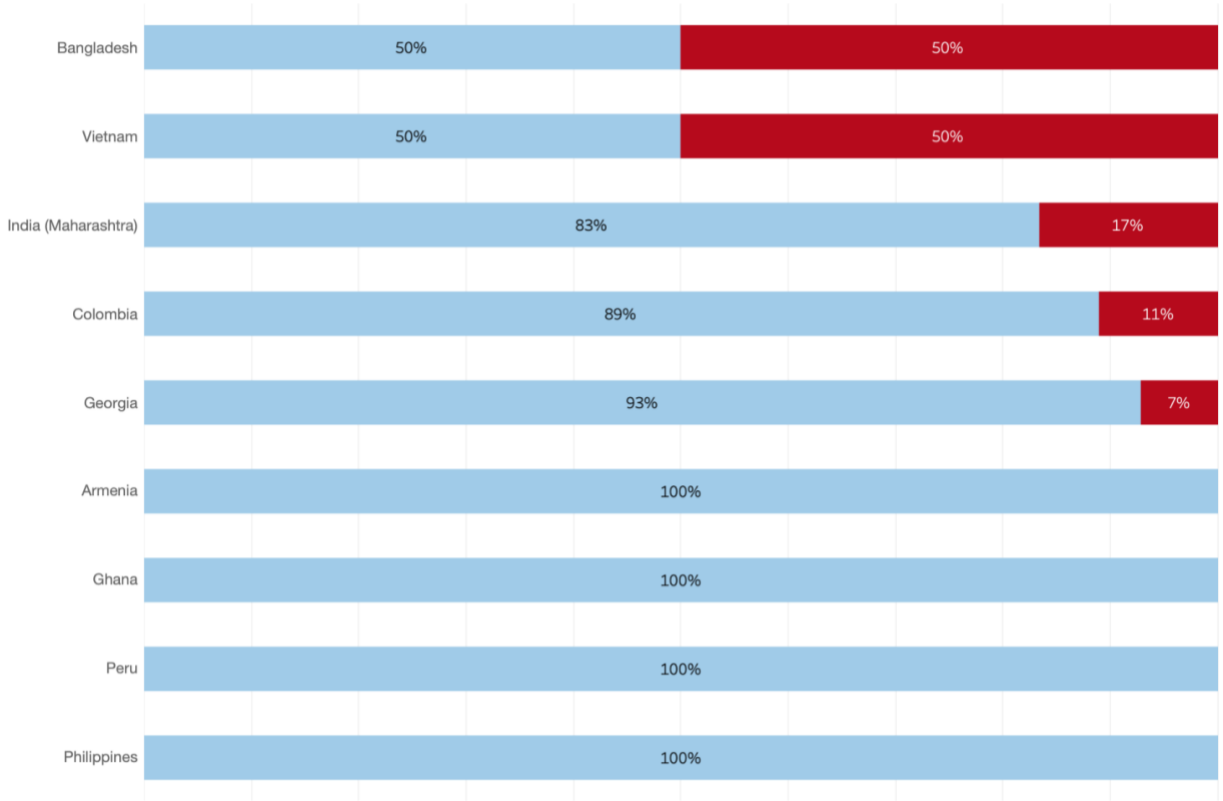
Summary of Results for Paint Intended for Crafts, Arts and Specialty Uses by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	4	ND	3	19	0
Bangladesh	2	ND	1903	3805	50
Colombia	9	ND	ND	93500	11
Georgia	14	ND	ND	4449	7
Ghana	3	ND	ND	ND	0
India - Maharashtra	12	ND	ND	1616	17

Peru	17	ND	ND	32	0
Philippines	3	ND	ND	ND	0
Vietnam	6	ND	ND	612	7296	50

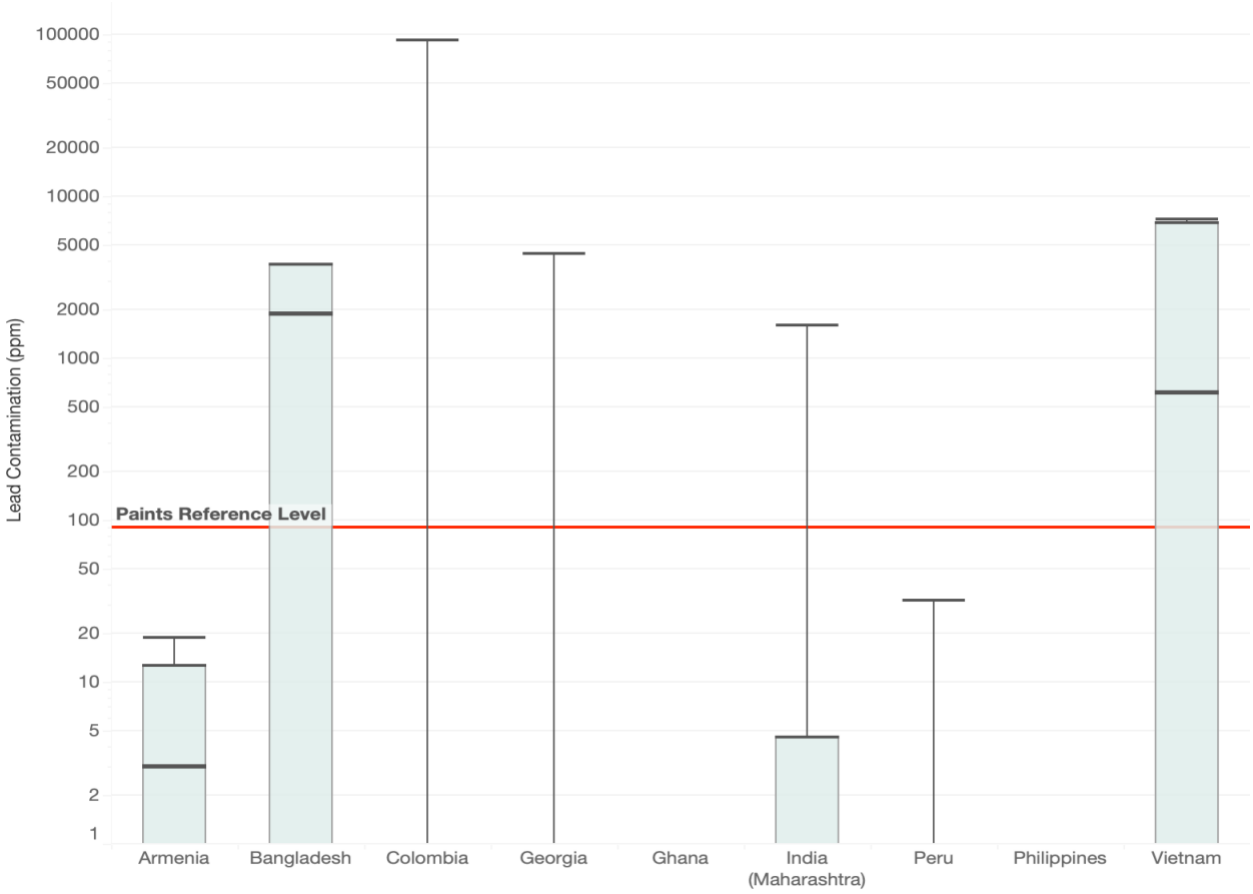
Orange text indicates countries with legally binding regulations on lead concentrations in paint according to information submitted to the WHO Global Health Observatory.
ND = "non-detect" (lead concentration was below the XRF's lower detection limit)

Percentage of Samples of Paints Intended for Crafts, Arts and Specialty Uses That Are Below and Above the Reference Level by Country

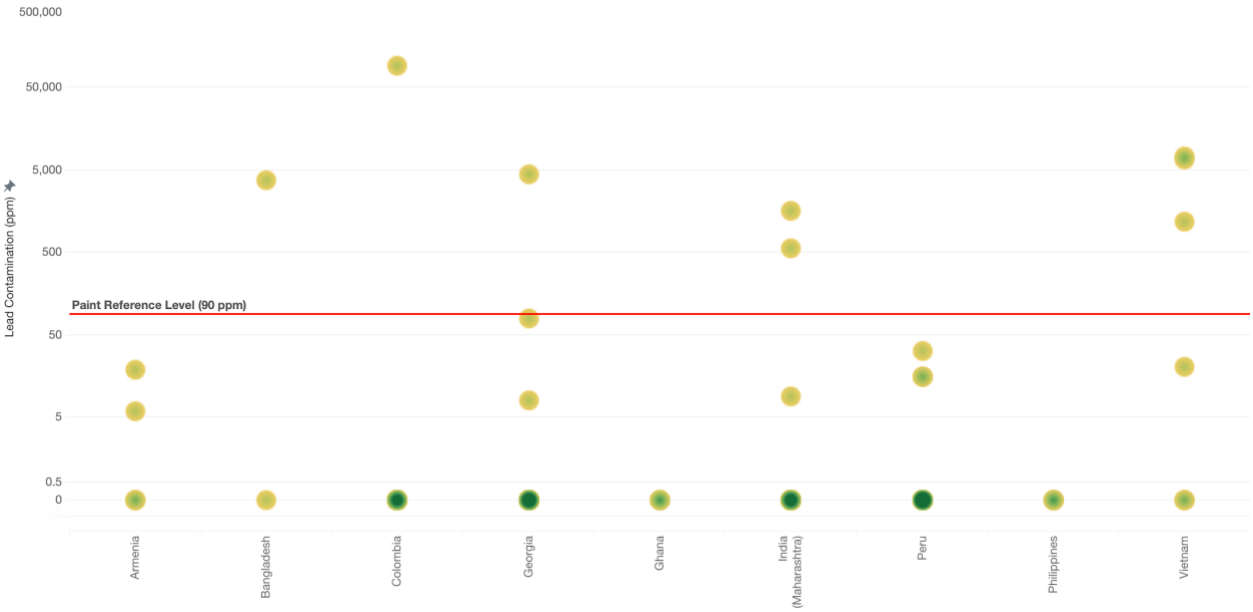


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Only 2 samples were analyzed from Bangladesh.

Distribution of Sample Results by Quartile



Distribution of Results by Individual Samples



Spices

Out of 1,084 spice samples, 2% showed lead levels exceeding the reference level of 2 ppm.

Previous studies have identified elevated lead levels in certain spices from countries around the Mediterranean, the Caucasus, and South Asia, among other regions.[4] In several countries, prior programs have confirmed that elevated lead concentrations were the result of producers adding lead-based pigments to spices to make their colors brighter.[5,6] This has been a well-publicized issue for turmeric in particular, but has also been documented in other yellow, orange, and red spices.[7]

The RMS was not designed to focus specifically on countries known to have contaminated spices, nor to focus solely on the types of spices that have been identified as more often contaminated. Rather, the RMS includes a broad range of spice types from countries that were selected based on product-agnostic criteria. As a result, the findings generally show low levels of lead in spices.

However, the RMS results should not cause readers to conclude that spices are not an important lead exposure source. There are, in fact, several reasons why it is both important and a good use of resources to focus on spices in certain regions. First, other recent assessments that have focused on commonly contaminated spices in "hotspot" regions have found a high prevalence of elevated lead levels among certain spices, particularly in North and Northeast India. Second, lead levels in spices have been successfully reduced through efforts to improve consumer and producer awareness, monitoring, supply chain tracking, and regulatory enforcement. Recent interventions in Bangladesh and Georgia, in particular, have resulted in dramatic declines in lead levels among certain targeted spices. Third, the intentional introduction of lead into spices is completely unnecessary, and eliminating the practice does not require significant changes to farming or production practices. Finally, spices represent an exposure source that can impact incredibly large populations, and thus programs to reduce lead levels in spices can have considerable impacts and returns on investments.

Readers should note that the minimum detection level for the XRF is often between 2-4 ppm for spices, and thus it is possible that some samples had a reading of "non-detect" but actually exceeded the reference level of 2 ppm. Readers should also note the very small sample size in Tajikistan. Field XRF results of spice samples from Tajikistan and Kazakhstan were expunged by the Quality Control Team, and thus the results below represent a small number of samples that were tested in accredited labs. Lastly, there is

[4] Hore P, Alex-Oni K, Sedlar S, Nagin D. A Spoonful of Lead: A 10-Year Look at Spices as a Potential Source of Lead Exposure. J Public Health Manag Pract. 2019 Jan/Feb;25 Suppl 1, Lead Poisoning Prevention:S63-S70. doi: 10.1097/PHH.0000000000000876. PMID: 30507772.
[5] Forsyth, Jenna E., et al. "Sources of blood lead exposure in rural Bangladesh." Environmental science & technology 53.19 (2019): 11429-11436.
[6] Forsyth, Jenna E., et al. "Food safety policy enforcement and associated actions reduce turmeric lead chromate adulteration across Bangladesh." *Environmental Research* (2023): 116328.
[7] Ericson, Bret, et al. "Elevated levels of lead (Pb) identified in Georgian spices." *Annals of Global Health* 86.1 (2020).

some uncertainty in the levels of lead in spices from Pakistan, as laboratory results were lower than those from the XRF. This is discussed in the Quality Control section.

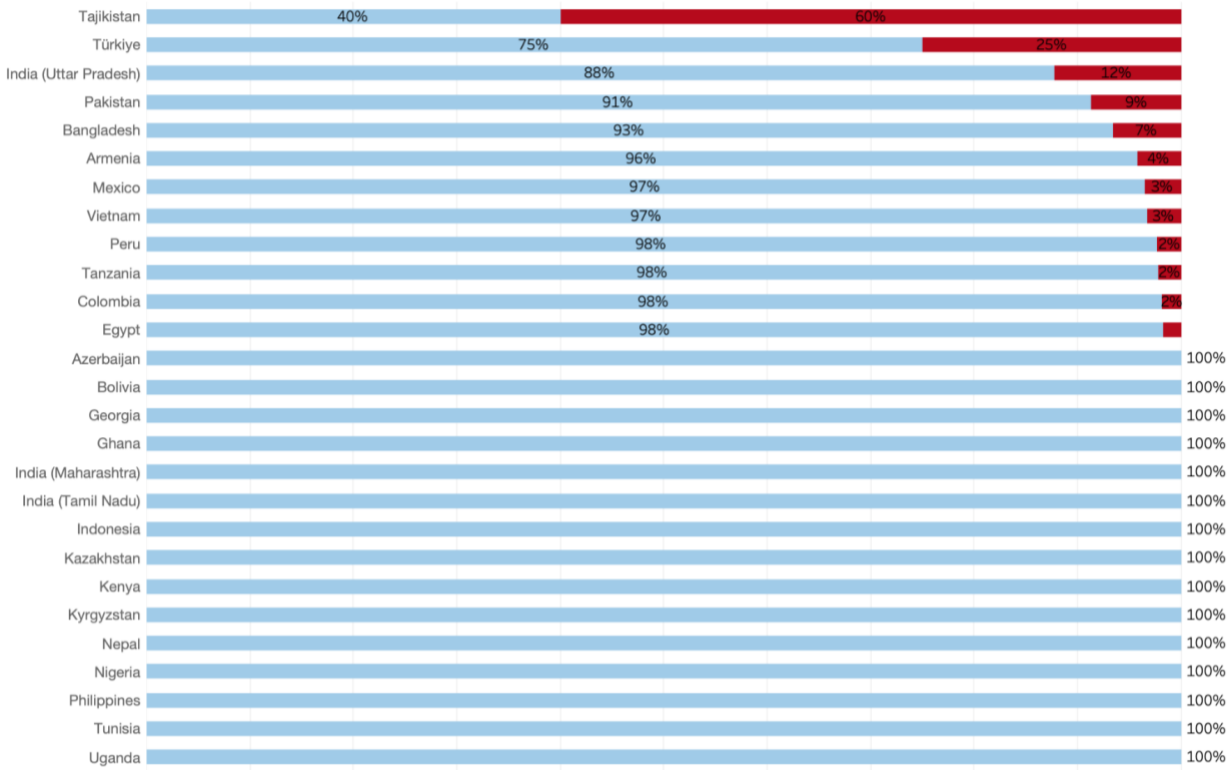
Summary of Spices Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	48	ND	ND	12	4
Azerbaijan	4	ND	ND	ND	0
Bangladesh	46	ND	ND	4	7
Bolivia	61	ND	ND	ND	0
Colombia	54	ND	ND	19	2
Egypt	59	ND	ND	3	2
Georgia	45	ND	ND	ND	0
Ghana	47	ND	ND	ND	0
India - Maharashtra	50	ND	ND	ND	0
India - Tamil Nadu	44	ND	ND	ND	0
India - Uttar Pradesh	41	ND	ND	622	12
Indonesia	34	ND	ND	ND	0
Kazakhstan	8	ND	ND	ND	0
Kenya	41	ND	ND	ND	0
Kyrgyzstan	48	ND	ND	ND	0
Mexico	29	ND	ND	10	3
Nepal	53	ND	ND	ND	0
Nigeria	67	ND	ND	ND	0
Pakistan	46	ND	ND	160	9
Peru	43	ND	ND	7	2

Philippines	55	ND	ND	2	0
Tajikistan	5	ND	ND	381	60
Tanzania	45	ND	ND	21	2
Tunisia	36	ND	ND	ND	0
Türkiye	4	ND	ND	4	25
Uganda	40	ND	ND	ND	0
Vietnam	31	ND	ND	9	3

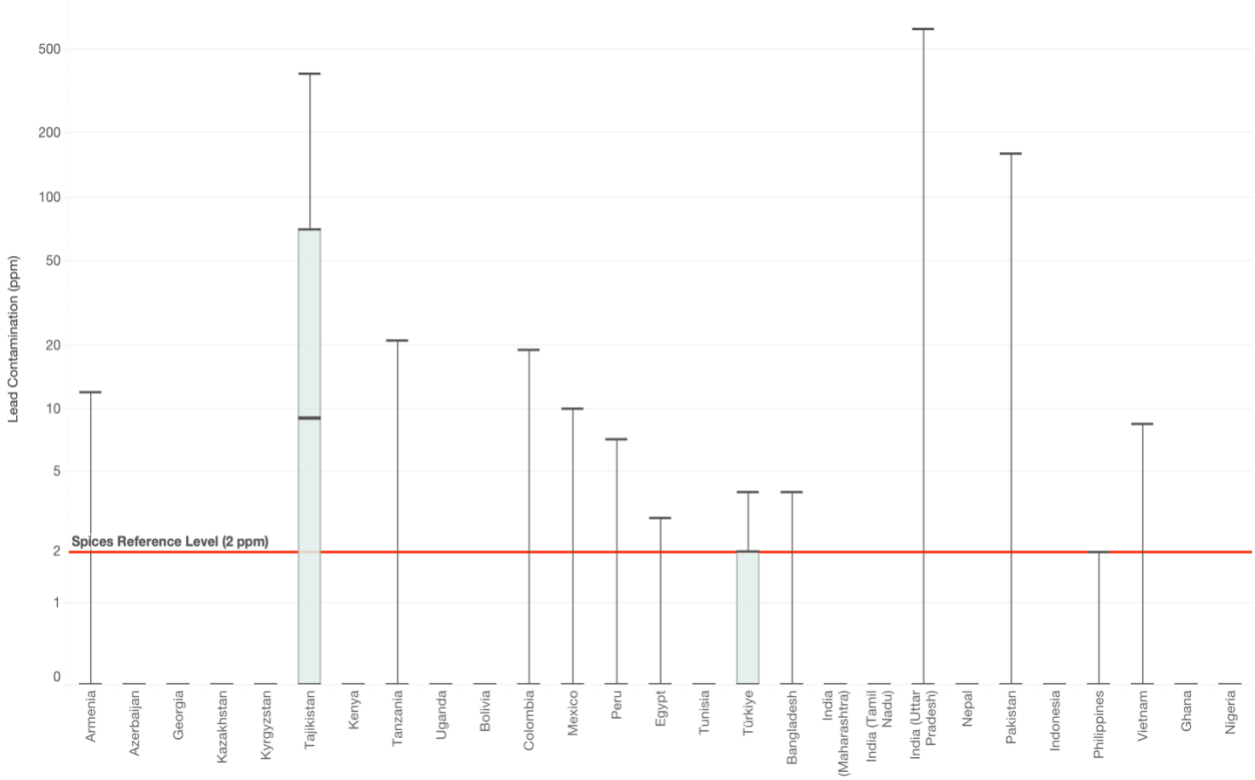
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples of Spices That Are Below and Above the Reference Level by Country



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Tajikistan and Türkiye have only 5 and 4 samples, respectively represented here.

