GRIT GUIDANCE DOCUMENTS on **REDUCING BLOOD LEAD LEVELS**

A Strategy for Lead

Global Toxics Research Initiative (GRIT)
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Work on lead poisoning in LMICs is moving forward quickly, and it is very satisfying to see funding and momentum growing. I have been fortunate to play an outsized role in initiating this work. Over the past few decades, I have learned some lessons that may help the lead community work more effectively towards our shared goal of reducing lead exposure. These recommendations reflect my reading of the current science. I may be wrong, so I have stated my level of certainty for each key finding, and I will update this Guidance as the evidence develops. I thank the many friends and colleagues who reviewed earlier drafts.

In brief

If we want to make a significant impact in this field, **the goal is to reduce blood lead levels (BLLs) at scale in LMICs.** Progress should be measured as **lead burden (cpBLL, or cumulative population BLLs)**. Burden incorporates increases in BLL with exposure, gives better results for policy makers than counting exposure sources alone.

Population-level exposures, not hotspots, account for most lead burden. Certainty: high

Apart from food, single consumer sources rarely exceed 10% of a country's burden. Certainty: medium, research needed

Food is the largest pathway of lead exposure globally, probably accounting for around 40–50% of the blood lead burden in LMICs. It has been missed because Codex limits were established on commercial requirements, not on increases in BLL. Plus, many laboratories may not have equipment and methods capable of detection at low levels. Certainty: high

Food is a pathway, not a source. The evidence points to airborne industrial emissions, especially fine and ultrafine particles, as the main upstream source. Emissions can be controlled at the stack far more easily than soils can be cleaned up. Inhalation may also be important. Research needed

A Note on Units

Throughout this Guidance, BLLs are expressed in micrograms per liter (µg/L), consistent with the other GRIT Guidance documents and IHME. The rationale is set out in [1] and [2].

Section 1: The Goal: Reduce BLLs at Scale

All our work in the lead prevention community should share one clearly stated goal: **reduce BLLs at scale in LMICs**.

1.1 **BLLs drive the outcomes that matter.** Lead exposure, reflected in elevated BLLs, cause loss of IQ points and cardiovascular disease (CVD), which in turn cause economic losses. These are the key impact outcomes. Dementia seems likely to be included soon as well.

1.2 **The biggest gains come at low BLLs.** The dose–response curves for IQ loss and CVD are steepest at low BLLs and flatten as BLLs rise. Reducing BLLs from 80 to 20 µg/L therefore does more good than the same 60 µg/L reduction from 180 to 120 µg/L.

1.3 **Baseline measurements are affordable.** BLLs can be measured with relatively inexpensive tests, so a national BLL baseline is within reach of most governments. It is encouraging that this has become an accepted first step. Surveillance systems are key. Capable laboratories are needed.

1.4 **BLLs can be predicted from exposure.** Using the US EPA All Ages Lead Model (AALM) [3] or the JECFA and FDA rules of thumb [4, 5], measured lead intake (by ingestion and inhalation) can give reasonable first estimates of BLLs without blood testing. These estimates can be validated against measured BLLs.

1.5 **BLLs are not a perfect marker.** Bone lead is a better indicator for some outcomes, because lead stored in bone creates a delay before outcomes such as CVD and dementia appear. Even so, the literature shows clear relationships between BLLs and the key outcomes. A future Guidance might give a simplistic tool to convert BLLs into outcomes such as premature deaths. IHME is developing a more robust method.

Section 2: Measure Progress as Lead Burden

The best way to judge whether interventions will reduce BLLs at scale is to calculate **lead burden**. The metric is the cumulative population blood lead level (cpBLL): the sum of BLLs across a population [6]. The most common source-analysis tools use estimates of the number of people exposed. A burden calculation goes further, as it includes how many are exposed **and** how much that exposure raises their BLLs.

2.1 **Burden is straightforward to calculate.** Estimate the population exposed to a source (often through a survey), then estimate the average amount by which the source raises their BLLs. For the second step, one could estimate how much lead people are consuming in their diet then convert intake to a BLL increase with AALM or the JECFA/FDA rules of thumb. An RCT study may give a more reliable result. Multiply the two and compare the result with the country's total burden to find the source's share. Two GRIT Guidance documents set out the method with many worked examples [2, 7].

2.2 **Every source study should calculate burden.** It shows where the biggest problems are, so that resources go to tractable problems where they can do the most good.

2.3 **Burden is not the only metric.** Other important metrics will track BLL distributions amongst age, income inequalities and most importantly, BLLs the upper end of exposure where health concerns become even more significant.

2.4 **Exposure alone can mislead.** Studies of homes and marketplaces, even when they measure blood lead, look for associations driven mainly by exposure. The example below shows why this matters.

