GRIT GUIDANCE DOCUMENTS on REDUCING BLOOD LEAD LEVELS

Quantifying the Lead Burden of a Single Exposure Source

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This GRIT Guidance document gives a step-by-step method for deciding whether a given lead source is worth investing in mitigation. We work through an example: lead in rice in Odisha, India, using the JECFA rule of thumb and the AALM for conversion of lead intake to BLL increase.

A Note on Units: Why We Use µg/L, Not µg/dL

Throughout this guide we express blood lead levels (BLLs) in micrograms per litre (µg/L) rather than the more familiar micrograms per decilitre (µg/dL). The two are directly convertible:

1 µg/dL = 10 µg/L

We adopt µg/L for two reasons. First, at the low concentrations that matter most for population-level work, µg/dL forces awkward fractional values, whereas µg/L keeps numbers as clean whole figures — the current US CDC blood lead reference value of 3.5 µg/dL becomes a round 35 µg/L [14]. The high-income benchmark we use in this guide, 1 µg/dL, becomes 10 µg/L. Second, using a single consistent unit (equivalent to ppb) across exposure, burden and reduction calculations removes a common source of arithmetic error and enables comparison with other toxics.

This convention, and the rationale for it, is set out in full in the Environmental Health Perspectives paper by Dr Jack Caravanos, myself and others [2].

About the Lead Burden Index

The Lead Burden Index — also known as the Cumulative Population Blood Lead Level, or cpBLL — is a simple way to assess the overall impact of lead poisoning within a community. Lead burden is the sum of the increases in blood lead level across a defined population. CpBLL is often calculated as the average BLL across a population (typically a country) multiplied by the number of people in that population, a method described in a BMJ Global Health paper by myself, Howard Hu, David Hanrahan and others published in 2025 [1]. Using lead burden one can compare countries side by side. More importantly, you can examine specific sources of lead and determine how much any one source contributes to the totality of lead poisoning within a community. 1 cpBLL = 1 person x 1 µg/L.

Section 1: Establishing the Baseline and Sizing a Single Source

The goal of this section is to answer one question: of all the lead burden in the geography you care about, what share does your chosen source account for? That share is what tells you whether the source deserves a large, small, or negligible slice of your intervention resources.

Step-by-step

1. **Understand the existing lead burden in your geography.** Your geography might be a single town, a country, or the world. Establish two things: the average BLL of the population, and the affected

population. A good source is the Institute for Health Metrics and Evaluation (IHME) dataset [3], where one can download average BLLs at national and subnational levels. You can also use the cpBLL resource at leadpollution.org [4], which draws on the latest IHME data and World Bank population figures (but note that this website reports in µg/dL, not µg/L).

2. **Choose a particular source of concern.** Select the single lead source you want to evaluate — for example contaminated food, leaded ceramics, adulterated spices, or informal battery recycling. The rest of the method quantifies this one source.

3. **Evaluate how much that source raises BLLs, and for what portion of the population.** There are several practical routes. The first is to review the literature for measured BLL increases attributable to the source. The second is to use the All Ages Lead Model (AALM) from the US EPA [5] to calculate the expected increase from a measured ingestion or soil exposure. A third is to use rules of thumb put forward independently by FDA and JECFA (the example shows this in practice). Use the rules of thumb or the AALM route whenever you have a concentration measurement and a consumption estimate but no epidemiological study of the source.

Rules of thumb for intake-to-blood conversion

If you know the amount ingested daily, FDA (US Food and Drug Administration) and JECFA (Joint FAO/WHO Expert Committee on Food Additives) both publish conversion factors. Both agencies state them in µg/dL of BLL increase per µg/day of lead intake; the µg/L equivalents are given here for consistency with this guide.

FDA [15]. An increase of 0.16 µg/dL (1.6 µg/L) of BLL for each µg/day of lead intake for children aged 0–6. For females of childbearing age 0.04 µg/dL (0.4 µg/L) of BLL increase per µg/day of lead intake. Note this second figure is for women of childbearing age specifically, not adults in general.

JECFA [16]. A range of 0.05–0.1 µg/dL per µg/day for children and infants, equivalent to 0.5–1.0 µg/L, and 0.023–0.07 µg/dL (0.23–0.7 µg/L) per µg/day for adults. JECFA published ranges only; the midpoints of 0.75 and 0.465 µg/L are our own arithmetic, not JECFA values.

Note that these slopes are empirical models fitted at blood lead concentrations of roughly 10–25 µg/dL. JECFA is explicit that uncertainty increases outside that range.