Distribution of Sample Results by Quartile



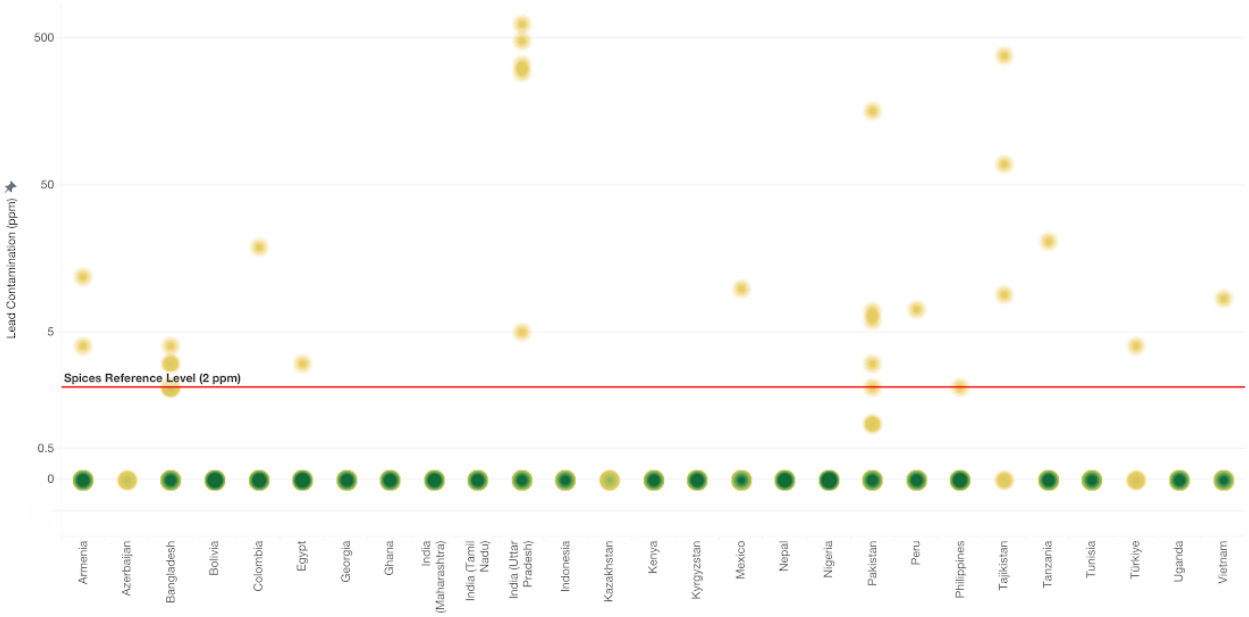
* **Note:** Tajikistan and Türkiye have 5 and 4 samples, respectively represented here.

The 24 spice samples found to exceed the reference level were from 12 countries, with the highest number from the state of Uttar Pradesh in India (5), followed by Pakistan (4), Bangladesh (3), Tajikistan (3), Armenia (2), Türkiye (1), Egypt (1), Tanzania (1), Vietnam (1), Mexico (1), Colombia (1) and Peru (1), representing a high level of geographic diversity.

Turmeric was the most common spice among those with elevated lead levels, representing 9 of the 24 samples. Furthermore, out of the 7 samples with the highest lead concentrations, 6 were turmeric samples. The maximum concentration of lead in turmeric was found to be 622 ppm, more than 300 times the reference level. Levels this high point to likely adulteration with a lead-based pigment.

Other spices identified as having elevated lead levels were certain spice mixes such as garam masala, curry powder, and mole, as well as cardamom, achiote (annatto), coriander, caraway, ginger, salt, chili, paprika, cinnamon, and pepper.

Distribution of Results by Individual Samples



Sweets

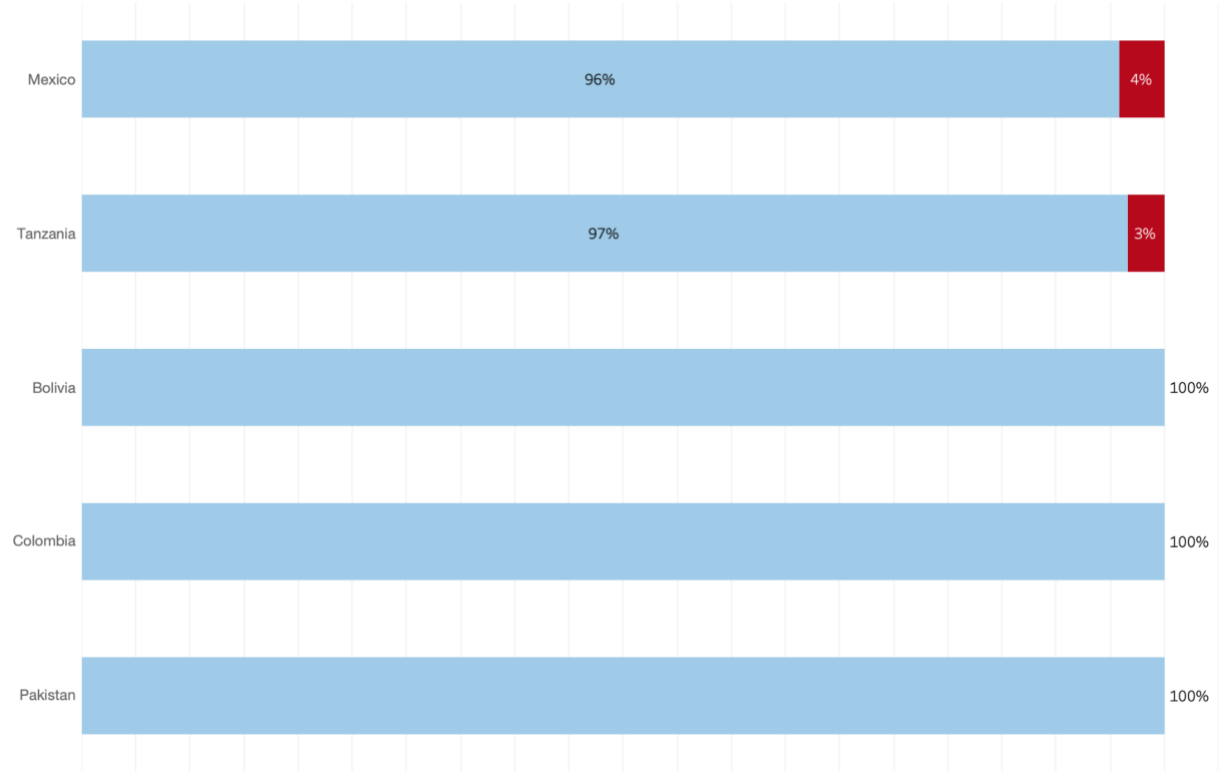
Out of 111 samples of sweets, 3% showed lead levels exceeding the reference level of 0.1 ppm. Readers should note that the reference level for sweets is below the XRF's limit of detection. Therefore, it is possible that samples had a reading of "non-detect" but actually exceeded the reference level.

Summary of Sweets Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Tanzania	30	ND	ND	4	3
Bolivia	2	ND	ND	ND	0
Colombia	11	ND	ND	ND	0
Mexico	48	ND	ND	5	4
Pakistan	20	ND	ND	ND	0

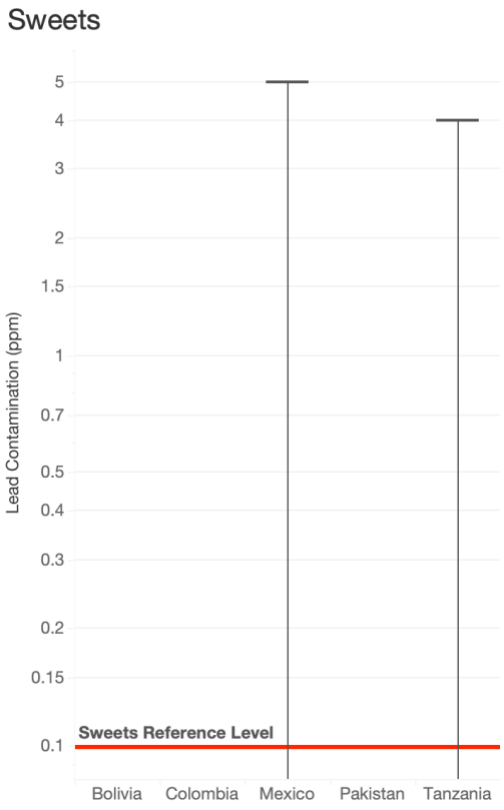
ND = "non-detect" (lead concentration was below the XRF's lower detection limit)

Percentage of Samples of Sweets That Are Below and Above the Reference Level by Country

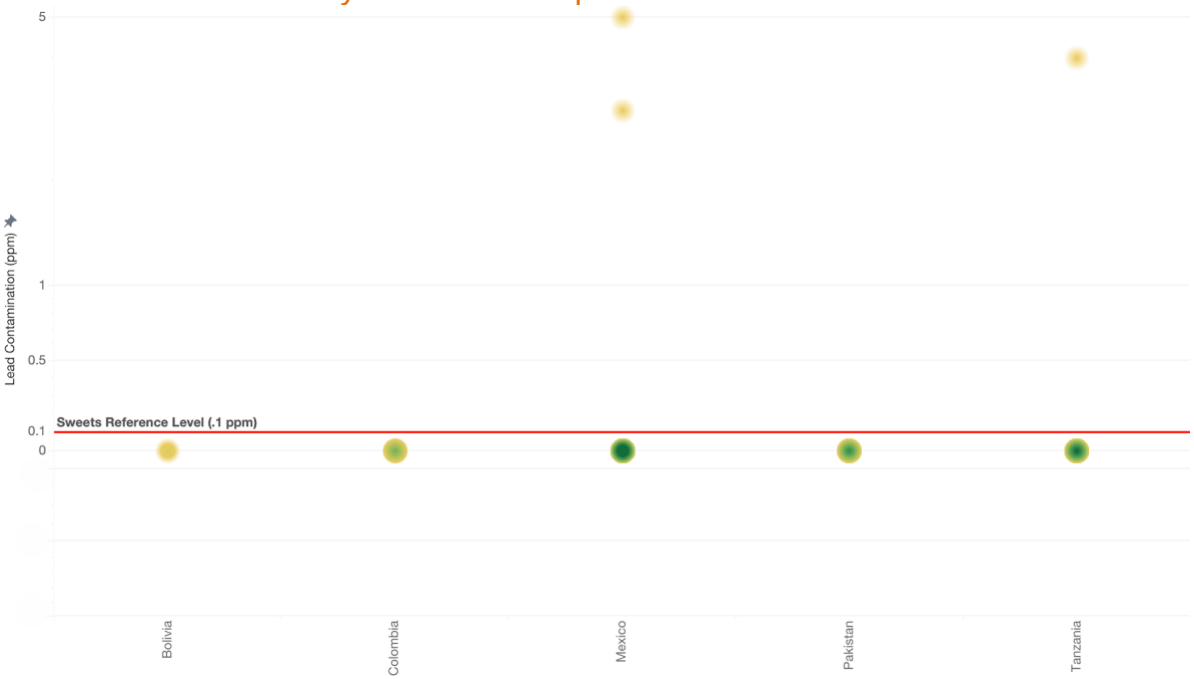


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Only 2 samples were analyzed from Bolivia.

Distribution of Sample Results by Quartile



Distribution of Results by Individual Samples



Staple Dry Foods

Out of 364 samples of dry foods that local RMS Investigators felt were common enough to consider as “staples,” 1% showed lead levels exceeding the reference level of 0.2 ppm.

Readers should note that the reference level for staple dry foods is below the XRF’s limit of detection. Therefore, it is possible that samples had a reading of “non-detect,” but actually exceeded the reference level.

Summary of Staple Dry Foods Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Armenia	9	ND	ND	3	11
Georgia	5	ND	ND	ND	0
Kazakhstan	3	ND	ND	ND	0
Kyrgyzstan	14	ND	ND	ND	0
Tajikistan	3	ND	ND	ND	0
Kenya	8	ND	ND	ND	0
Tanzania	9	ND	ND	ND	0
Uganda	17	ND	ND	3	6
Bolivia	6	ND	ND	ND	0
Colombia	9	ND	ND	ND	0
Mexico	11	ND	ND	ND	0
Peru	10	ND	ND	ND	0
Egypt	4	ND	ND	ND	0
Tunisia	18	ND	ND	ND	0
Bangladesh	12	ND	ND	8	17
India - Maharashtra	10	ND	ND	ND	0
India - Tamil Nadu	9	ND	ND	ND	0

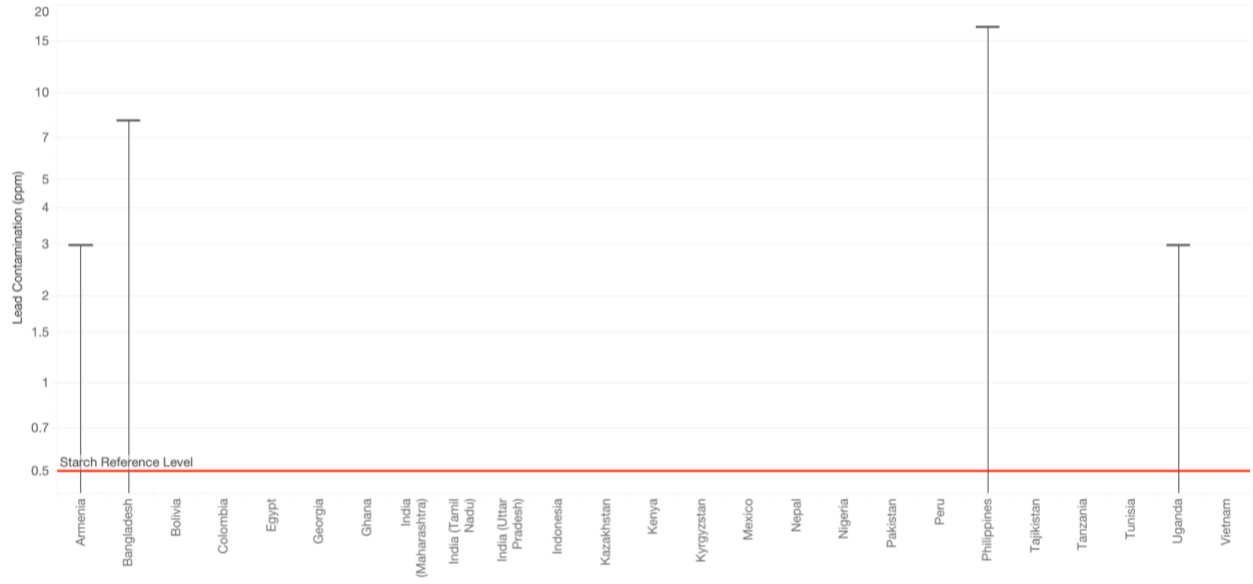
India - Uttar Pradesh	3	ND	ND	ND	0
Nepal	16	ND	ND	ND	0
Pakistan	9	ND	ND	ND	0
Indonesia	9	ND	ND	ND	0
Philippines	49	ND	ND	17	2
Vietnam	9	ND	ND	ND	0
Ghana	29	ND	ND	ND	0
Nigeria	83	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

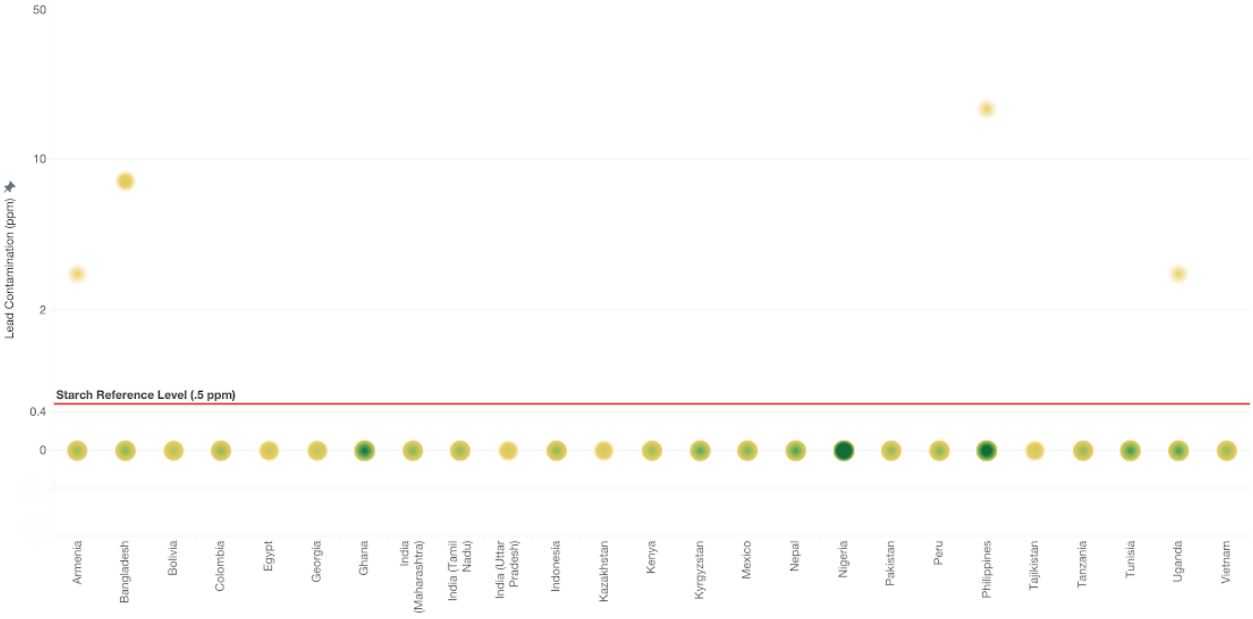
Percentage of Samples of Staple Dry Foods That Are Below and Above the Reference Level by Country

Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Distribution of Sample Results (by Quartile)



Distribution of Sampling Results by Individual Samples



Herbal/Traditional Medicines

Out of 54 samples of herbal and traditional medicines, 4% showed lead levels exceeding the reference level of 10 ppm.