> **Worked logic: exposure share versus burden share**
>
> A country has 100 million people and an average BLL of 50 µg/L. Its total lead burden is 5,000 million cpBLLs. Above the 10 µg/L high-income floor, 4,000 million cpBLLs are available to reduce [2].
>
> Household and marketplace studies find that **55% of people** are exposed to lead from aluminium cookware. That looks like a strong result, and governments are advised to act on cookware.

> But leaching tests and intake estimates show that the cookware raises BLLs by an average of **5 µg/L** among those exposed.
>
> Burden from cookware = 55 million × 5 µg/L = 275 million cpBLLs, or **about 7% of the available burden**.
>
> Removing this source would lower national BLLs but only slightly. Under the GRIT investment bands, a source in the 5–10% band merits a low-cost intervention if one exists, not a major programme [2].

This problem appears often in current source assessment reports. It is one of **two significant shortcomings** in the source-analysis methodology presented at CGD in late July 2026 [8]. The other, its treatment of food, is discussed under Key Issue 1. That methodology is excellent for identifying sources and being representative, but without burden calculations its results may improperly skew recommendations to governments. I am publishing this Guidance so that the methodology can be extended to include burden and food in the hope that this can be **corrected while many studies are in the design stage.**

In short: to judge whether a source matters, we must estimate how much lead is ingested, not just whether people are exposed, and use that to calculate how large a source it is.

2.5 **Burden can be calculated for toxic sites.** Totals may be modest because the populations are small, but very high individual BLLs give these sites a special place in prioritization.

2.6 **The method also works for specific groups**, such as a birth cohort. If the baseline uses the same parameters, comparing the likely effectiveness of interventions is simple.

Section 3: Two Categories of Exposure

Work on lead divides into two broad categories of exposure: **hotspots** (point sources) and **population-level exposures**. Although there are important overlaps, they differ in many key respects and require different theories of change.

	Hotspots (point sources)	Population-level exposures
Examples	Smelters, battery (ULAB) recyclers and other industry; abandoned contaminated sites	Food, spices, paint, cookware and other consumer goods
Typical BLL impact	High BLLs	Smaller BLL increases
People affected	Small populations, often within a defined radius	Very large populations
Lead agencies	Ministries of environment; mainly industry-focused	Ministries of health; food-safety and consumer-product regulators
Share of burden	Smaller	Dominant **Certainty: high**

3.1 **Food dominates population-level exposures.** See Section 4.

3.2 **The categories have overlap.** Industrial emissions do not only affect neighboring citizens: particulates can contaminate crops far downwind, turning a point source into a population-level exposure. Conversely, a single product can cause a local cluster: a box of lead toy soldiers might poison a generation of children at one school.

3.3 **Most effort in LMICs has gone to point sources.** Regulation of large industry is almost always an existing priority. Unregulated industry and abandoned contaminated sites may not be focuses of attention and lack resources.

3.4 **Mitigation strategies are completely different.** Hotspots are issues for Ministries of Environment. Population exposures need Ministries of Health and regulators for consumer products. Working on lead broadly therefore means **separating the two** and tackling each with its own theory of change.

3.5 **Population-level exposures dominate burden.** Certainty: high Large populations with modest BLL increases produce burdens far larger than point sources. Because the dose–response is steepest at low BLLs, population exposures are almost certainly the largest cause of IQ loss and CVD.

3.6 **But both categories need effort.** The severe effects of high BLLs, especially in children, make work on hotspots a moral imperative. Hotspot work also builds skills within governments that they can then apply to population-level exposures.

3.7 **BLLs are log-normally distributed.** Most people cluster near the middle, with a long tail of high values. The smaller number of people in that tail are most likely living near point sources. The difference between mean and median raises technical questions, but it does not change the theory of change for either category.

Section 4: Key Findings

Because population-level exposures dominate burden, the rest of this Guidance focuses on them.

Finding 1: The main consumer sources are probably already known

I would be surprised if a major new consumer source emerged, though it is a world full of surprises. Annex B lists the main consumer sources, with notes on burden and intervention potential based on what is currently known.

Finding 2: Apart from food, single consumer sources rarely carry a large burden. Certainty: medium

Recent burden calculations find that it is rare for any single consumer source to exceed 10% of a country's lead burden. Exceptions, such as spices in Georgia and Bihar will continue to be found, but even these do not appear to exceed 20%. Yes, data is sparse. But what is measured or reasonably estimated is consistent with this finding. A Guidance with burden calculations for a range of consumer goods and foods can be found here.

Finding 3: Food is the largest pathway of lead exposure globally. Certainty: high

The evidence is strong.

(a) **Diet studies.** A recent analysis of total diet studies by Chris Kinally, Howard Hu and I finds that dietary lead accounts for around 40–50% of the blood lead burden in LMICs [9]. Although total diet studies are sporadic in LMICs (except China), the evidence is compelling.