4. **Calculate the affected population.** Estimate how many people actually receive this increase because of the source. It is often hard to be precise, so use a range. The important thing is to make a defensible first estimate as a starting point, then refine it as you progress. A rough number you can improve beats no number.

5. **Compute the source's total lead burden.** Multiply the per-person BLL increase by the affected population. The product is the total BLL attributable to your source — its lead burden.

Lead burden of source = (BLL increase per person, µg/L) × (number of people affected)

6. **Compare against the geography's total lead burden.** Return to the IHME data and determine what percentage of the total available lead burden your source represents. This number helps to determine the overall impact and thus importance of that source.

Section 2: Measuring Burden Above a 10 µg/L Floor

There is one important subtlety when you compute total lead burden. You should probably not count the entirety of each person's BLL. Instead, count only the portion above the high-income country benchmark — currently around 10 µg/L (1 µg/dL). (Please feel free to adjust this number as you see fit).

Why? Because the realistic policy goal is to bring low- and middle-income countries down to high-income standards, not to zero. Pre-industrial blood lead levels were probably around 0.16 µg/L [13], but such levels are unachievable in the world we now inhabit, where millions of tons of lead were released into the air from leaded gasoline and continue to circulate. The benchmark of roughly 10 µg/L represents what is currently reasonably achievable. The burden that is actually "available" to reduce is the headroom above that floor.

> **Worked logic: the headroom calculation**
>
> Suppose a country averages 50 µg/L (5 µg/dL) and has a population of 1 million. The floor is 10 µg/L (1 µg/dL).
>
> Total lead burden = 1,000,000 × 50 = 50 million cpBLLs.
>
> Available headroom per person = 50 − 10 = 40 µg/L, so available lead burden = 1,000,000 × 40 = 40 million cpBLLs.
>
> Your intervention reduces BLL by 20 µg/L, but only for one third of the population: 333,333 × 20 = 6.67 million cpBLLs, which is **16.7% of the available lead burden.**

Section 3: Turning the Share into an Investment Decision

Once you have the source's share of available burden, you can judge whether it is worth investing in. The principle is proportionality: resources should track the share of burden a source is responsible for.

- **Under ~5% of available burden:** the source should receive only a small, proportionate share of available intervention resources.
- **5–10%:** worth monitoring and worth a low-cost intervention if one already exists, but unlikely to justify a dedicated programme on its own.
- **10–30%:** a meaningful target; warrants serious investment if a viable intervention exists.
- **Above ~30% with a viable intervention:** an extremely high-priority target; a large share of resources should be directed here.

These bands are judgements, not thresholds derived from data. Two considerations should override them. A source with a large share but no viable intervention is not an investable target, however large it looks. A source with a modest share but a cheap, fast and durable intervention may well outrank a larger one.

A number of interventions will be covered in future guidance documents. You can find all guidances at www.toxicsresearch.org

Example: Lead in Rice in Odisha, India

This example uses the JECFA rules of thumb and AALM at Step 3 and is worked end to end. It would need further study to validate accurately, as the results show that there is not enough data to be representative. Treat it as an illustration of the method, not as definitive.

Odisha is a useful case because it combines three things: among the highest rice consumption of any Indian state, published field measurements of lead in locally grown rice, and a large, predominantly rural population eating rice grown where they live.

Step 1: Establish the baseline

Population of Odisha (2026)	47.2 million (Census 2011: 41.97 million, 83.3% rural; Census projection for 2026) [12]
Mean BLL used	104 µg/L (10.4 µg/dL) — ICMR pooled mean for Indian children aged ≤14 years, 95% CI 95.5–112 µg/L, from 51 studies [10]. This average is used as a proxy for children <u>and</u> adults, as no adult level is available.
High-income floor	10 µg/L (Section 2)
Available headroom per person	104 − 10 = 94 µg/L
Total available lead burden	47.2 million × 94 = 4,437 million person-µg/L

Step 2: Choose the source

Lead in rice grown and eaten within the state.

Step 3: Estimate the BLL increase using the JECFA rules of thumb

An easy first pass is to use the FDA or JECFA conversion factors. Here we use the JECFA adult range and discuss options for further analysis.