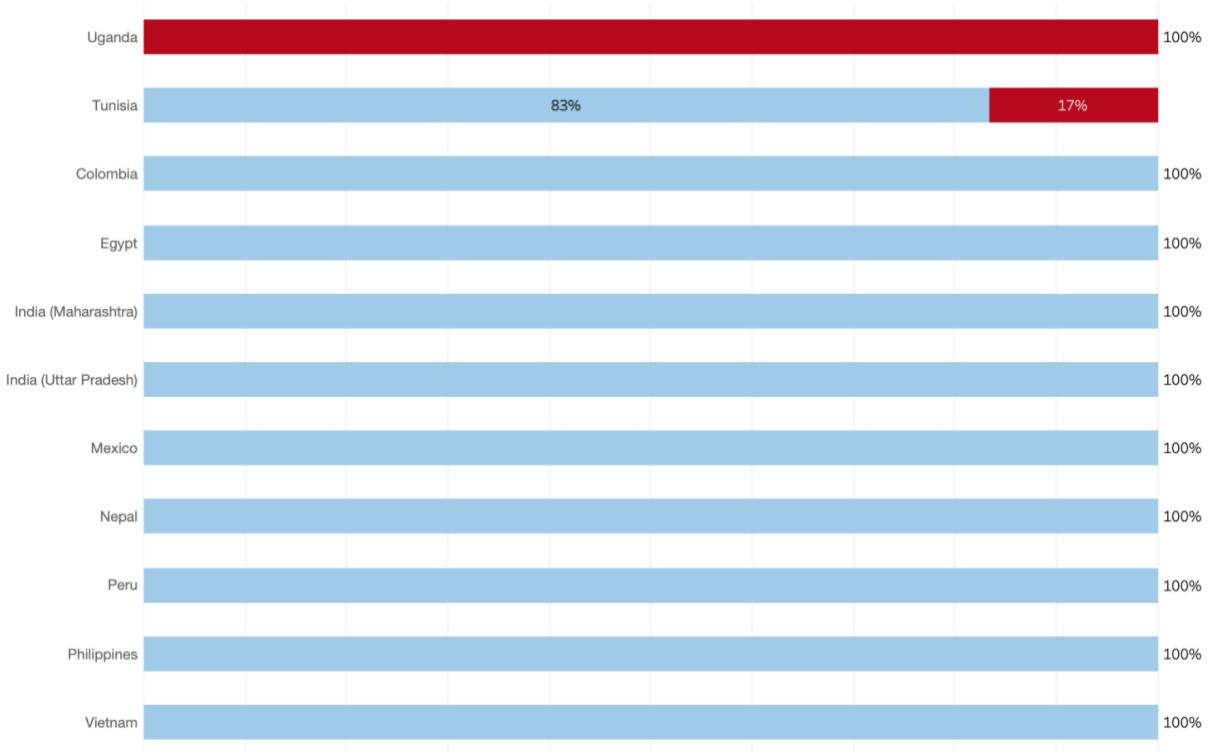
Summary of Herbal/Traditional Medicines Results by Country

Country Name	# of Samples	Min Value (ppm)	Median Value (ppm)	Max Value (ppm)	% Above Reference
Uganda	1	31	31	31	100

Colombia	8	ND	ND	ND	0
Mexico	4	ND	ND	ND	0
Peru	2	ND	ND	ND	0
Egypt	10	ND	ND	ND	0
Tunisia	6	ND	ND	19	17
India - Maharashtra	3	ND	ND	ND	0
India - Uttar Pradesh	4	ND	ND	ND	0
Nepal	9	ND	ND	ND	0
Philippines	2	ND	ND	ND	0
Vietnam	5	ND	ND	ND	0

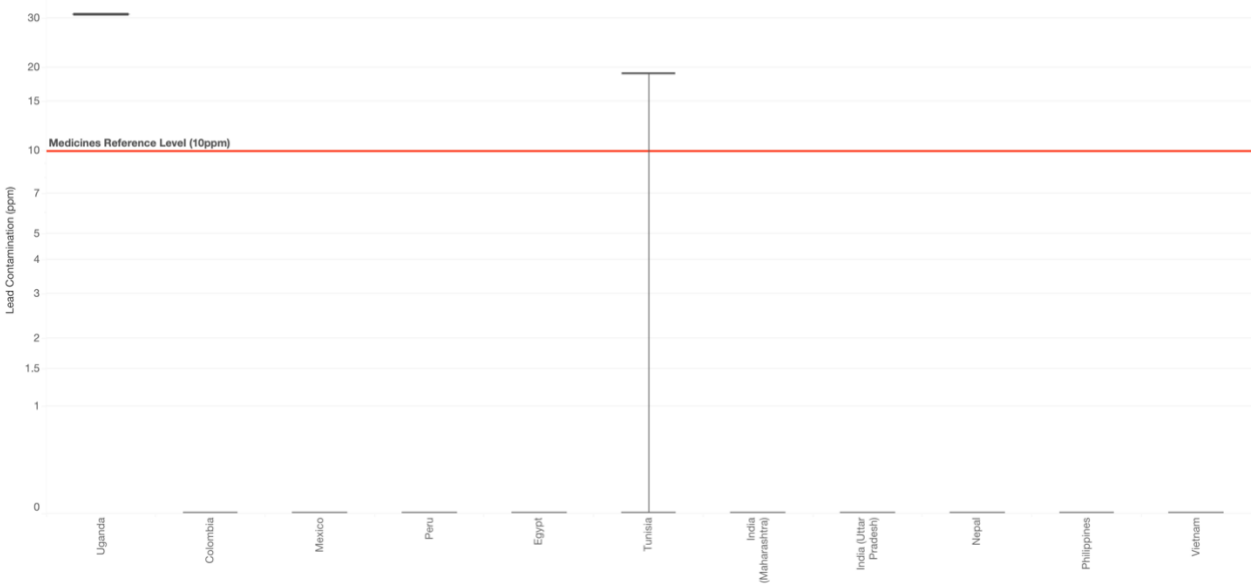
ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples of Herbal/Traditional Medicines That Are Below and Above the Reference Level by Country

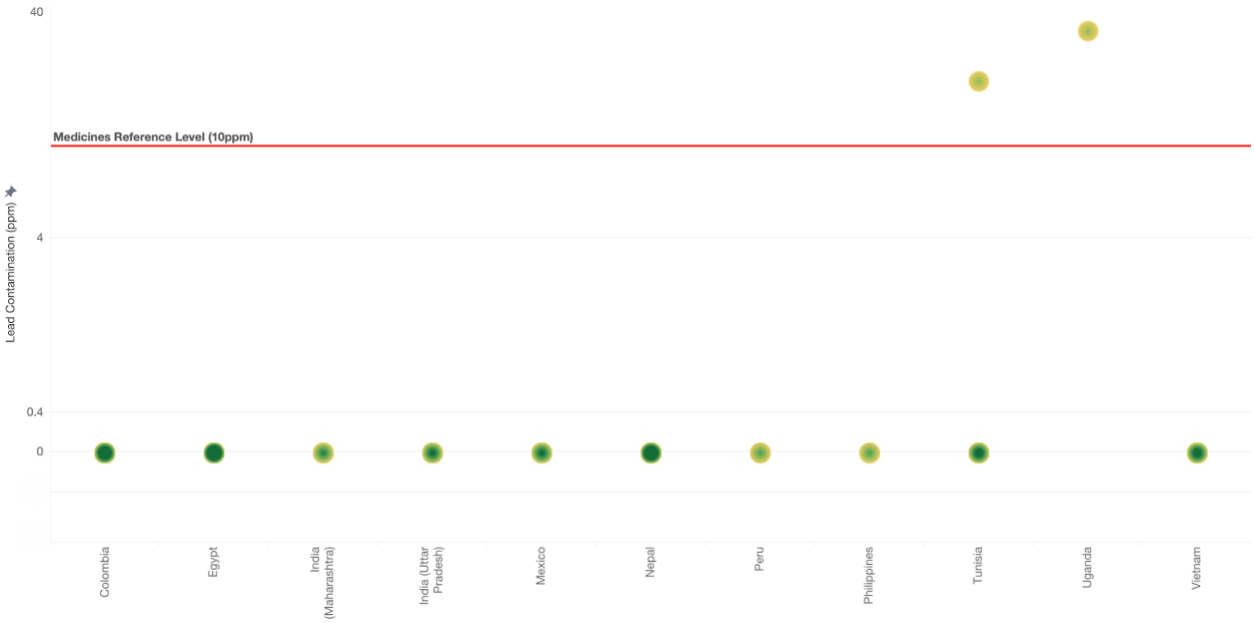


Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: Uganda has only 1 sample represented here.

Distribution of Sample Results by Quartile



Distribution of Herbal/Traditional Medicine Sampling Results by Individual Samples



Findings by Country

Armenia

Pure Earth analyzed a total of 180 samples from Armenia, and of these, 7% exceeded the relevant reference levels. As with other countries, a high percentage of ceramic

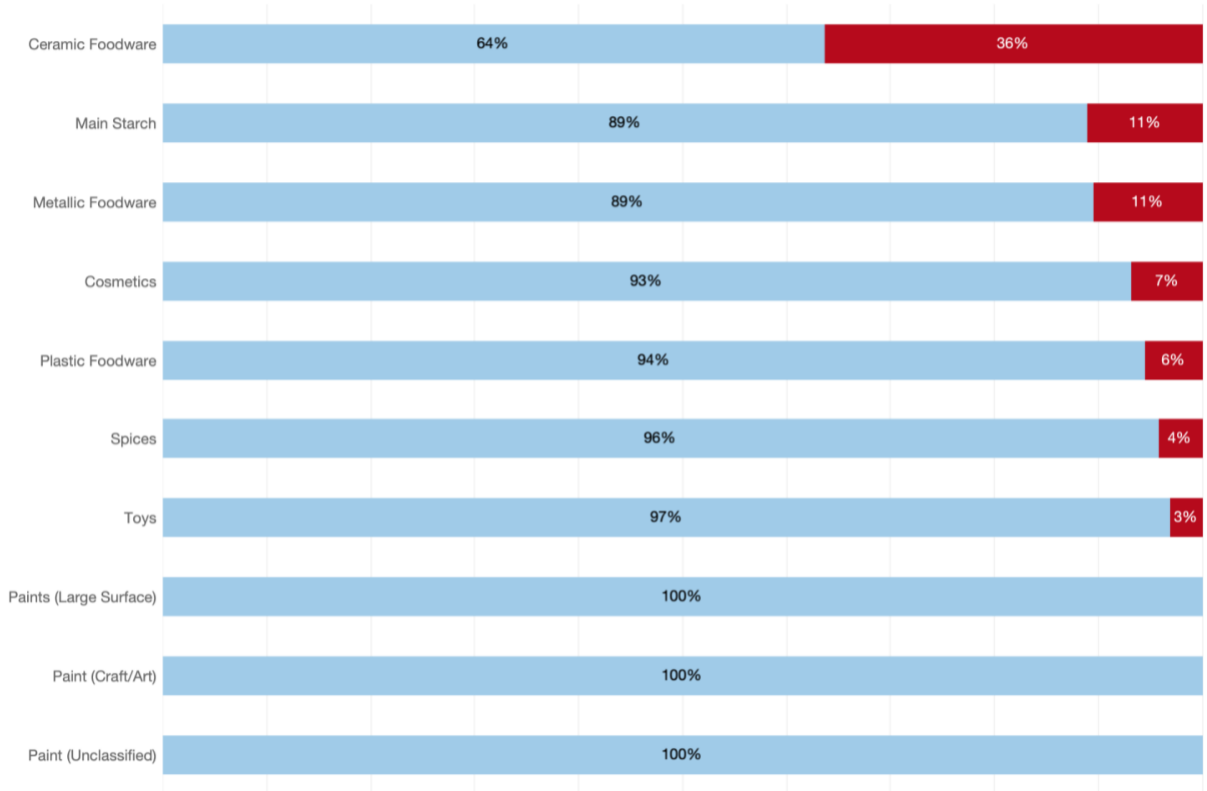
foodware exceeded the reference level (36%). Overall, samples from Armenia had comparatively lower lead levels than many other countries.

Summary of Results from Armenia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% above reference
Ceramic foodware	11	ND	58	9280	36
Staple dry food	9	ND	ND	3	11
Metallic foodware	19	ND	ND	287	11
Cosmetics	29	ND	ND	174	7
Plastic foodware	18	ND	ND	478	6
Spices	48	ND	ND	12	4
Toys	32	ND	ND	3125	3
Paint - unclassified	3	ND	ND	ND	0
Paint - craft/art	4	ND	3	19	0
Paint - large surfaces	7	ND	ND	6	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Armenia Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Azerbaijan

Pure Earth analyzed a total of 92 samples from Azerbaijan, and of these, 68% exceeded the relevant reference levels. A comparatively high percentage of samples of foodware, toys, and paints exceeded the reference levels, but almost all categories had samples with elevated lead levels.

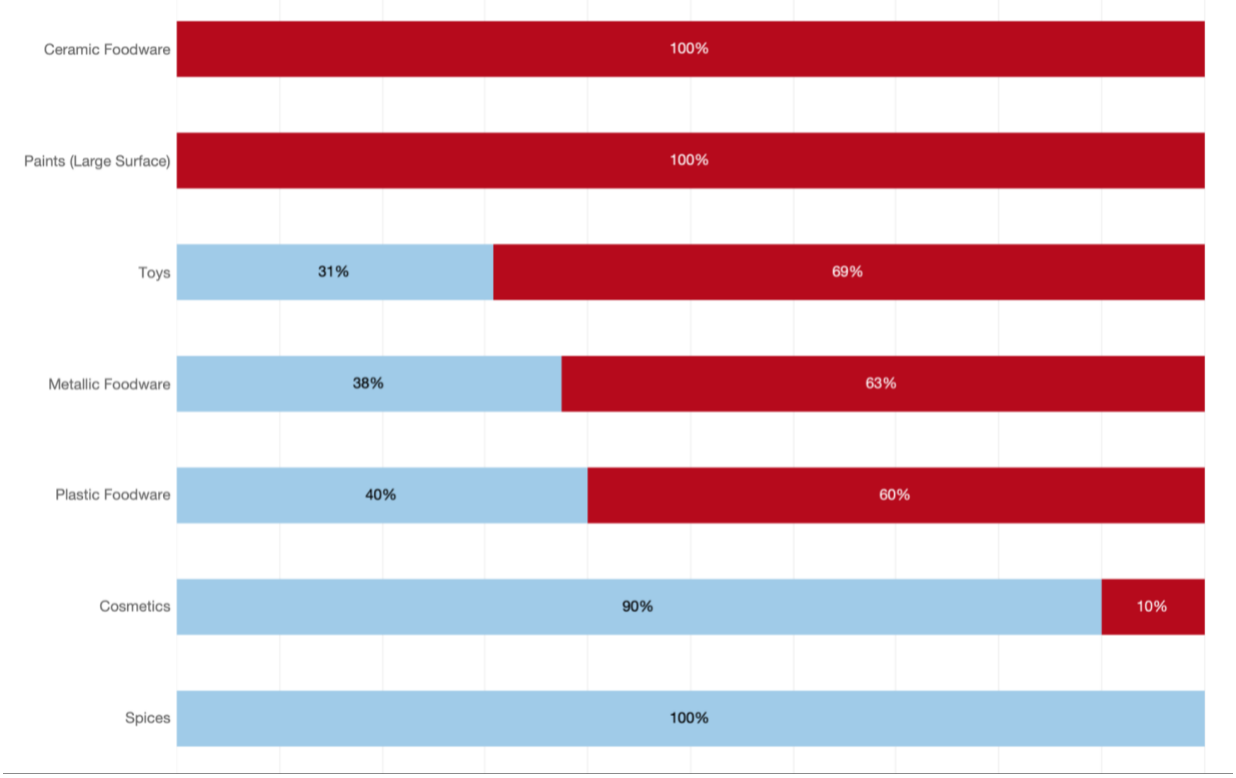
Summary of Results from Azerbaijan in Order of % Exceeding Reference Levels

Item category	# of Samples	Min Value (ppm)	Median	Max Value (ppm)	% above reference
Ceramic foodware	13	312	774	11400	100
Paints	18	600	2603	12400	100
Toys	26	ND	311	1175	69
Metallic foodware	16	ND	178	2342	63
Plastic foodware	5	ND	211	1196	60
Cosmetics	10	ND	ND	8	10

Spices	4	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Azerbaijan Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Bangladesh

Pure Earth analyzed 197 samples from Bangladesh, and of these, 24% exceeded the relevant reference levels. Metal foodware, ceramic foodware, and paint stand out as product types that had a particularly high percentage of samples exceeding the reference levels.

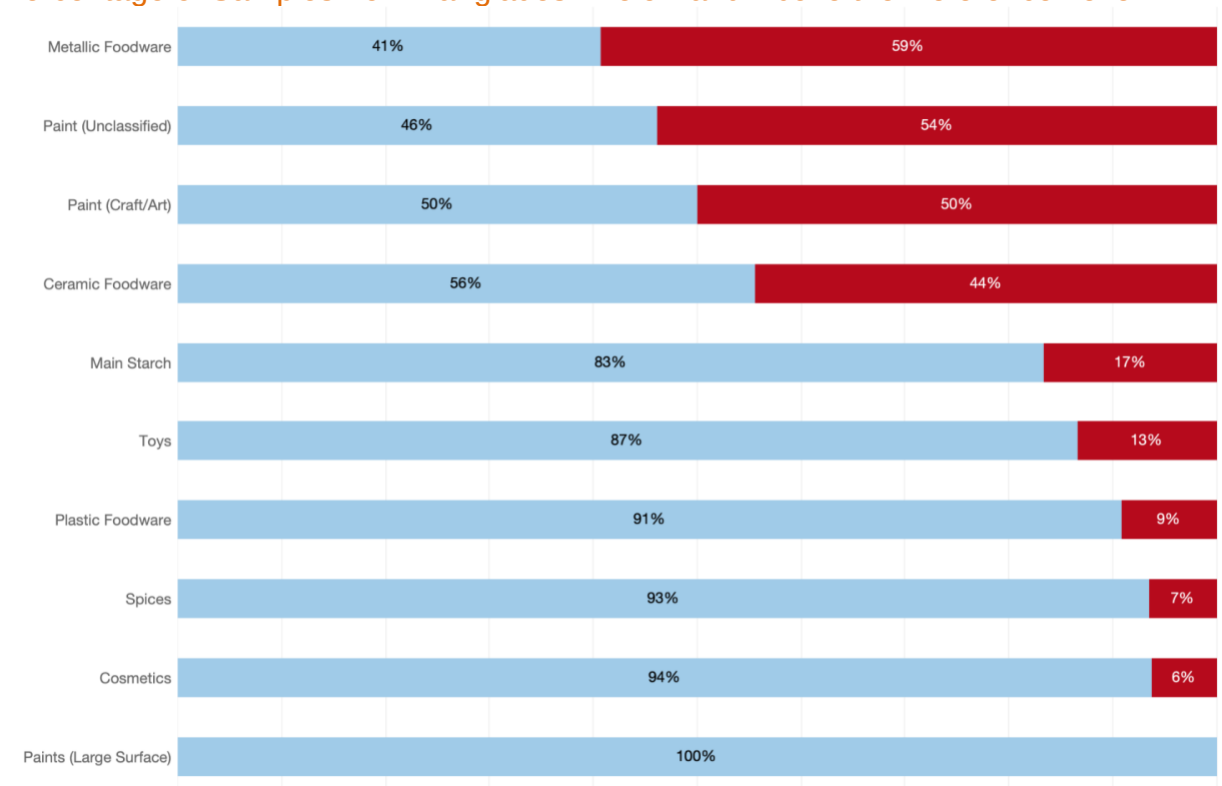
Summary of Results from Bangladesh in Order of % Exceeding Reference Levels

Item category	# of Samples	Min Value (ppm)	Median	Max Value (ppm)	% Above Reference
Metallic foodware	27	ND	186	8186	59
Paint - unclassified	26	ND	345	31360	54
Paint craft/art	2	ND	1903	3805	50
Ceramic foodware	9	ND	22	4636	44

Staple dry food	12	ND	ND	8	17
Toys	30	ND	ND	1814	13
Plastic foodware	11	ND	ND	672	9
Spices	46	ND	ND	4	7
Cosmetics	32	ND	ND	186	6
Paint - large surfaces	2	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Bangladesh Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The categories of Paints (large surface) and Paints (craft/art) each have only 2 samples.