(b) **WHO estimates of foodborne disease.** The WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) attributes 466,000 deaths in 2021 to lead in food, almost a third of the 1.52 million deaths caused by the 42 foodborne hazards it assessed [10]. Those calculations were based on GBD's estimate of 1.2 million deaths. More recently, using better dose-response relationships, GBD 2023 now attributes 3.5 million deaths to lead exposure [11]. When future FERG rounds reflect the higher GBD 2023

numbers, lead will easily become the single largest cause of death from contaminated food. Even now it is already the largest chemicals cause of premature death.

(c) **China.** Childhood BLLs in China have fallen from about 80 µg/L in 2000 to about 17 µg/L in 2025, bringing BLLs close to high-income levels [12]. GBD 2023 estimates show a smaller fall, from 72 µg/L in 2008 to 42 µg/L in 2023 [11] but may not have integrated some of the more recent datasets. The decline followed the phase-out of leaded petrol and, from 2011, the closure of the worst battery recyclers. Recyclers still operating must now meet standards for emission controls found in high-income countries, with secondary HEPA filters or electrostatic precipitators after the baghouses. Lower emissions reduce airborne lead, which reduces lead inhalation, reduces lead in food, and thus reduces BLLs. A paper documenting these three parallel declines is in preparation.

Once the lead community recognizes how dominant the food pathway is, the questions of where the lead in food comes from (and how to stop it) will need further research.

Why has the food pathway been overlooked?

Codex limits are not based on health impact. Almost all countries follow Codex maximum levels for lead in food [13]. Most food recommendations for lead were set in the early 2000s. Limits for staples such as rice and wheat were not based on BLL/health impact but on commercial practicality: broadly, a level that about 95% of samples already met. They are too high. The Codex limit for cereal grains is 0.2 mg/kg (200 ppb). An adult eating 300 g of rice a day at that level takes in 60 µg of lead a day, which means a BLL of 24 ug/L. A child eating 150 grams will have a BLL of 48 ug/L:

GRIT's calculator estimates BLLs from lead in food and compares them with Codex limits [14].

Detection limits are too high. Lead in food at only tens of parts per billion matters. For someone eating 250 g of rice a day, 50 ppb (0.05 mg/kg) raises BLLs by about 5 µg/L. Many laboratories report working limits of quantification of 0.1–0.2 mg/kg, adequate for checking Codex compliance but far too high for this purpose. As a result, many studies report lead in food as "not detected" or "below the standard". Yet most ICP-MS can measure well below 0.02 mg/kg with correct methodologies. But even that starting point - access to ICM-MS – can be very difficult in many LMICs.

Lead from different foods adds up. People eat more than rice. Leafy greens, root vegetables and other staples are also contaminated. With four or five foods contributing, BLLs of 50–60 µg/L are easily reached, a level typical in LMICs. A calculator allows for multiple foods to be input at once can be downloaded here. GBD 2023 estimates all-ages mean BLLs of 60 µg/L in India, 73 µg/L in sub-Saharan Africa and 75 µg/L in South Asia [11]. GBD BLL data for all countries can be found here.

Because of these two errors, the food pathway for lead poisoning in LMICs has been missed for decades.

Section 5: Food Is a Pathway, not a Source

We must always remember that food is a **pathway**, not a source. The main upstream source of lead in food is probably airborne particulates from industry, especially battery recyclers, but this is not yet well established.

Several studies point to airborne emissions, and isotope studies, especially in China, a recent Columbia University study in Kenya, and one in Kolkata, India[15], find that most lead in food comes from atmospheric deposition rather than from soil. This is good news: controlling industrial emissions is far easier than cleaning up contaminated soil.

Much more work is needed:

- **Particle size probably matters most.** Fine and ultrafine particles (below 1 µm, and especially below 0.1 µm) can travel hundreds of kilometers or more downwind of an industrial source and settle on farm crops. The Columbia University team has studies underway on this in India and Africa.
- **Inhalation may also be a significant contributor** to BLLs, especially in cities. Emissions in urban industrial areas may be significant contributors to elevated BLLs in cities.
- **Industry is the likely primary source, but not only battery recycling.** Steel mills can also emit significant amounts of lead. Diesel emissions can have large lead content. Coal fired power plants, especially old ones without mercury scrubbers may contribute. Isotopic analysis is a useful tool to sort this out, but has its limitations as well.
- **Reported emissions data are a useful starting point.** Many governments publish industrial emissions inventories that can be used to begin estimating these exposures. Modeling will be most useful for both food and inhalation. Care will be needed to collect long range emissions in modeling, not just the larger particles falling close to a facility.