Lead in rice, western Odisha	0.98 mg/kg dry weight = 980 µg/kg (n=12; Sambalpur, Bargarh and Subarnapur districts) [7].
Rice consumption	0.30 kg per person per day, derived from all-India rural per capita cereal consumption of 9.4 kg per month [11]. Note this is total cereal, used here as a proxy for rice. Odisha is among the highest rice-consuming states, so the proxy is conservative for Odisha.
Daily lead ingested from rice	0.30 kg × 980 µg/kg = 294 µg/day
Counterfactual: Codex-compliant rice	0.30 kg × 200 µg/kg = 60 µg/day (Codex CXS 193-1995, GC 0081, cereal grains, lead ML 0.2 mg/kg [18])
Attributable increment in intake above compliance standard	294 − 60 = 234 µg/day
Increase in BLL, JECFA adult range [16]	Lower 0.23 × 234 = 53.82 µg/L
	Midpoint 0.465 × 234 = 108.81 µg/L
	Upper 0.70 × 234 = 163.8 µg/L

The example explores BLL increase above a Codex limit, which may be contentious. There are issues with Codex levels. Compliant products with regular consumption patterns can often produce significant increases in BLLs, and changes in Codex levels may be warranted. If we had excluded Codex calculations the results in this example would be even higher.

Sensitivity: where in the JECFA range we sit

JECFA adult coefficient	BLL increase	Lead burden from rice above compliance standard, rural population
Lower — 0.23 µg/L per µg/day	53.8 µg/L	2,109 million cpBLLs
Midpoint — 0.465 (our arithmetic)	108.8 µg/L	4,265 million cpBLLs – About 100% total burden
Upper — 0.70 µg/L per µg/day	163.8 µg/L	6,421 million cpBLLs Note - >100% total burden

Checking against AALM

Running AALM for 234 µg/day in food gives an average BLL of about 100 µg/L with adults higher than children. This BLL is at the level of the average for India, and at the mid-point for the JECFA rule of thumb. This result would imply that rice is responsible for all of the lead exposure in Odisha, an unlikely assumption as leafy green vegetables and consumer goods are also known sources of lead. Hence, we see the inaccuracies inherent in these calculations, likely because of a sparsity of data. Only 12 samples are used in the source paper, clearly inadequate to properly quantify a state-level average. It is also not clear whether results are from dry weight or as-purchased, which can affect levels. A state-level BLL average may be higher than the country average (Odisha has high rice consumption rates).

Nevertheless, given the results we can be confident that contaminated rice is an extremely significant source of lead poisoning in Odisha, and is most likely the largest single source of lead poisoning in the state. Even taking the lowest bound of the JECFA range gives a result that rice is responsible for about one half of the available burden in the state.

Steps 4 to 6: Population, burden and share – lowest JECFA range

4. Affected population	Rural population of Odisha ≈ 83% × 47.2 million = 39.2 million, taken as those eating locally grown rice.
5. Source lead burden	39.2 million × 53.8 µg/L = 2,109 million cpBLLs
6. Share of available burden	2,109 ÷ 4,437 = 48% of Odisha's available lead burden
Decision	This falls in the "above 30%" band and becomes an extremely high-priority target. Because of uncertainties detailed below, the result should be considered indicative only. Nevertheless, it is clear that contaminated rice is a major cause of lead poisoning. The next question is to work out how the lead gets into rice, and can it be stopped. Future GRIT Guidances will discuss these issues.

Assumptions, and what would change the answer

Concentration. The figure used rests on 12 samples from three western districts [7]. Much more sampling is required to establish a reasonable state-level average. The national mean for Indian wheat and rice is 0.12 mg/kg [6], about eight times lower than the figure used here, which is itself a reason to want state-representative sampling. That campaign is the single highest-value refinement available.

Standards context. At 0.98 mg/kg, Odisha rice is 4.5 times India's own FSSAI limit for cereal grains (0.2 mg/kg [17]), 4.9 times the Codex lead ML for cereal grains (0.2 mg/kg, GC 0081 [18]) and about 5 times China's grain limit (0.2 mg/kg, GB 2762-2022 [19]). The reference [6] described this rice as domestically compliant against a 2.5 mg/kg limit, which is the FSSAI catch-all for foods not otherwise specified rather than the cereal limit; and it compared against 0.4 mg/kg as "the Codex limit for rice", which is the Codex limit for cadmium. The rice is not compliant with any lead standard that applies to it.

Consumption. The 0.30 kg/day figure is all-India rural per capita total cereal consumption [11] used as a proxy for rice. Odisha's rice share is higher than the national average, so this is conservative for Odisha, but a state-specific rice figure from the HCES unit-level data would be better.

Baseline BLL. No Odisha-specific pooled BLL has been published; the national ICMR figure is used here, and is for children less than 14 years old, not adults. [10]. If Odisha sits above the national mean, the available burden rises and the source share falls, and vice versa.

Where the lead comes from. This method sizes the burden from a source; it does not identify the origin of the contamination. The only lead-isotope study of Indian foodstuffs to date attributed 68.5–86.7% of food lead to atmospheric deposition rather than soil [9], which if confirmed for staple crops would point intervention towards industrial air-emission control rather than soil remediation.

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