Bolivia

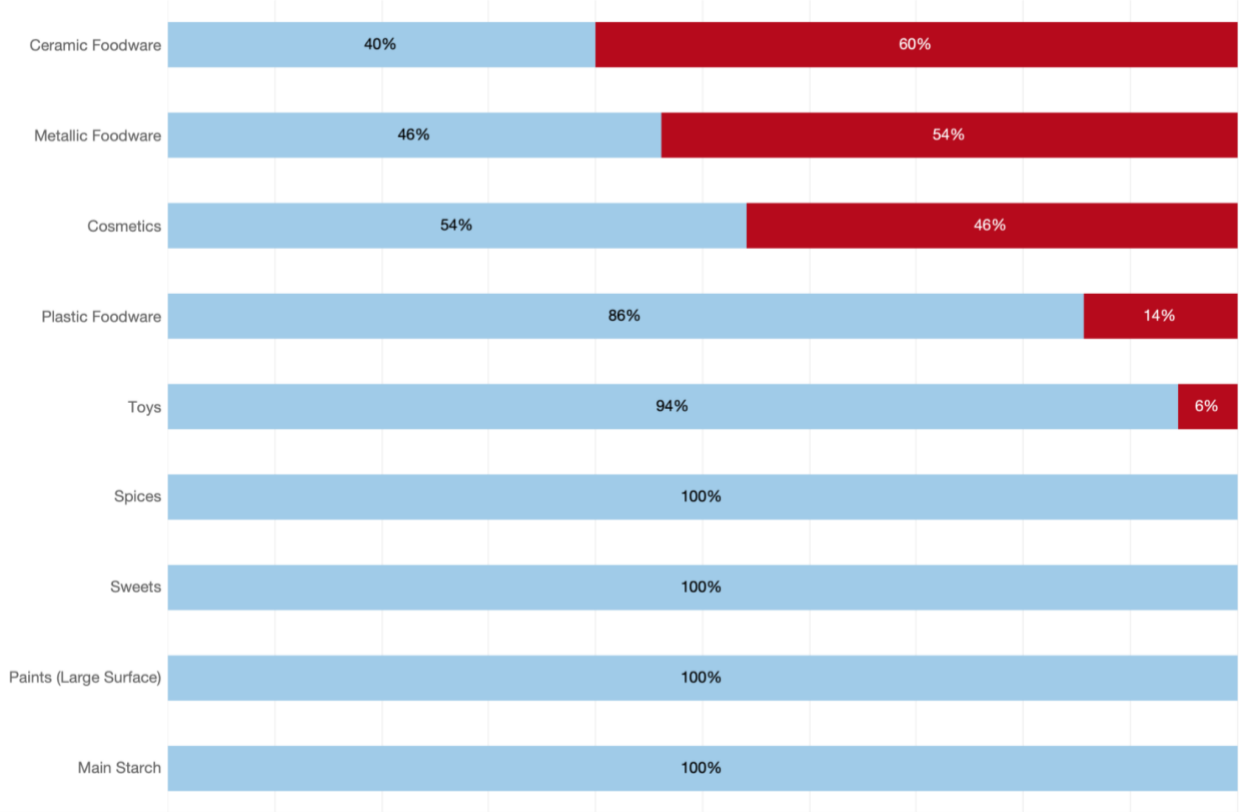
Pure Earth analyzed a total of 153 samples from Bolivia, and of these, 18% exceeded the relevant reference levels. As in many countries, a high percentage of metal and ceramic foodware samples exceeded the relevant reference levels, but unlike many countries, nearly 50% of the 24 cosmetics samples exceeded the relevant reference level.

Summary of Results from Bolivia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	10	35	131853	397100	60
Metallic foodware	13	ND	164	2049	54
Cosmetics	24	ND	ND	693	46
Plastic foodware	14	ND	ND	2073	14
Toys	18	ND	ND	1238	6
Paints	5	ND	ND	27	0
Spices	61	ND	ND	ND	0
Staple dry food	6	ND	ND	ND	0
Sweets	2	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Sweets only has 2 samples.

Colombia

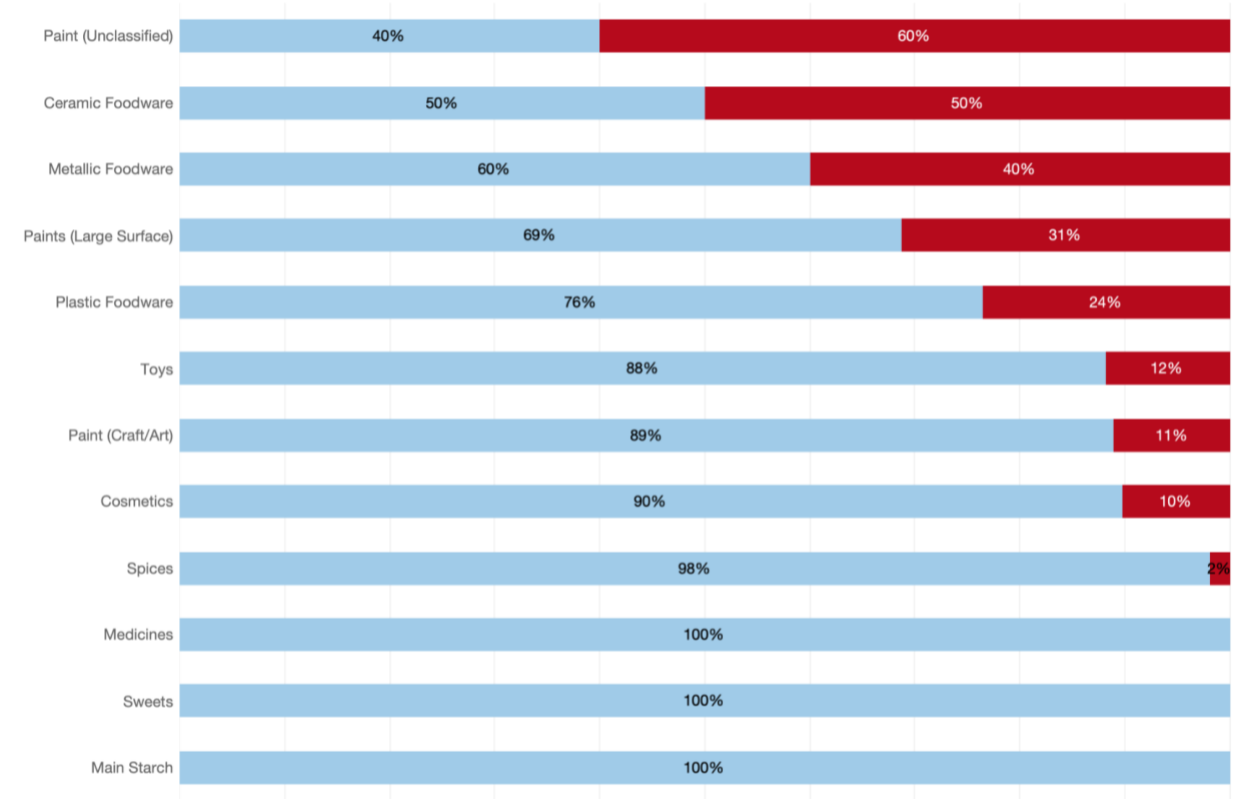
Pure Earth analyzed a total of 260 samples from Colombia, and of these, 18% exceeded the relevant reference levels. Metal foodware, ceramic foodware, and paint stand out as product types that had a particularly high percentage of samples exceeding the reference levels, but samples of cosmetics and toys also showed elevated lead levels.

Summary of Results from Colombia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paint - unclassified	10	ND	3268	58700	60
Ceramic foodware	18	ND	237	29100	50
Metallic foodware	35	ND	51	2679	40
Paints - large surfaces	16	ND	ND	66200	31
Plastic foodware	17	ND	ND	1687	24
Toys	34	ND	ND	455	12
Paint - craft/art	9	ND	ND	93500	11
Cosmetics	39	ND	ND	6751	10
Spices	54	ND	ND	19	2
Medicines	8	ND	ND	ND	0
Staple dry food	9	ND	ND	ND	0
Sweets	11	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Colombia Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Egypt

Pure Earth analyzed a total of 157 samples from Egypt, and of these, 15% exceeded the relevant reference levels. Like many countries, metal and ceramic foodware had a particularly high percentage of samples exceeding the reference levels, but cosmetics also showed unusually elevated lead levels among the 19 samples.

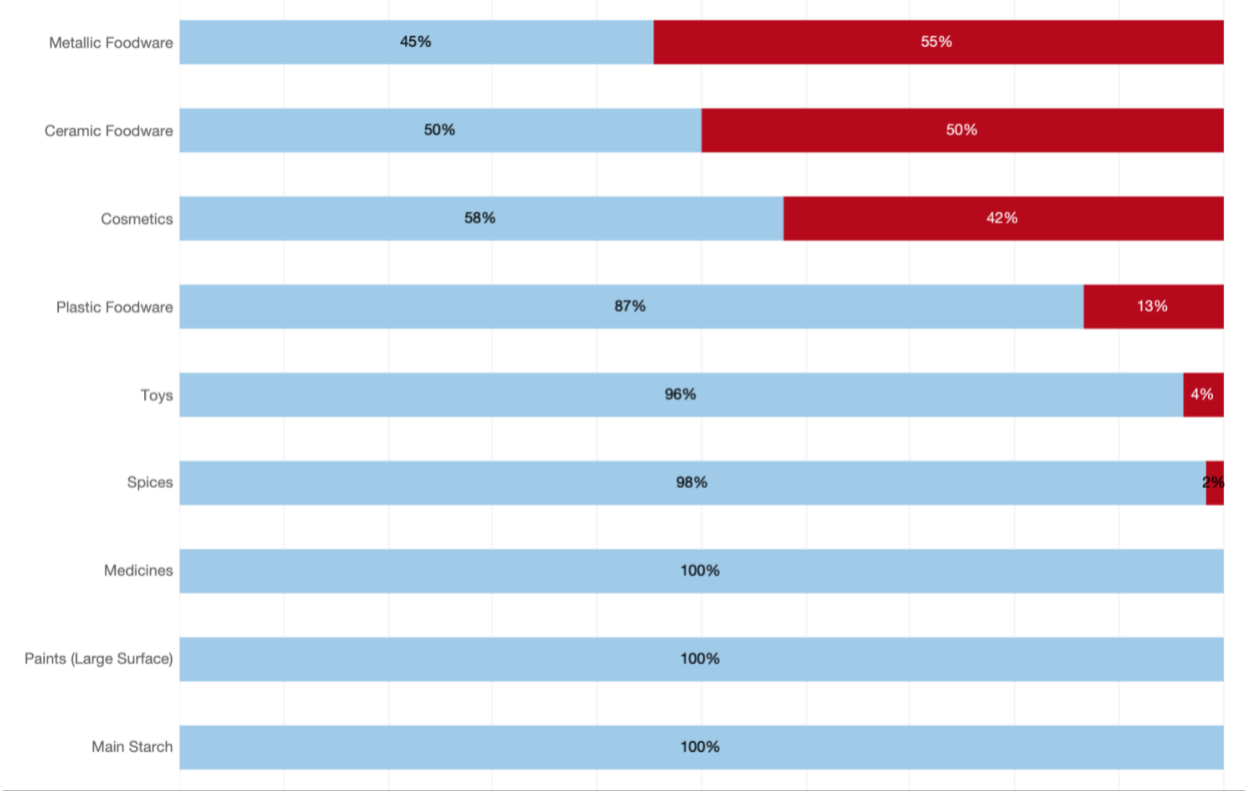
Summary of Results from Egypt in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Metallic foodware	11	ND	180	1086	55
Ceramic foodware	10	ND	158	50600	50
Cosmetics	19	ND	ND	13700	42
Plastic foodware	15	ND	ND	1121	13
Toys	26	ND	ND	967	4
Spices	59	ND	ND	3	2

Medicines	10	ND	ND	ND	0
Paints - large surfaces	3	ND	ND	ND	0
Staple dry food	4	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Egypt Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Georgia

Pure Earth analyzed 186 samples from Georgia, and of these, 12% exceeded the relevant reference levels. Like many countries, foodware and paints had a particularly high percentage of samples exceeding the reference levels. The absence of any spice samples with elevated lead levels is particularly notable and is discussed in greater detail below.

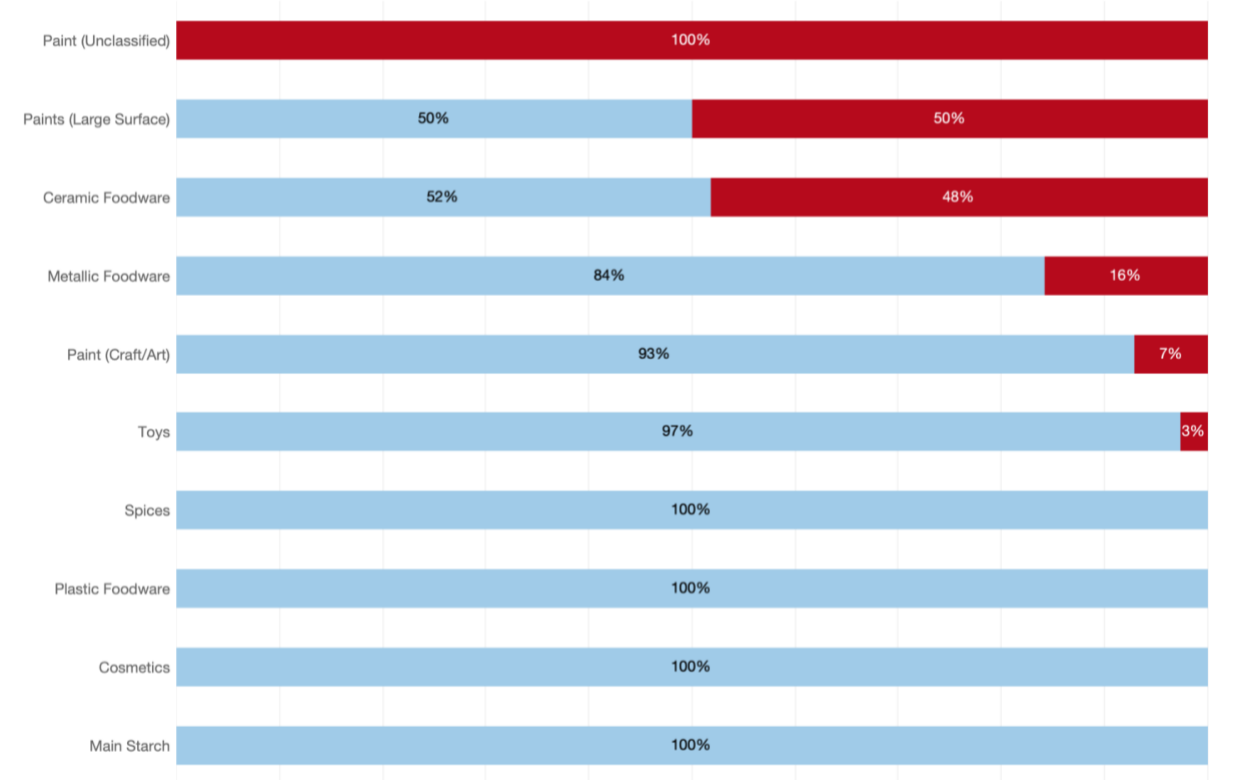
Summary of Results from Georgia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value 9ppm)	% Above Reference
Paint - unclassified	2	685	881	1077	100

Paints - large surfaces	4	ND	376	22600	50
Ceramic foodware	27	ND	76	13200	48
Metallic foodware	19	ND	ND	119500	16
Paint - craft/art	14	ND	ND	4449	7
Toys	38	ND	ND	376	3
Cosmetics	27	ND	ND	ND	0
Plastic foodware	5	ND	ND	ND	0
Spices	45	ND	ND	ND	0
Staple dry food	5	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Georgia Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Paint (unclassified) only has 2 samples.

Of particular interest in the RMS results was the absence of any Georgian spice samples with detectable lead levels. Since 2018, Georgia has been the subject of much research and activity by the Government of Georgia, Pure Earth, UNICEF, and others

aimed at assessing and reducing childhood lead poisoning following findings from a 2018 survey that suggested 41% of Georgian children had blood lead levels exceeding 5 µg/dL. Since then, particular emphasis has been placed on eliminating the practice of adulterating spices with lead-based pigments, particularly lead chromate, which had been used by some spice producers to enhance color. Under a separate program unrelated to the RMS, Pure Earth assessed lead levels in hundreds of spice sample between 2020 and 2023. The sampling results from those prior assessments show a considerable decline in lead levels since 2020. The RMS results are aligned with the trends seen in these other assessments and suggest that efforts to eliminate the practice of adulteration have been successful.

Results from Prior Assessments of Lead in Georgian Spices by Pure Earth

Region in Georgia	1st round of testing (2020)			2nd round of testing (2022)		
	Number of samples tested	Maximum lead concentration (ppm)	Average lead concentration (ppm)	Number of samples tested	Maximum lead concentration (ppm)	Average lead concentration (ppm)
Adjara	93	14800	359	93	46	4
Tbilisi	23	156	7	23	6	0.8
Imereti	38	47	2	31	11	1.3
Shida Kartli	21	2	0	21	3	0.5
Kvemo Kartli	12	5	1	12	7	1.5
Guria	10	98	10	10	12	2.8
Samegrelo	23	4	0.5	23	4	1.1
Samtskhe	13	4	0.4	13	10	2.7
Kakheti	19	3	0.5	19	4441*	234*
Mtskheta-Mtianeti	10	2	0.7	10	5	1.4

*We believe the results in red are influenced by a single spice sample from an old batch of spices that the producer manufactured years earlier, prior to interventions aimed at preventing adulteration.

Ghana

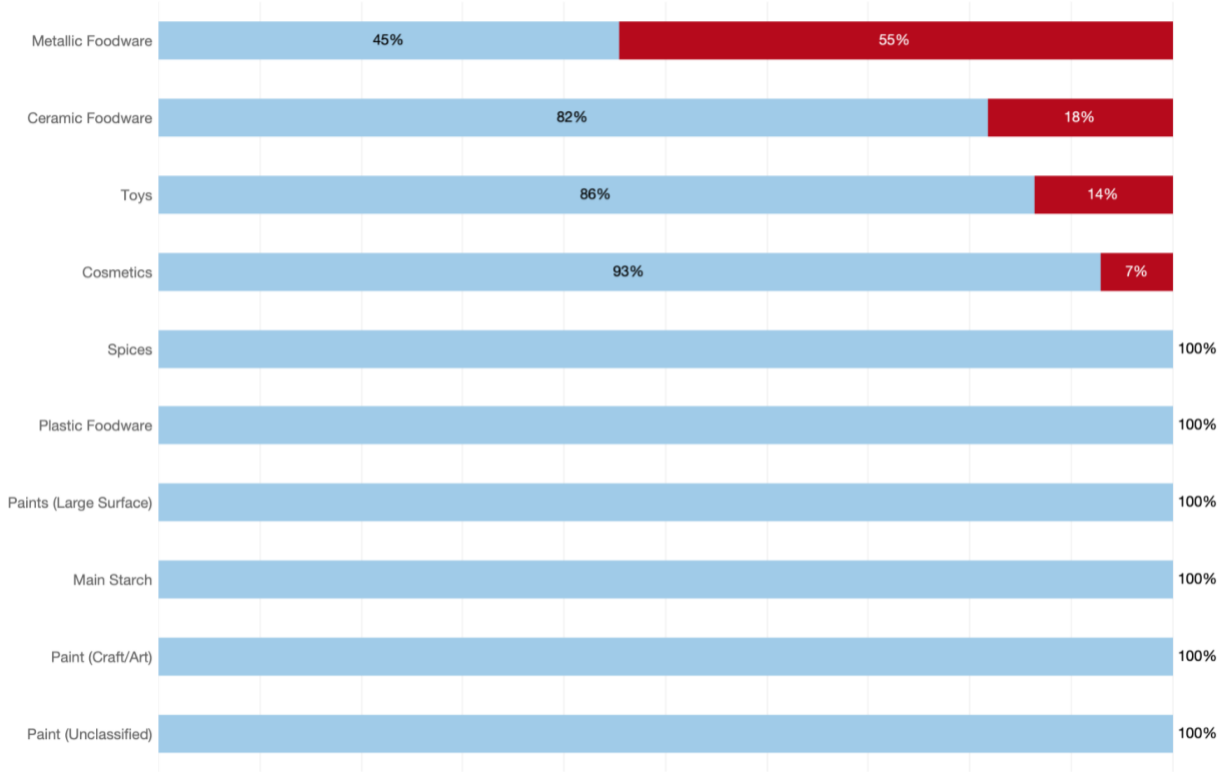
Pure Earth analyzed a total of 193 samples from Ghana, and of these, 10% exceeded the relevant reference levels. As in many countries, metallic foodware had a particularly high percentage of samples exceeding the reference levels.