Section 6: Four Key Issues

Key issue	What needs to happen
1. Source apportionment methods need fixing	The recent source-analysis methodology [8] has two shortcomings: it measures exposure, not burden, and it downplays food as a pathway. Both can be remedied. Food should be an integral part of household and marketplace assessments, and laboratory methods must measure down to 0.02 mg/kg (20 ppb) or lower.
2. Food diet studies are needed that are representative	Total diet studies should be carried out in the countries that matter most, including India, Nigeria, Bangladesh and Indonesia.
3. We need to understand how lead gets into food	More isotope analysis of food is needed, together with research on particle size. We need better data on average emissions from industrial sources (especially battery recyclers), including particle size distributions and lead loading by size. Modelling must go beyond standard US EPA dispersion tools, because ultrafine particles travel very long distances, and deposition onto crops needs specialized modelling. Emissions monitoring must become affordable.
4. Source analysis on consumer goods should continue, but food and inhalation should be integrated. These should become the major focus for investment.	General source analysis projects, combined with burden, are important to determine what sources cause the most impact. A consumer good may be identified that has a large burden. But without metrics on food as a pathway, we may miss key sources and spend time and energy on projects that will not make much of a difference.

Section 7: Recommendations

Funders

- Convene experts with broad experience across all types of lead source, including WHO FERG experts and specialists in total diet studies.
- Require lead burden to be a core part of every source analysis and support research on leaching rates to help calculate it.
- Fund total diet studies in priority countries.
- Fund laboratory capacity in LMICs for measurements of lead in food, with isotopic capabilities.
- Support work to make the AALM more user-friendly and to extend it to calculate burden.
- Fund research on the upstream sources of lead in food: particle size, lead loading, isotopes and deposition modelling.

NGOs and UN agencies

- Include lead burden estimates in every source analysis, using leaching tests and the AALM, for example. Compare each source with the national total and build this approach into government practice.
- Make sure laboratory analysis of food can measure below 0.02 mg/kg (20 ppb).
- Do not treat Codex limits as a measure of safety. Estimate BLL impact with AALM or the JECFA/FDA rules of thumb.

Governments

- Undertake total diet studies.
- Collect data on lead emissions to air. Do this with self-reported data from industry and with independently run monitors. Make this data publicly available.
- Set food-safety limits for staple foods based on BLL impact, and press for revision of the Codex limits.

Researchers and laboratories

- Evaluate leaching rates across multiple locations for consumer goods
- Develop strategies to repair Codex inadequacies and give better guidance to governments
- Conduct isotopic evaluations to determine primary sources for food exposures, including particle size and lead distribution from industrial sources. Develop these capabilities within LMICs

Annex A: Important Resource Links

More Guidance documents and tools are available on the GRIT Resources page.

WHO Foodborne Disease Burden Epidemiology Reference Group (FERG)

GRIT Guidance: Quantifying Lead Burden for a Single Source

GRIT Guidance: Further Estimates of Lead Burden from Various Sources

Calculator: Food Lead BLL Calculator

Lead Burden Index (cpBLL)

GBD country lead levels 2023

Annex B: Consumer-Related Sources and burden estimates

I have prepared notes on the main consumer-related sources, their likely burden and intervention potential, based on results found in various papers. A more detailed set of examples of various sources can be found in a separate GRIT Guidance: Further Estimates of Lead Burden from Various Sources.

Please note that these results are indicative only. Some total diet studies show burdens that exceed the available burden for a country, indicating that either IHME's estimates for BLL are too low, or that food sampling was not representative. Small sample sizes for many consumer product estimates disqualify them from consideration as representative. The estimates on burden are thus my own and will have biases and inaccuracies. They are based on calculations from papers, many of them with inadequate data. At a minimum, the message ought to be that we need survey and RCT trials to be undertaken to give more clarity to these questions.

Source	Where it occurs	Likely burden	Notes
Food (staple grains, leafy greens and other regularly eaten foods)	Everywhere	Highest of all; averaging 40–50% of blood lead burden in LMICs. Some countries will be higher than this, others lower	See Sections 4 and 5.
Paint	Everywhere	Probably less than 5%	Less concerning in LMICs than in HICs
Lead-glazed ceramics	Pockets of use everywhere; systemic in a few countries such as Mexico	Can be significant where use is ubiquitous. But probably never more than 20%	Regulated out of HICs and most LMICs during the early 20th century.
Adulterated turmeric	Only a few countries	Usually negligible, Perhaps over 20% in a few countries	Now being well addressed. Are other spices also contaminated for color?
Aluminium cookware	Everywhere	Likely modest	The standard acetic-acid leaching test overstates real-world exposure.
Toys	Everywhere	Unlikely to be significant	
Kohl / surma eyeliner	Muslim traditional	Generally, less than 10 percent	
Traditional medicines	Ayurvedic medicine especially	Unknown – wild card	India uses a lot of lead in their products – perhaps significant?
Drinking water and plumbing	Everywhere	probably small	

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