Summary of Results from Ghana in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above reference
Metallic foodware	22	ND	181	24100	55
Ceramic foodware	11	30	50	6570	18
Toys	22	ND	ND	1533	14
Cosmetics	28	ND	ND	220	7
Paint - unclassified	18	ND	ND	4	0
Paint - craft/art	3	ND	ND	ND	0
Paints - large surfaces	1	ND	ND	ND	0
Plastic foodware	12	ND	ND	32	0
Spices	47	ND	ND	ND	0
Staple dry food	29	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Ghana Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Paint (large surface) only has 1 sample.

India - Maharashtra State

Pure Earth analyzed a total of 257 samples from Maharashtra State, India, and of these, 17% exceeded the relevant reference levels. Foodware, paints, and toys showed particularly high lead levels compared with other sample categories. Interestingly, contaminated spices, which other research projects have found to be prevalent in North and Northeast India, did not show up in the spice samples from Maharashtra, which spans from Central India to the West Coast.

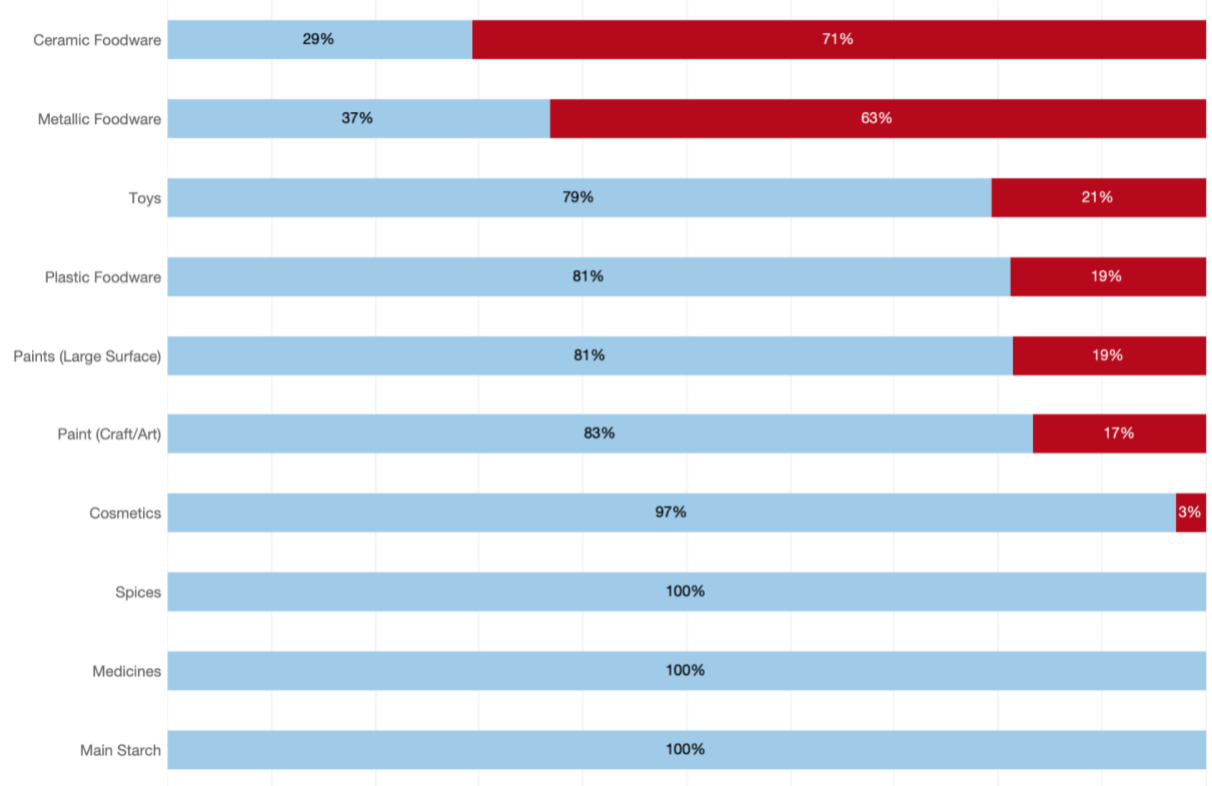
Summary of Results from Maharashtra in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above reference
Ceramic foodware	17	ND	1910	80000	71
Metallic foodware	19	ND	720	6590	63
Toys	34	ND	ND	97300	21
Plastic foodware	16	ND	ND	437	19
Paints - large	27	ND	ND	164000	19

surfaces					
Paint - craft/art	12	ND	ND	1616	17
Cosmetics	69	ND	ND	60	3
Medicines	3	ND	ND	ND	0
Spices	50	ND	ND	ND	0
Staple dry food	10	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Maharashtra Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

India - Tamil Nadu State

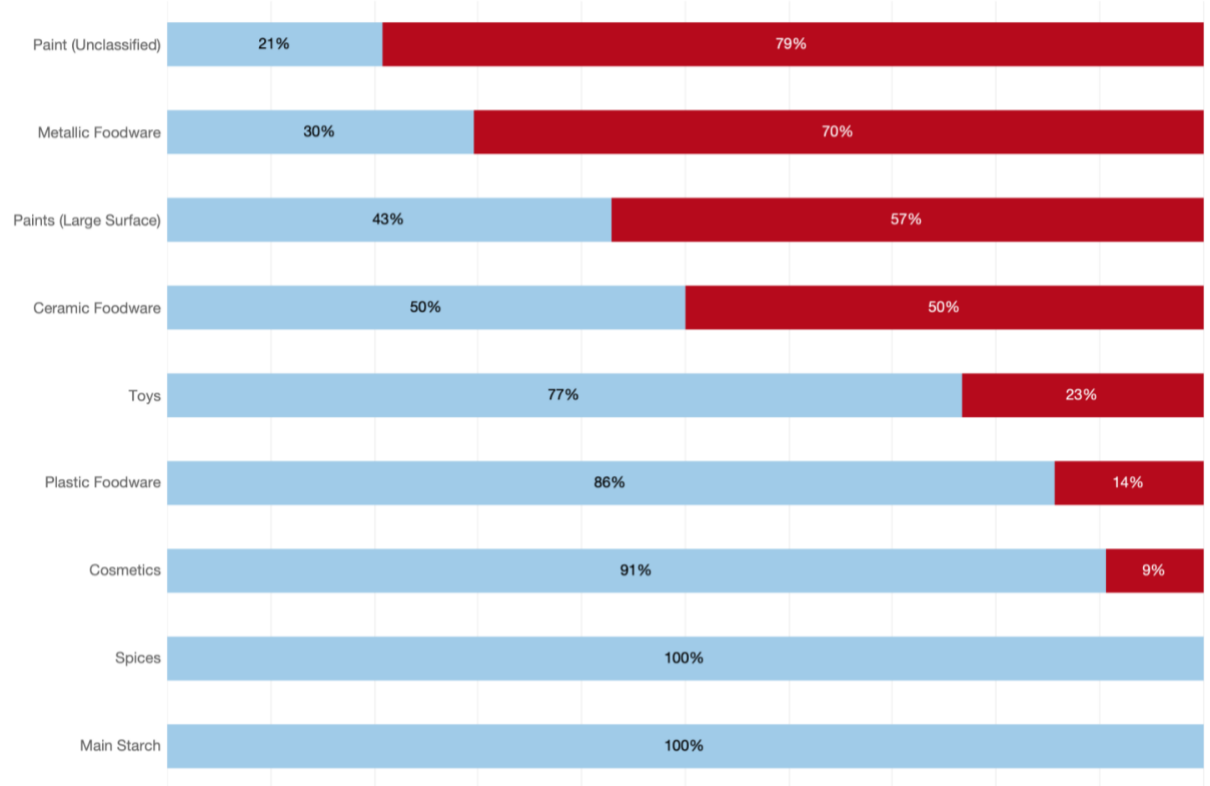
Pure Earth analyzed 188 samples from Tamil Nadu State, India, and of these, 30% exceeded the relevant reference levels. As with many locations, samples of foodware and paints often exceeded reference levels, with samples of toys and cosmetics also showing elevated levels among some samples. As with Maharashtra State, spice samples from Tamil Nadu, which sits at the Southeastern tip of India, did not show the type of elevated lead levels that have been found in India’s Northern and Northeastern States.

Summary of Results from Tamil Nadu in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paint - unclassified	24	ND	2915	40700	79
Metallic foodware	27	ND	870	13900	70
Paints - large surfaces	7	ND	2356	13400	57
Ceramic foodware	8	ND	75	5230	50
Toys	30	ND	ND	3250	23
Plastic foodware	7	ND	ND	872	14
Cosmetics	32	ND	ND	231	9
Spices	44	ND	ND	ND	0
Staple dry food	9	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Tamil Nadu Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

India - Uttar Pradesh State

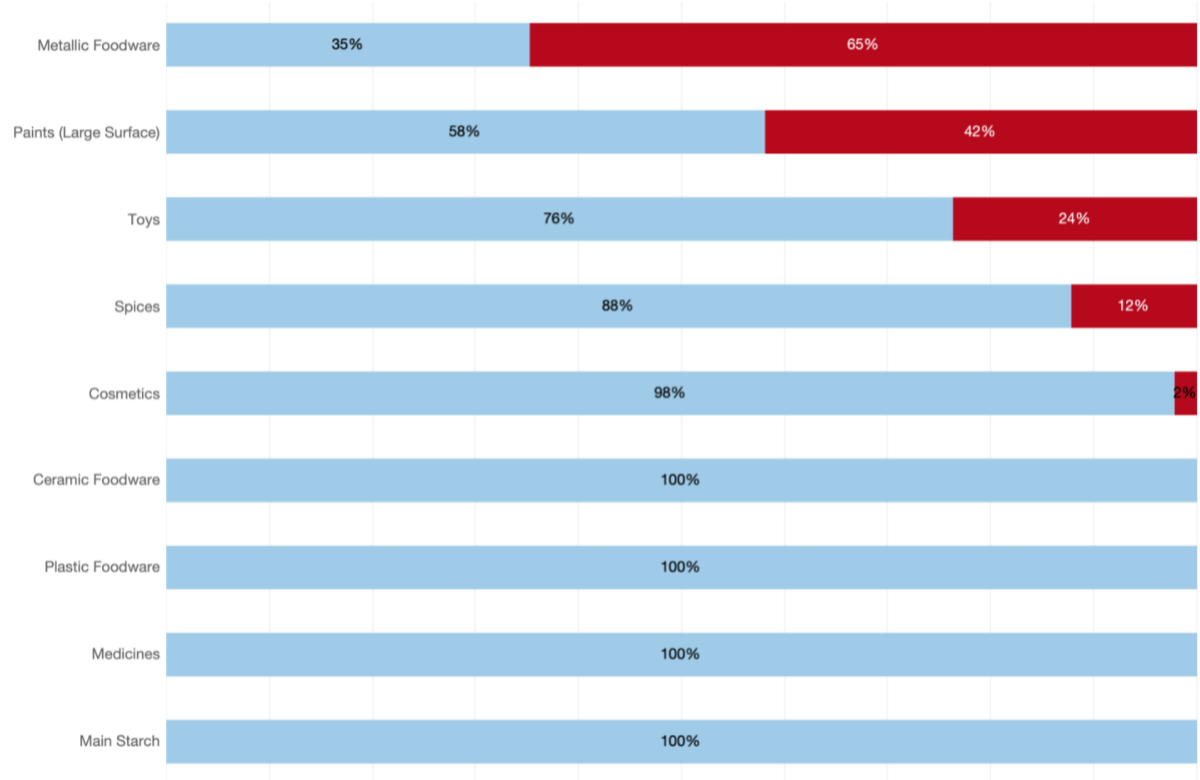
Pure Earth analyzed a total of 204 samples from Uttar Pradesh State, India, and of these, 19% exceeded the relevant reference levels. Samples of metallic foodware and paints often exceeded the relevant reference levels. Unlike Maharashtra and Tamil Nadu States, spice samples from Uttar Pradesh did exhibit elevated lead levels, which is consistent with findings from other recent lead exposure source assessment programs that have identified lead-contaminated spices in India's north and northeast.

Summary of Results from Uttar Pradesh in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median	Max Value (ppm)	% Above Reference
Metallic foodware	17	ND	850	74600	65
Paints - large surfaces	31	ND	ND	33200	42
Toys	38	ND	ND	4680	24
Spices	41	ND	ND	622	12
Cosmetics	46	ND	ND	58	2
Ceramic foodware	6	ND	20	80	0
Medicines	4	ND	ND	ND	0
Plastic foodware	18	ND	ND	11	0
Staple dry food	3	ND	ND	ND	0

ND = "non-detect" (lead concentration was below the XRF's lower detection limit)

Percentage of Samples from Uttar Pradesh Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Indonesia

Pure Earth analyzed a total of 176 samples from Indonesia, and of these, 40% exceeded the relevant reference levels. Metallic foodware, paints, and cosmetics emerged as the products with the highest percentage of samples exceeding the relevant reference levels. Of particular note is that among the 31 paint samples, 97% exceeded the reference level of 90 ppm.

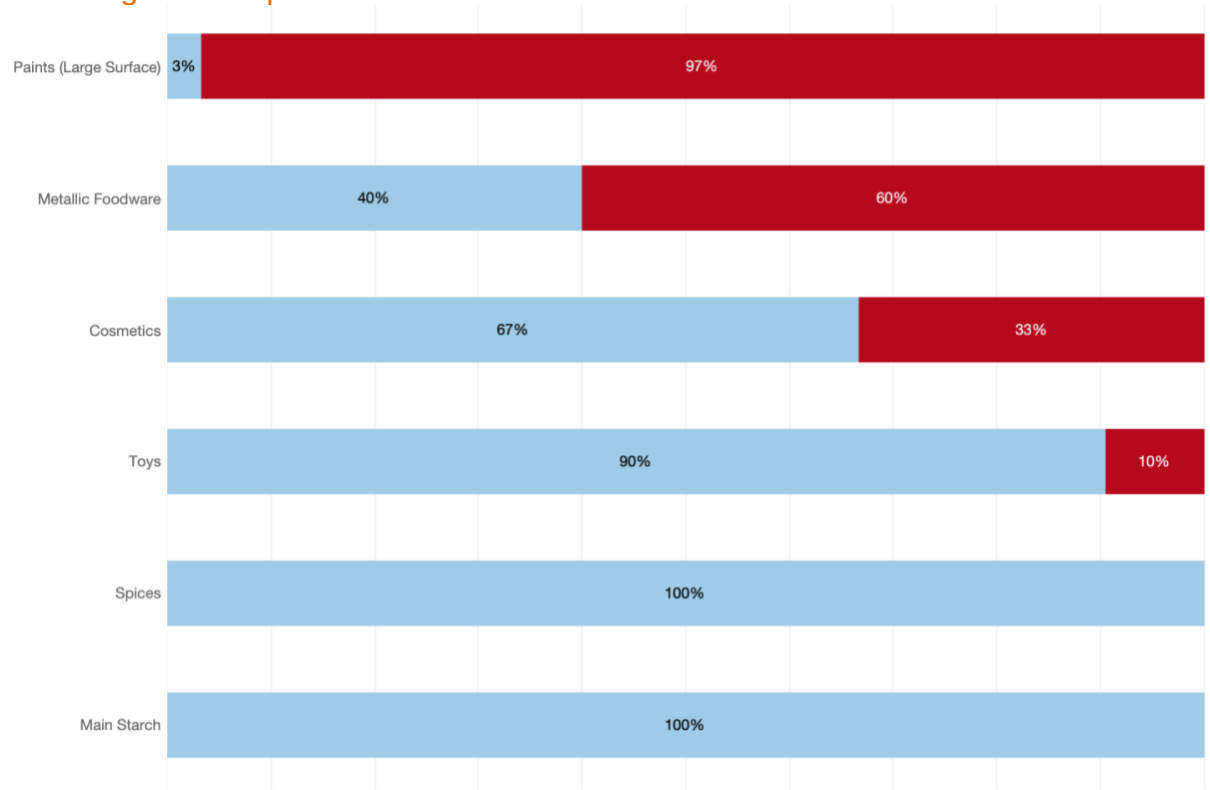
Summary of Results from Indonesia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paints - large surfaces	31	1	3142	51400	97
Metallic foodware	45	ND	410	18100	60
Cosmetics	36	ND	ND	12	33
Toys	21	ND	ND	314	10
Spices	34	ND	ND	ND	0

Staple dry food	9	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Indonesia Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Kazakhstan

This report includes lead concentrations found in 18 samples from Kazakhstan, and of these, 6% exceeded the relevant reference levels. Readers should note that Pure Earth collected and conducted field XRF analyses on 163 samples from Kazakhstan, however, the field XRF results were expunged after confirmatory testing of samples sent to New York suggested that the field XRF used in Kazakhstan was not providing sufficiently accurate readings. This issue is discussed more fully in the Quality Control section. The results below are from a subset of samples sent to New York for confirmatory analysis.

Summary of Results from Kazakhstan in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Toys	3	ND	ND	1138	33
Cosmetics	4	ND	ND	ND	0

Spices	8	ND	ND	ND	0
Staple food	3	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Kazakhstan Below and Above the Reference Level

Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Kenya

Pure Earth analyzed a total of 192 samples from Kenya, and of these, 19% exceeded the relevant reference levels. Metallic foodware, ceramic foodware, and paint samples most commonly exceeded reference levels.

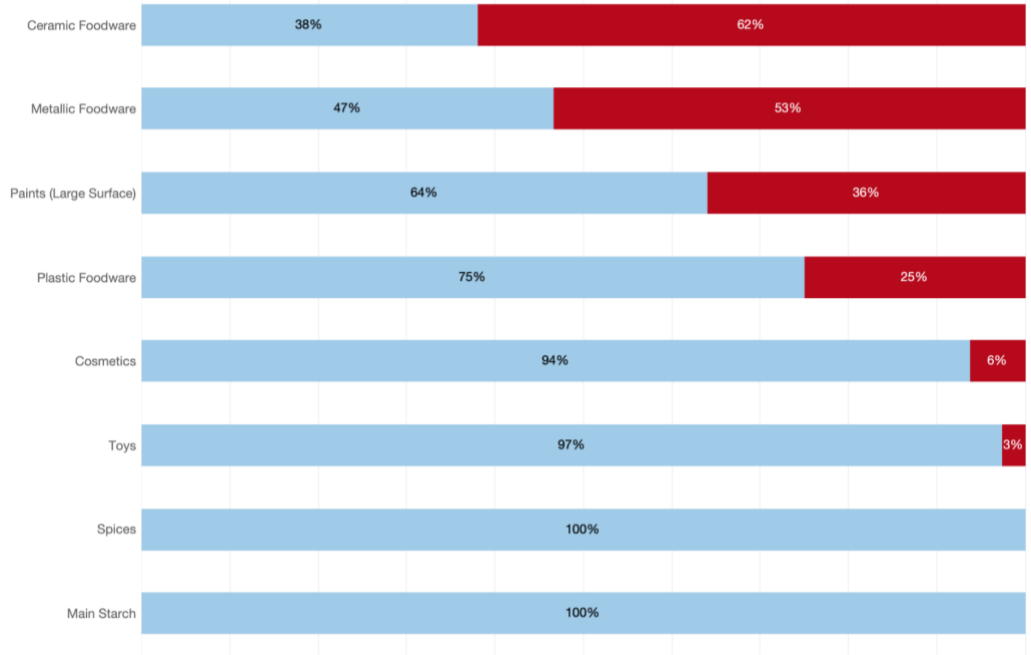
Summary of Results from Kenya in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	21	ND	4210	91000	62
Metallic foodware	15	21	130	3600	53
Paints - large surfaces	25	ND	7	7788	36

Plastic foodware	12	ND	ND	2395	25
Cosmetics	32	ND	ND	6	6
Toys	38	ND	ND	139	3
Spices	41	ND	ND	ND	0
Staple dry food	8	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Kenya Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Kyrgyzstan

Pure Earth analyzed a total of 209 samples from Kyrgyzstan, and of these, 14% exceeded the relevant reference levels. Foodware, paints, and cosmetics stand out as possible issues of concern.

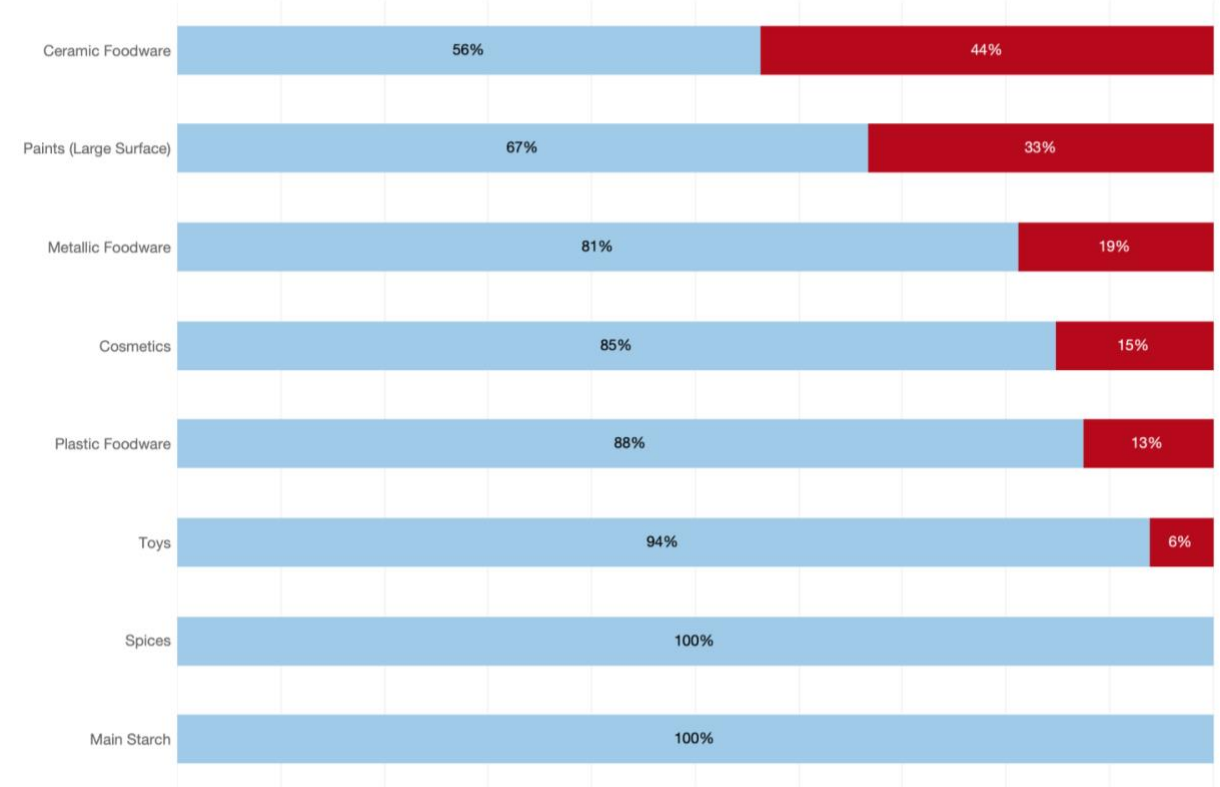
Summary of Results from Kyrgyzstan in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	16	ND	73	240500	44
Paints - large	33	ND	10	890	33

surfaces					
Metallic foodware	16	ND	8	494	19
Cosmetics	33	ND	ND	7	15
Plastic foodware	16	ND	ND	368	13
Toys	33	ND	ND	314	6
Spices	48	ND	ND	ND	0
Staple dry food	14	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Kyrgyzstan Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Mexico

Pure Earth analyzed a total of 206 samples from Mexico, and of these, 17% exceeded the relevant reference levels. Ceramic foodware, metallic foodware, paints, and toys emerged as the products with the highest percentage of samples exceeding the relevant reference levels. Contaminated ceramic foodware is a well-known challenge in Mexico, and the high prevalence of samples exceeding the reference level is in line with

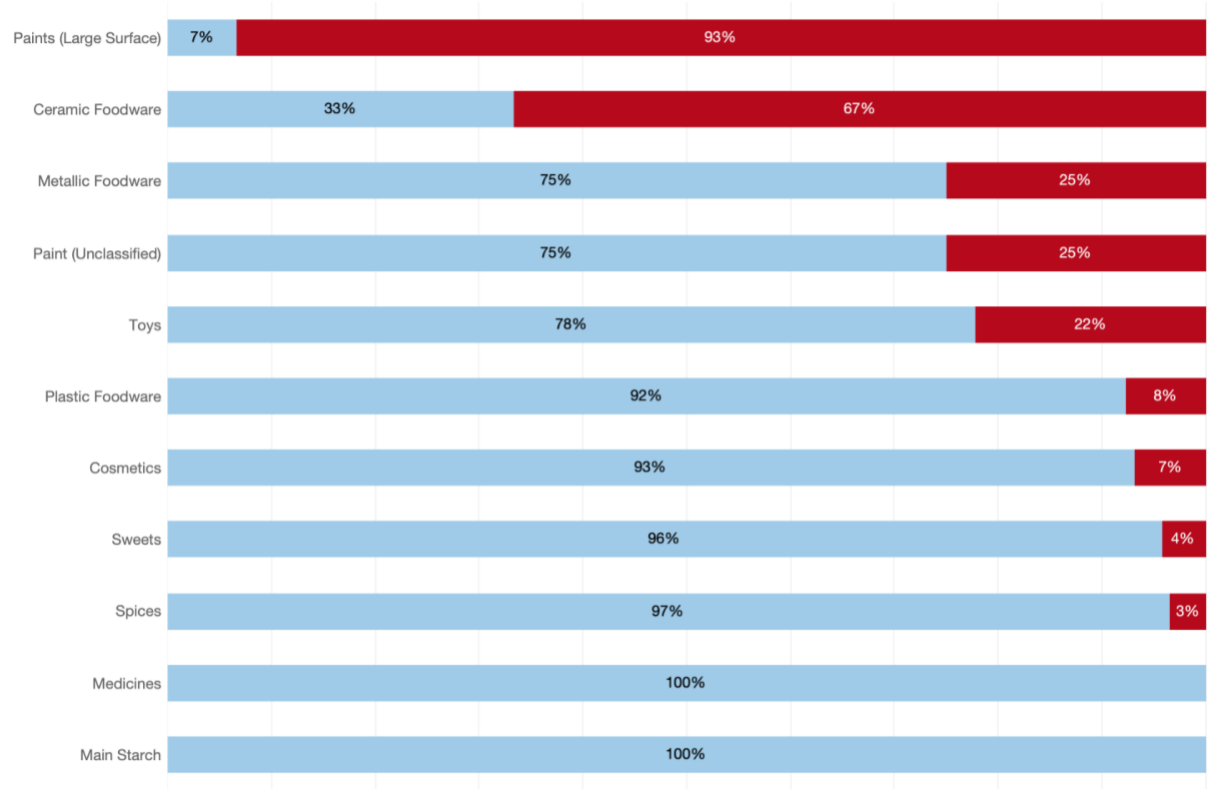
findings from other assessments. Of particular note is the fact that out of the 15 samples of paint intended for large surfaces, 93% exceeded the reference level of 90 ppm.

Summary of Results from Mexico in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paints - large surfaces	15	3	53700	807309	93
Ceramic foodware	6	ND	19215	65700	67
Metallic foodware	16	ND	30	900	25
Paint - unclassified	8	ND	2	79000	25
Toys	27	ND	ND	1070	22
Plastic foodware	13	ND	ND	853	8
Cosmetics	29	ND	ND	50	7
Sweets	48	ND	ND	5	4
Spices	29	ND	ND	10	3
Medicines	4	ND	ND	ND	0
Staple dry food	11	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Mexico Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Nepal

Pure Earth analyzed a total of 168 samples from Nepal, and of these, 8% exceeded the relevant reference levels. In Nepal, lead was only detected in ceramic foodware (18% of samples), metallic foodware (100%), and plastic foodware (6%).

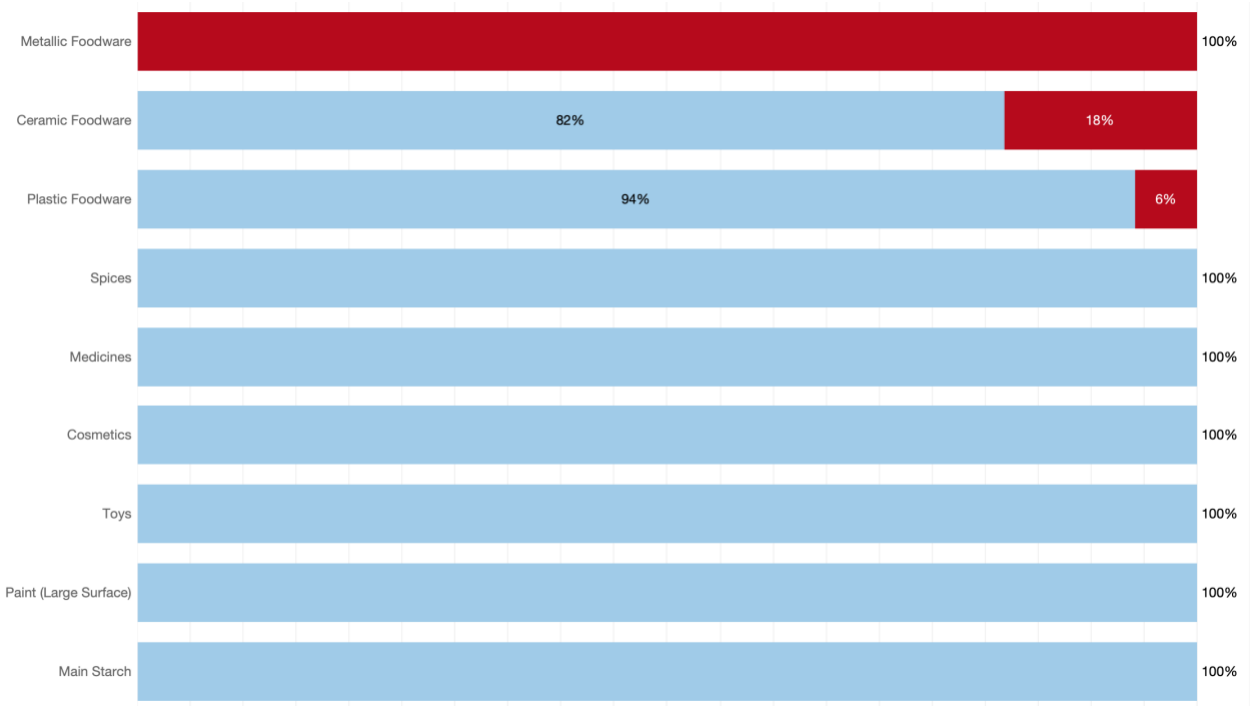
Summary of Results from Nepal in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Metallic foodware	11	170	750	3960	100
Ceramic foodware	11	ND	ND	9220	18
Plastic foodware	17	ND	ND	3448	6
Cosmetics	21	ND	ND	ND	0
Medicines	9	ND	ND	ND	0
Paints - large surfaces	20	ND	ND	ND	0

Spices	53	ND	ND	ND	0
Staple dry food	16	ND	ND	ND	0
Toys	10	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Nepal Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Nigeria

Pure Earth analyzed a total of 353 samples from Nigeria, and of these, 19% exceeded the relevant reference levels. As with many other countries, metallic foodware, ceramic foodware, and paints emerged as the products with the highest percentage of samples exceeding the relevant reference levels. Samples of cosmetics and toys also showed elevated lead levels.

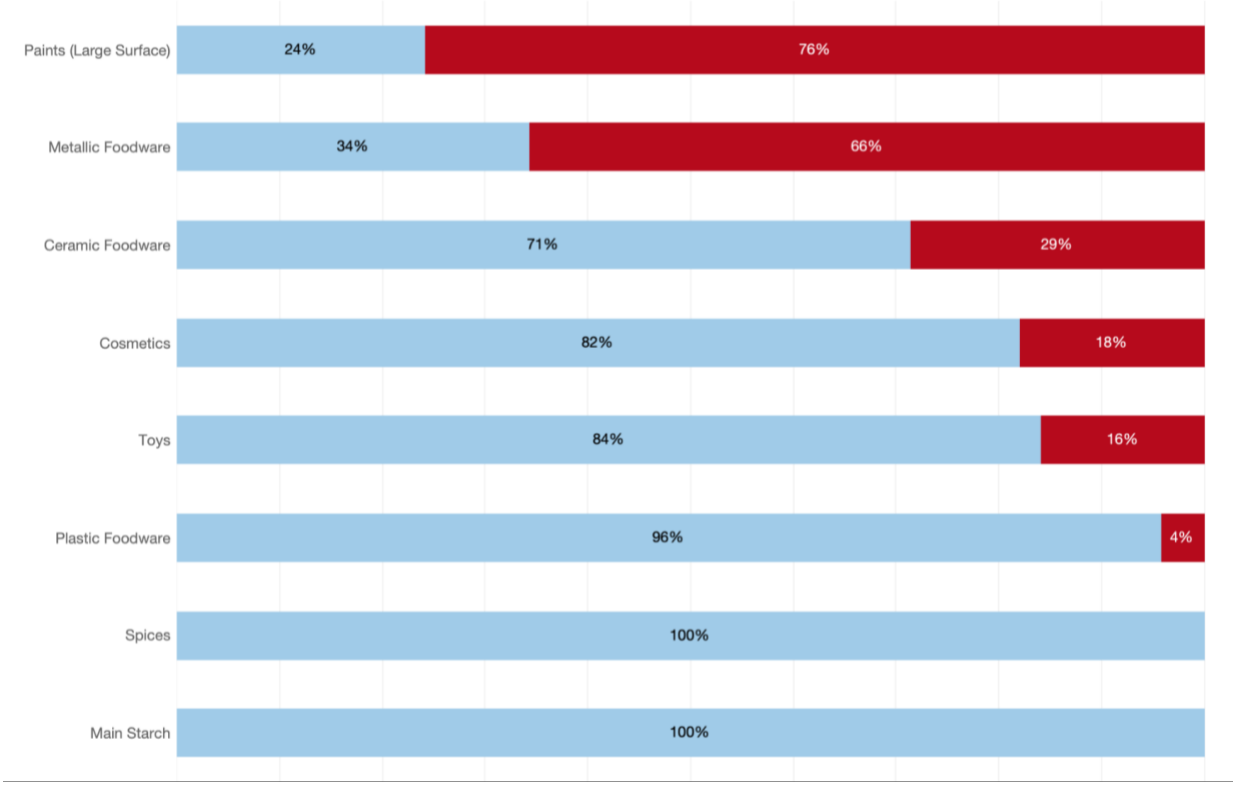
Summary of Results from Nigeria in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paints - large surfaces	29	ND	494	20700	76

Metallic foodware	35	ND	410	1000	66
Ceramic foodware	21	20	40	46000	29
Cosmetics	50	ND	ND	1150	18
Toys	44	ND	ND	2292	16
Plastic foodware	24	ND	ND	280	4
Spices	67	ND	ND	ND	0
Staple dry food	83	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Nigeria Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Pakistan

Pure Earth analyzed 203 samples from Pakistan, and of these, 24% exceeded the relevant reference levels. As with many other countries, a high percentage of metallic foodware exceeded the relevant reference levels, with >20% of paints, cosmetics, and ceramics also showing elevated levels. Pakistan produces certain types of eyeliners that have been found to contain high concentrations of lead.

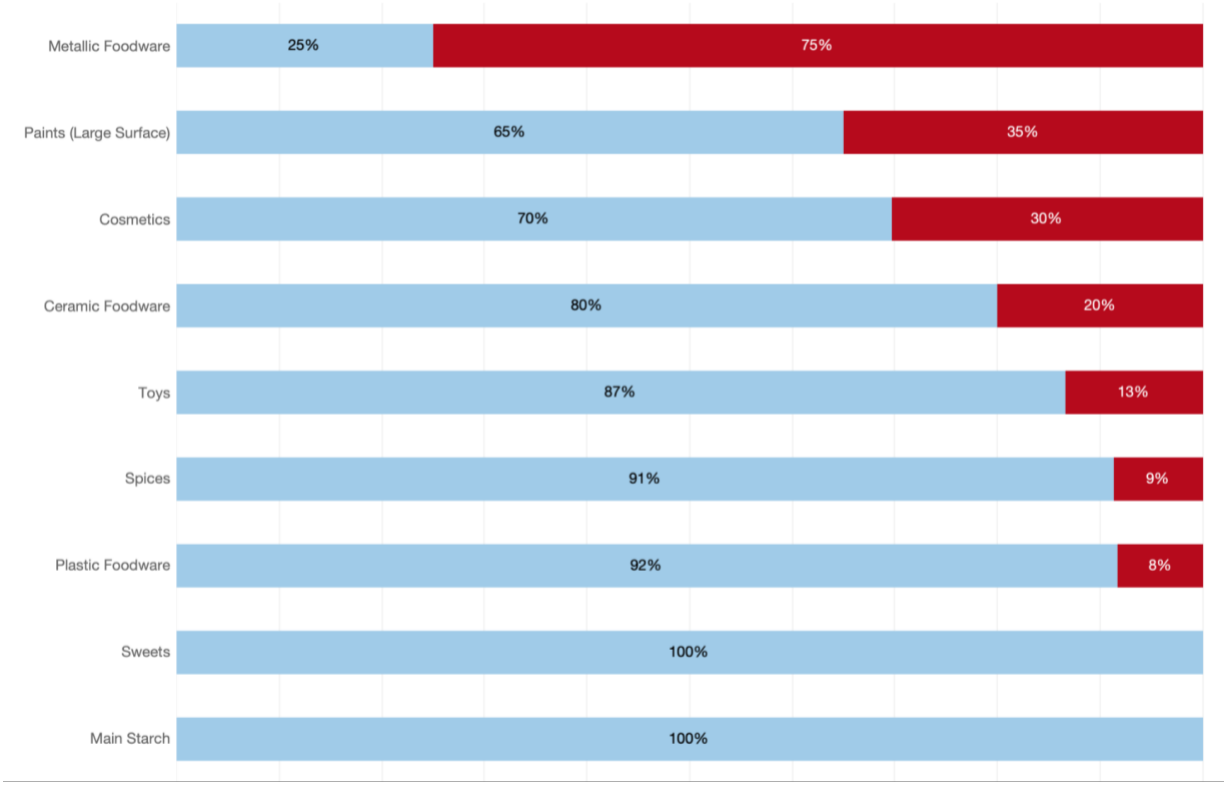
Note that there is some uncertainty with the levels of lead in spices from Pakistan as laboratory testing indicated lower levels than the XRF. Unlike field XRF results from Kazakhstan and Tajikistan, it was not clear to the Quality Control Team that the field XRF results for spice were inaccurate, or if other factors had contributed to discrepancies between field and lab results. Ultimately, field results were retained with a note regarding the uncertainty.

Summary of Results from Pakistan in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Metallic foodware	28	ND	3238	7858	75
Paints - large surfaces	20	ND	ND	7370	35
Cosmetics	33	ND	ND	1000000	30
Ceramic foodware	5	ND	69	103	20
Toys	30	ND	ND	1481	13
Spices	46	ND	ND	160	9
Plastic foodware	12	ND	ND	2419	8
Staple dry food	9	ND	ND	ND	0
Sweets	20	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Pakistan Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Peru

Pure Earth analyzed a total of 228 samples from Peru, and of these, 15% exceeded the relevant reference levels. As with many other countries, foodware and paint most commonly exceeded the relevant reference levels.

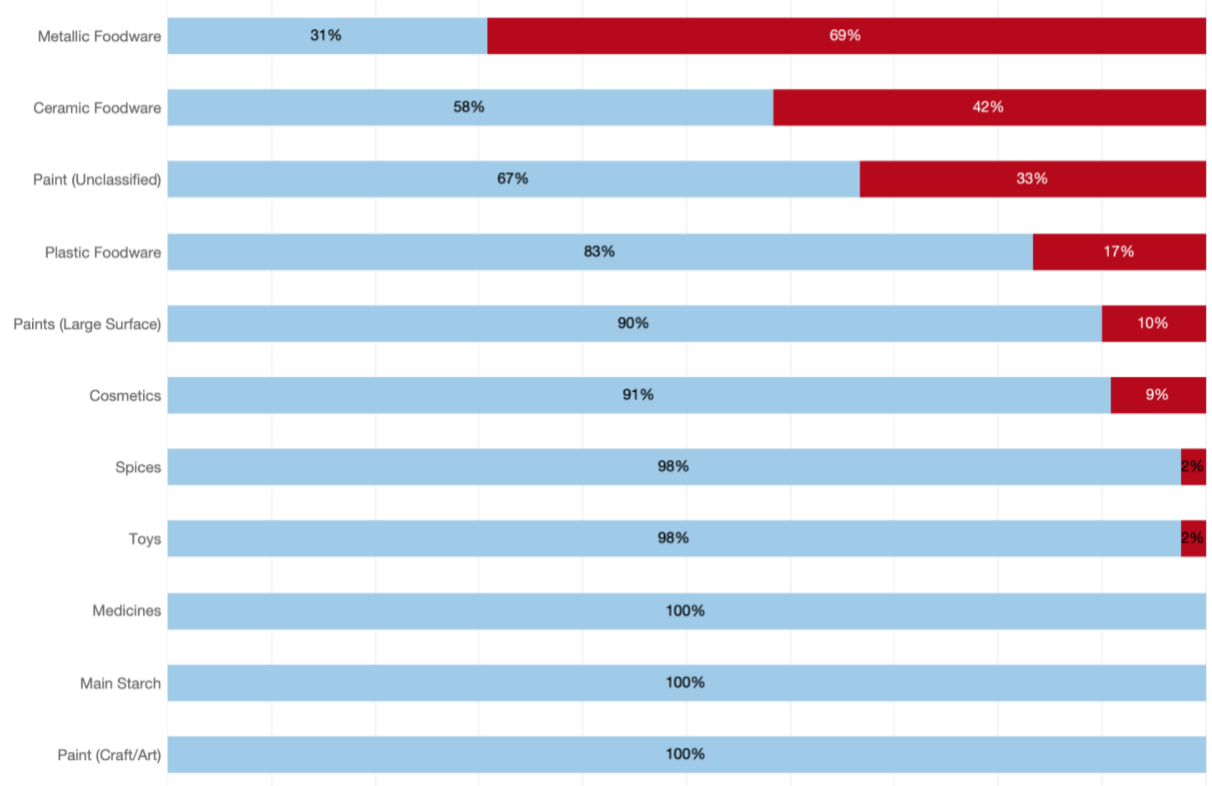
Summary of Results from Peru in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Metallic foodware	26	ND	217	90400	69
Ceramic foodware	12	ND	65	18600	42
Paint - unclassified	3	ND	ND	846	33
Plastic foodware	18	ND	ND	1643	17
Paints - large surfaces	10	ND	ND	2822	10
Cosmetics	44	ND	ND	128400	9

Spices	43	ND	ND	7	2
Toys	43	ND	ND	442	2
Medicines	2	ND	ND	ND	0
Paint - craft/art	17	ND	ND	32	0
Staple dry food	10	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Peru Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Medicines only has 2 samples.

The Philippines

Pure Earth analyzed a total of 265 samples from the Philippines, and of these, 8% exceeded the relevant reference levels. With one of the largest national datasets, the Philippines showed comparably low percentages of samples exceeding reference levels.

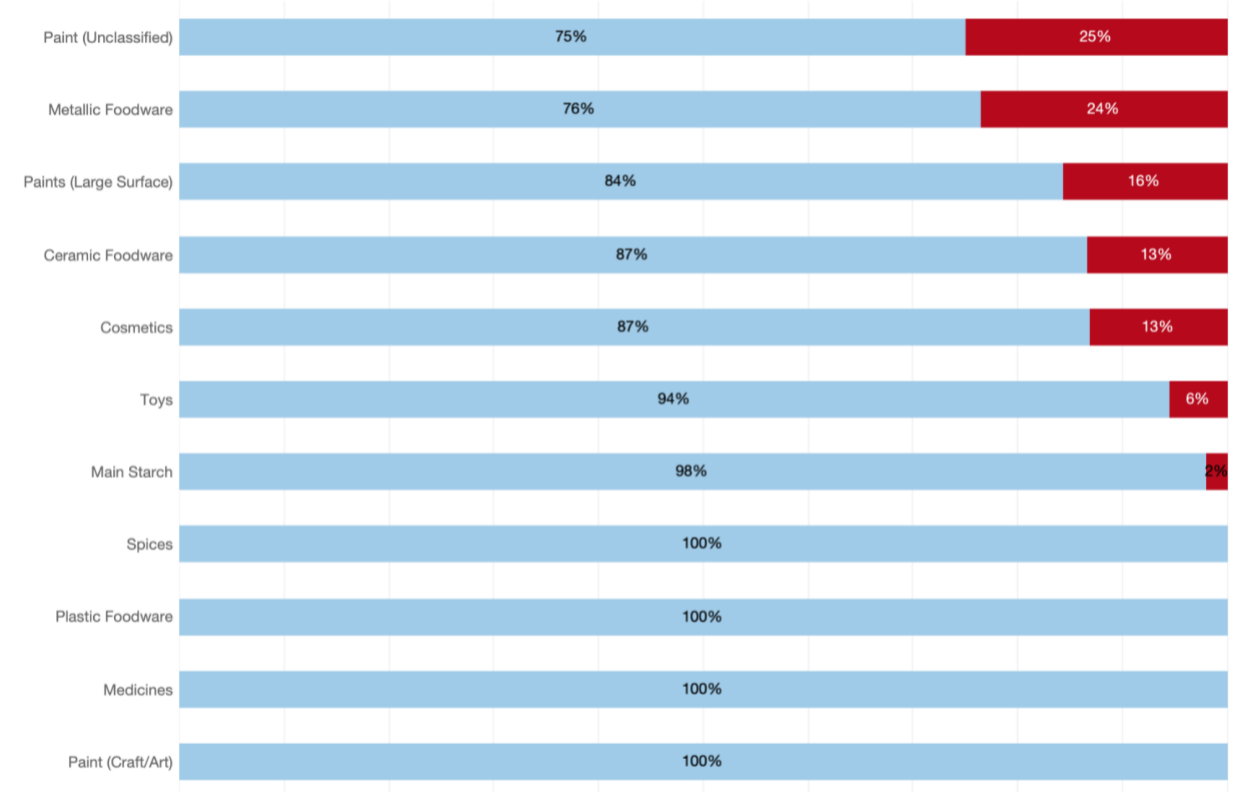
Summary of Results from the Philippines in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value	Median	Max Value	% Above Reference

		(ppm)	(ppm)	(ppm)	
Paint - unclassified	4	ND	10	25281	25
Metallic foodware	17	ND	26	1253	24
Paints	32	ND	ND	41801	16
Ceramic foodware	15	ND	35	1159	13
Cosmetics	38	ND	ND	42350	13
Toys	36	ND	ND	2123	6
Staple food	49	ND	ND	17	2
Medicines	2	ND	ND	ND	0
Paint - craft/art	3	ND	ND	ND	0
Plastic foodware	14	ND	ND	ND	0
Spices	55	ND	ND	2	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from the Philippines Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Note: The category of Medicines only has 2 samples.

Tajikistan

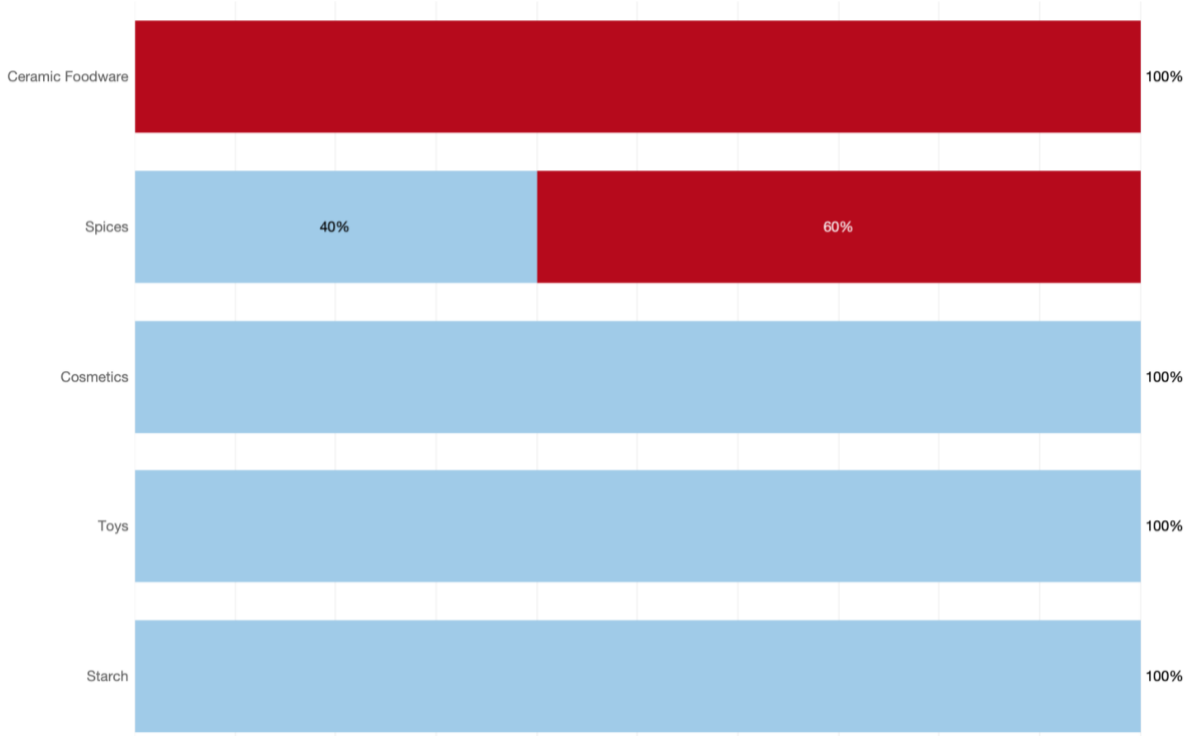
This report includes lead concentrations found in 20 samples from Tajikistan and of these, 30% exceeded the relevant reference levels. Readers should note that Pure Earth collected and conducted field XRF analyses of 191 samples from Tajikistan in total, however, the field XRF results were expunged after confirmatory testing of a subset of samples sent to New York suggested that the field XRF analyzer used in Tajikistan did not provide sufficiently accurate readings. This is the same XRF that was used in Kazakhstan, where field results were also expunged. This issue is discussed more fully in the Quality Control section. The results presented below represent only those results from the subset of samples sent to New York that were subjected to confirmatory testing by the New York-based XRF and an accredited lab.

Summary of Results from Tajikistan in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	3	100700	133400	266000	100
Spices	5	ND	9	381	60
Cosmetics	4	ND	ND	ND	0
Staple dry food	3	ND	ND	ND	0
Toys	5	ND	ND	34	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Tajikistan Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Tanzania

Pure Earth analyzed a total of 212 samples from Tanzania, and of these, 10% exceeded the relevant reference levels. As with many countries, samples of foodware most commonly exceeded the relevant reference levels.

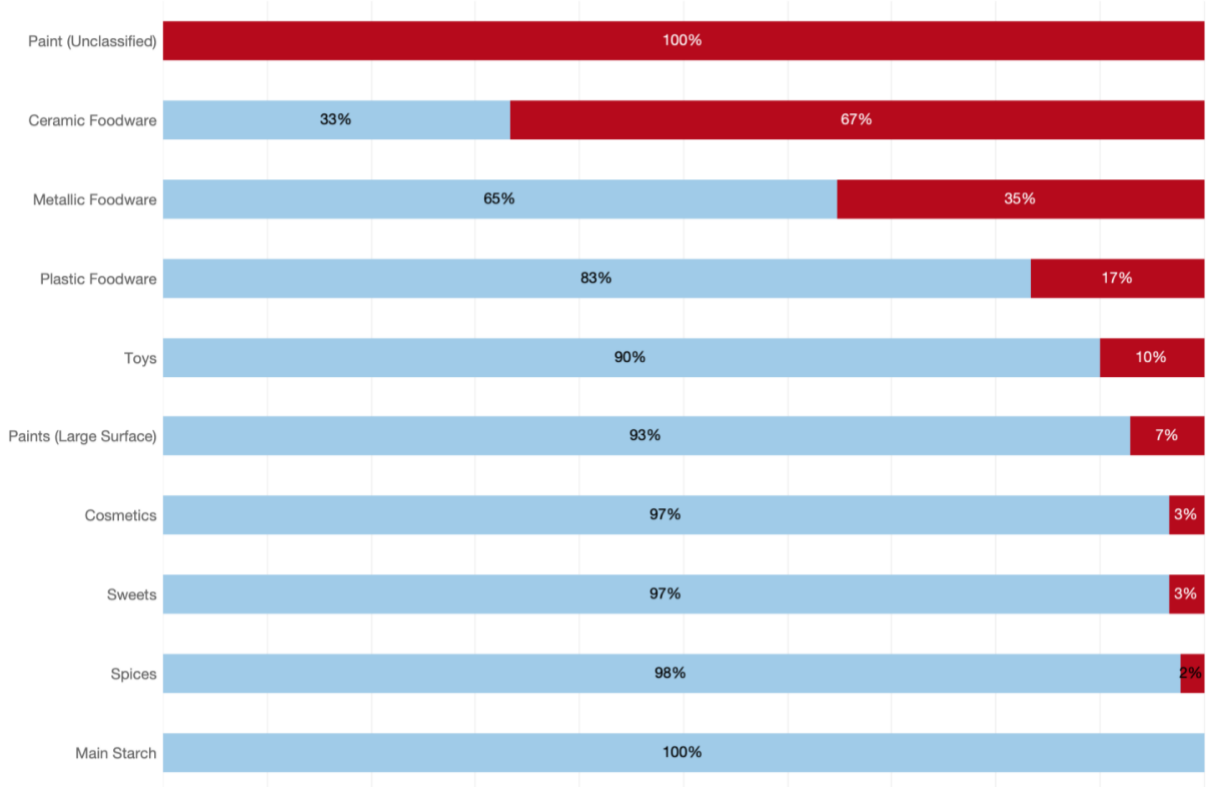
Summary of Results from Tanzania in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paint - unclassified	2	2139	3446	4752	100
Ceramic foodware	3	20	7780	22300	67
Metallic foodware	17	ND	30	15100	35
Plastic foodware	18	ND	ND	2791	17
Toys	30	ND	ND	698	10
Paints - large surfaces	28	ND	ND	866	7
Cosmetics	30	ND	ND	52	3

Sweets	30	ND	ND	4	3
Spices	45	ND	ND	21	2
Staple dry food	9	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)
Note: The category of Paint (unclassified) includes only two samples.

Percentage of Samples from Tanzania Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Tunisia

Pure Earth analyzed 190 samples from Tunisia, and of these, 13% exceeded the relevant reference levels. Samples of ceramic foodware and paint most commonly exceeded the relevant reference levels.

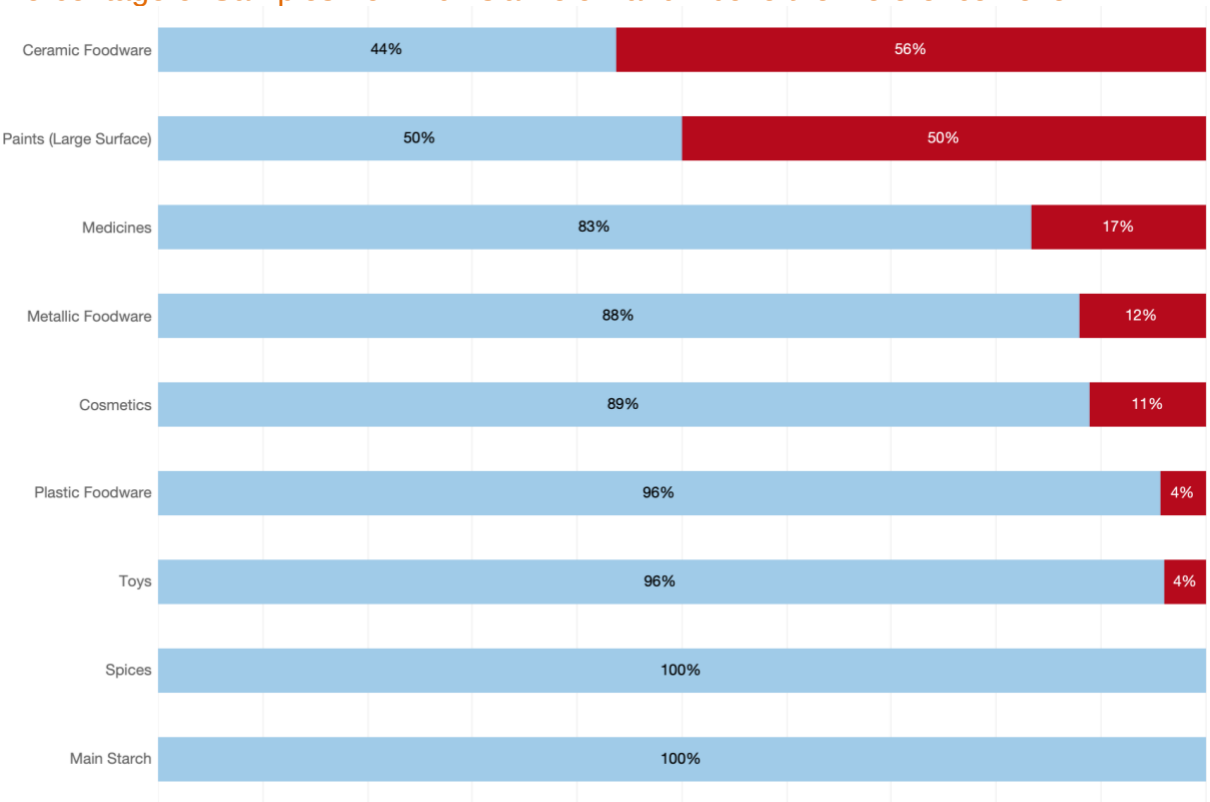
Summary of Results from Tunisia in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Ceramic foodware	16	ND	251	68600	56
Paints - large	14	ND	286	72000	50

surfaces					
Medicines	6	ND	ND	19	17
Metallic foodware	25	ND	ND	26600	12
Cosmetics	27	ND	ND	712	11
Plastic foodware	23	ND	ND	3289	4
Toys	25	ND	ND	176	4
Spices	36	ND	ND	ND	0
Staple dry food	18	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Tunisia Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.

Türkiye

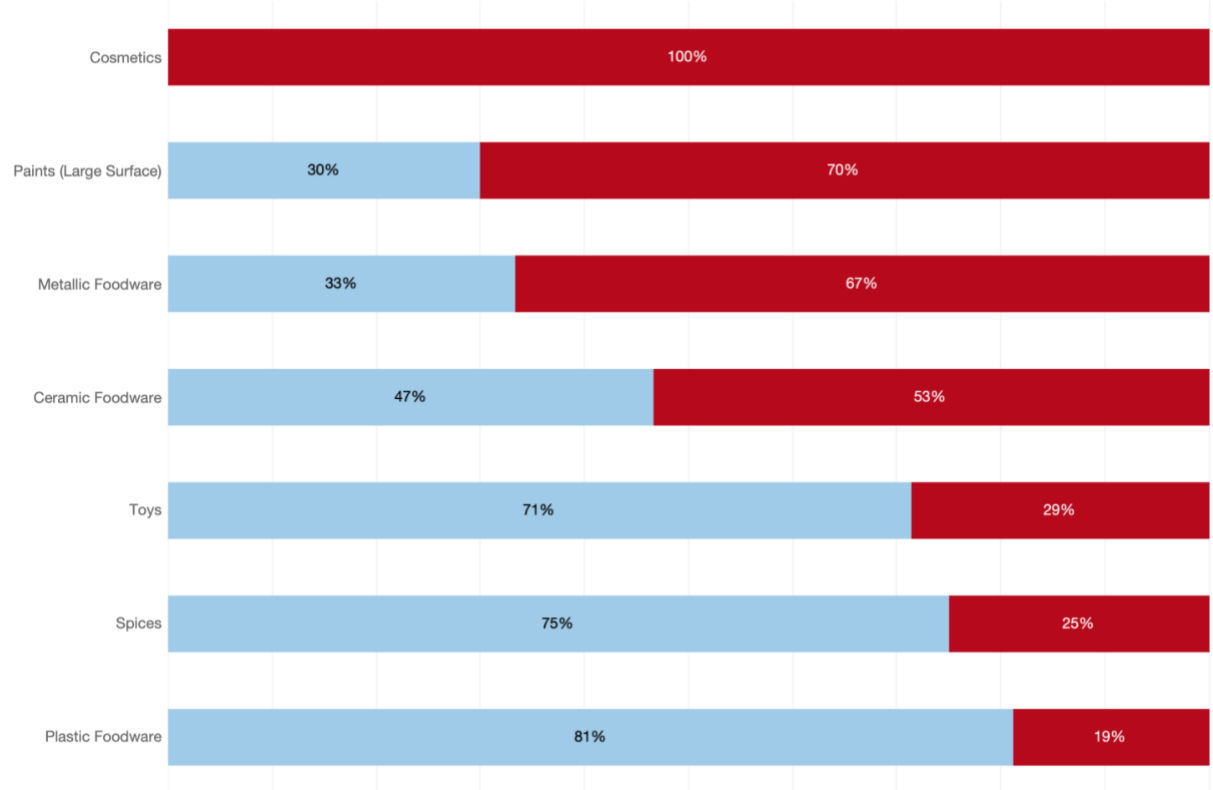
Pure Earth analyzed a total of 104 samples from Türkiye, and of these, 38% exceeded the relevant reference levels. Compared to other countries, a high percentage of samples from a wide variety of categories exceeded relevant reference levels.

Summary of Results from Türkiye in Order of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Cosmetics	1	121	121	121	100
Paints - large surfaces	10	ND	3937	11200	70
Metallic foodware	9	ND	171	903	67
Ceramic foodware	15	ND	119	14300	53
Toys	49	ND	22	4336	29
Spices	4	ND	ND	4	25
Plastic foodware	16	ND	ND	1281	19

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Türkiye Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Cosmetics includes only 1 sample.

Uganda

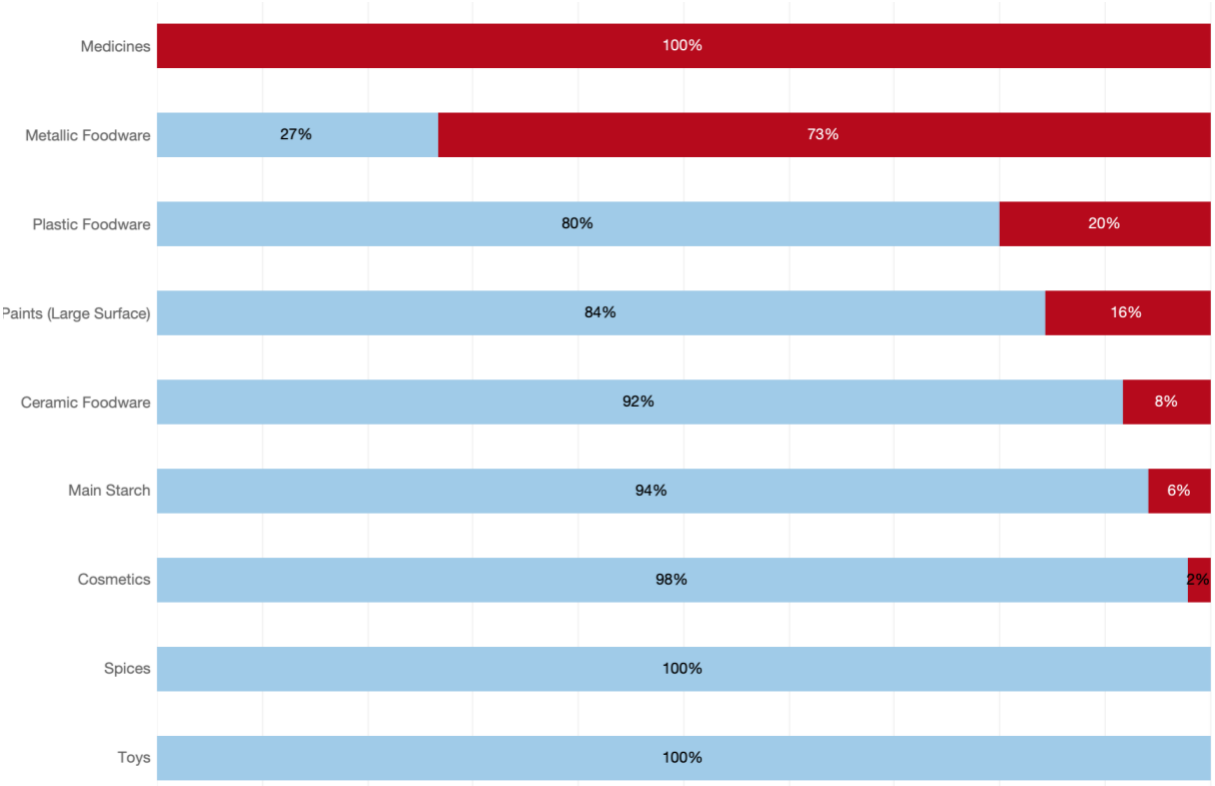
Pure Earth analyzed 224 samples from Uganda, and of these, 12% exceeded the relevant reference levels. Note that only one sample of medicine was analyzed, and thus the 100% of medicine samples exceeding the reference level should be viewed in that context. As with other countries, metallic foodware commonly exceeded the relevant reference level.

Summary of Results from Uganda in Ordered of % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Medicines	1	31	31	31	100
Metallic foodware	15	ND	303	1564	73
Plastic foodware	30	ND	ND	1032	20
Paints - large surfaces	32	ND	ND	12600	16
Ceramic foodware	12	17	23	6092	8
Staple dry food	17	ND	ND	3	6
Cosmetics	48	ND	ND	3	2
Spices	40	ND	ND	ND	0
Toys	29	ND	ND	81	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Uganda Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Medicines includes only 1 sample.

Vietnam

Pure Earth analyzed a total of 175 samples from Vietnam, and of these, 22% exceeded the relevant reference levels. As with other countries, metallic foodware, ceramic foodware, and paints most commonly exceeded the relevant reference levels.

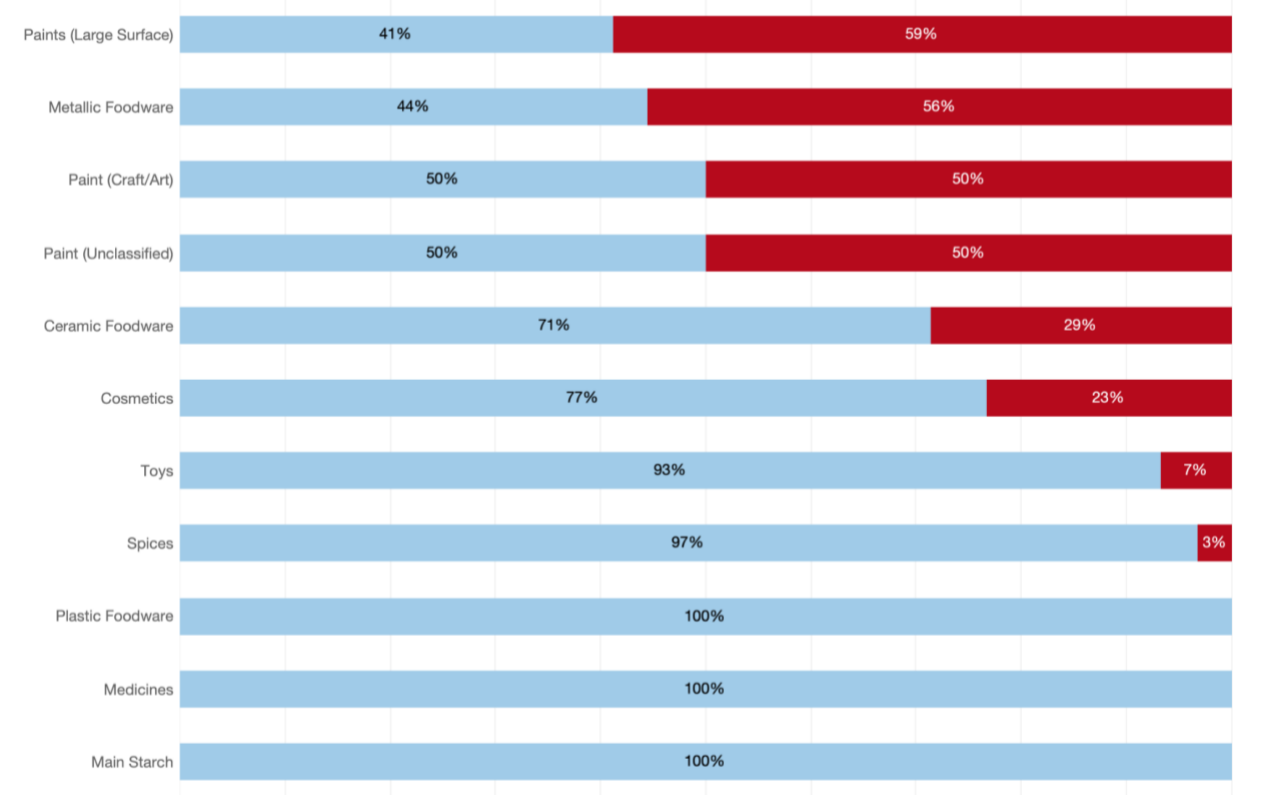
Summary of Results from Vietnam Ordered by % Exceeding Reference Levels

Item Category	# of Samples	Min Value (ppm)	Median (ppm)	Max Value (ppm)	% Above Reference
Paints - large surfaces	17	ND	777	25505	59
Metallic foodware	18	ND	269	13080	56
Paint - unclassified	2	ND	552	1104	50
Paint - craft/art	6	ND	612	7296	50
Ceramic foodware	14	ND	59	19789	29
Cosmetics	30	ND	ND	68	23

Toys	30	ND	ND	298	7
Spices	31	ND	ND	9	3
Medicines	5	ND	ND	ND	0
Plastic foodware	13	ND	ND	9	0
Staple dry food	9	ND	ND	ND	0

ND = “non-detect” (lead concentration was below the XRF’s lower detection limit)

Percentage of Samples from Vietnam Below and Above the Reference Level



Key: Blue = percentage of samples below reference level. Red = percentage above reference level.
Note: The category of Paint (unclassified) includes only 2 samples.

Quality Assurance and Quality Control

For this report, “quality assurance” refers to measures taken to encourage high quality data collection and analysis, such as the development of, and training in a standard RMS implementation protocol (available as Annex A). “Quality control” refers to processes to identify and correct errors, omissions, or other inaccuracies in the RMS process or data, including confirmatory testing of a subset of samples to validate or invalidate field XRF readings. The following is a summary of RMS quality assurance

and quality control process and findings. A more detailed description is available as Annex B on Pure Earth's RMS web page.

Quality Assurance

Pure Earth's primary means of encouraging quality data collection and analysis included the development of a standardized RMS Protocol guiding the methods and sequencing of each step of the program, the training of RMS Investigator teams in that protocol, and ongoing supervision and re-training of teams as the program was implemented.

Pure Earth divided the implementation of the RMS program into three phases: a Formative Research Phase in which we piloted the methodology in several countries to troubleshoot any implementation hurdles; Phase 1, in which the first 15 countries implemented the program; and Phase 2, in which the final 10 countries implemented the program. After each phase, the RMS team reviewed challenges and lessons from the implementation and made any necessary revisions to the protocol and training. Notable changes made after the formative phase included: guidance to specify and narrow the types of items purchased and analyzed; additional guidance on the number of samples desired; and clarification of the XRF setting to use during analysis. After Phase 1, the protocol was amended to shift from analyzing wet paint samples to dried paint swatches (to allow transport of the samples). Aside from the paint analysis method, the protocol did not differ substantially between phases and the analytical results from both Phases 1 and 2 are included here.

Quality Control

The primary quality control measures in the RMS program included:

1. Regular communication with, and oversight of RMS Investigator teams to ensure they understood the protocol, felt comfortable in their plans, and to address any challenges or questions.
2. Ongoing reviews of data uploaded into the SurveyCTO database platform to ensure that RMS Investigators collected appropriate sample types and numbers of samples, and that sample logs contained all required information.
3. A review of descriptions and item categorization choices made by RMS Investigators (e.g., are leafy herbs a spice, a medicine, or "other foods?") to ensure consistency with the RMS protocol and the descriptions and categorization choices made by other country teams.
4. A review of XRF field data uploaded by RMS Investigator teams to the SurveyCTO database to identify any formatting, unit, or input errors and to highlight any outliers that might require further quality control inquiries.
5. Shipping of a subset of more than 1,000 samples (approximately 20%) to New York for confirmatory analysis with an XRF analyzer in Pure Earth's headquarters that was operated by an experienced expert, was known to be in good working order, had shown consistency with lab results, and was regularly calibrated against a "standard" sample with a known lead concentration.
6. Confirmatory analysis of a subset of 354 samples by accredited laboratories using analytical methods known to be more accurate and sensitive than XRFs.

Summary Of XRF Performance As A Screening Tool

Lead concentrations measured with portable XRF analyzers proved highly comparable to results from laboratory analysis with the following two exceptions. First, the XRFs appeared to inflate lead concentrations among four samples for which lab results exceeded 30,000 ppm (3% lead), suggesting that the XRF's accuracy may have decreased at very high lead concentrations. Second, confirmatory screening with a New York-based XRF and lab testing suggested that one of the XRFs that was used in both Tajikistan and Kazakhstan provided inaccurate field results; accordingly, the field data from these countries were expunged by the RMS Quality Control team. We do not know if this was due to equipment malfunction, contamination of the XRF measurement window, or another type of user or mechanical error. In the case of these two countries, only samples that were sent to New York and analyzed with an XRF that proved to be consistent with lab results were included in this report.

Finally, we also note that we could not compare XRF results with lab results for items with comparatively low lead concentrations due to the lower detection limit of the XRFs, which for most materials is approximately 2-4 ppm, compared to 0.2-0.5 ppm in the lab. This fact does not suggest inaccuracy among the XRFs but is simply an analytical limitation of the device.

Item Type	# of samples sent for lab analysis
Ceramics	1
Cosmetics	64
Staple Dry Foods	65
Miscellaneous	9
Other Foods	15
Plastic Foodware	15
Spices	126
Toy - Painted	3
Toy - Plastic/Rubber	56
Total	**354**

Expunging Field XRF Data From Tajikistan And Kazakhstan

Despite the general consistency between field XRF, New York-based XRF, and lab results, the field XRF readings from Tajikistan and Kazakhstan had significant discrepancies across several item types when compared to New York-based XRF and lab results. Ultimately, Quality Control team expunged all field XRF data from these countries. Only samples that were sent to New York for analysis by a New York-based XRF or lab are included in this report.

Correlations Between XRF And Lab Results

Toys: There was excellent correlation between XRF and lab results for the plastic toy samples, with a correlation coefficient of 0.9811. Among the 11 toy samples for which the XRF did not detect lead, the lab analysis also reported no lead (ND<0.50 ppm).

Cosmetics. A total of 64 cosmetics samples were submitted for laboratory testing, including eye shadow, eyeliner, lipstick, face powders, and henna. The 40 cosmetic samples in which the lab detected lead below 1,000 ppm correlated very well with the field XRF results (R^2 = 0.7737). There was one sample of kohl from Tunisia for which the XRF measured 712 ppm for which the lab reported lead at a concentration of 5.08 ppm. There were four cosmetics samples in which the lab found extremely high lead concentrations ranging from 33,000 to 320,000 ppm. Among these samples, the XRF deviated substantially. The two items with the highest lead concentrations were both eyeliners, known as kajal or kohl, from Pakistan. These samples had concentrations of 637,600 ppm and 1,000,000 ppm (equivalent to 64 and 100%, respectively) based on XRF measurements. However, laboratory testing of these two samples indicated significantly lower concentrations (29% and 32%, respectively), albeit still extremely elevated. Given the accuracy of the XRF at lower lead levels, the results suggested to the Quality Control Team that the XRF's accuracy may simply diminish at extreme lead concentrations.

Staple Dry Foods. A total of 65 samples of dry foods representing local dietary staples were submitted for laboratory testing, including various grains, gain flours, and legumes. Lead was not detected by the lab in 44 of the samples. Lab results for 13 samples showed levels below 1 ppm, which is below the XRF lower detection limit. Lead was detected by the laboratory in a single sample at 14 ppm with a corresponding XRF measurement of 18 ppm for that sample. There was one sample for which the XRF measured 16.46 ppm for which the lab reported ND<0.1 ppm. Lab results for 6 samples were pending at the time of writing.

Plastic Foodware. A total of 15 plastic foodware items were submitted for lab testing. There was a fair correlation between XRF and lab results, with a correlation coefficient (R^2) of 0.7039. Laboratory results for 5 samples were pending at the time of writing.

Spices. A total of 126 spices were submitted for laboratory testing. Laboratory results for 9 samples are pending. The high number of spice samples sent to the lab reflects the fact that the reference level for spices is near the lower detection limit of XRFs. Types of spices sent to the lab included turmeric, chili, tamarind, peppers, sunelli, and ginger, among others. Lead was not detected by the laboratory in 42 of the samples. Lead was detected by the laboratory at concentrations of <2 ppm in 61 of the 126 samples and at concentrations of between 2 ppm and a high of 320 ppm in 14 of the 126 samples. For samples with laboratory lead concentrations >1 ppm, there was an excellent correlation between XRF and lab results, with a correlation coefficient (R^2) of 0.9039, with the XRF results coming in slightly higher than lab results. Note that three samples with the highest lab results, ranging from 66 to 320 mg/kg, were turmeric

samples obtained from 3 different markets in Tajikistan. There is some uncertainty in the actual levels of lead in spice samples from Pakistan, which is discussed in Annex B.

Overall, the XRFs proved to be an excellent screening tool for detecting elevated lead levels in products, particularly among items for which the reference level exceeds the XRF's lower detection limit. More information regarding the RMS Quality Control methods and comparisons between XRF and lab results are available in Annex B.