GRIT GUIDANCE DOCUMENTS on REDUCING BLOOD LEAD LEVELS

Further Estimates of Lead Burden from Various Sources

Global Toxics Research Initiative
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Draft, 15 October 2026 (revised)

This document is intended to assist and direct the conversation around source mitigation prioritization. Information is based on journal articles or other trusted sources, occasionally aided by Claude analysis and has been reviewed by external experts. Findings with data gaps (e.g. inadequate data on BLL increase or affected populations) are tagged for additional research. Corrections are welcomed; please email to fuller@toxicsresearch.org. This and other guidances can be found at www.toxicsresearch.org under Resources.

This GRIT Guidance document builds on Quantifying the Lead Burden of a Single Exposure Source [1] with further worked estimates of lead burden (cpBLL) from individual sources, each compared with the burden available in the same population. It gives examples for food (whole diets from total diet studies, and rice), spices, ceramic cookware, aluminum cookware, eyeliner, kohl, paint and secondhand tobacco smoke in various geographies.

We note that there is a fundamental difference between cost effectiveness of an intervention and burden. A source with a small burden may be extremely cost effective – leaded paint interventions are demonstrably cost effective, even though unlikely to be a major contributor to elevated BLLs in most countries. Burden says how much there is of it; cost effectiveness is how worthy it is of investment. The two combined? That overlap is most worthy of investigation. Regardless, even if the cost dynamics may not be the most favorable, high burden sources demand intervention simply because such interventions are the ones that are needed to reduce BLLs at scale.

We also note that burden is just one metric to consider. Other issues such as age profile, demographics, and high exposures — the tail of the BLL curve — need to be considered in the investment decision. Toxic sites, for example, demand consideration as high BLLs wreak havoc on children especially.

Section 1: Summary of Key Findings

These analyses are based on data extracted from published case studies. Each figure is the source's estimated share of the lead burden available above a 10 µg/L floor in the population studied. Central estimates are shown with ranges in brackets. Populations differ — national, state, city, children, birth cohort — so shares are not additive across rows.

The quality of these studies also varies greatly and should be considered provisional, given uneven evidence and modelling assumptions. Some are clearly not representative (e.g. Odissa rice, Iran TDS) while others show weaknesses in either the underlying baseline data or poor methodology (e.g. Brazil TDS, Kanpur TDS). This guidance has included them regardless, as the whole gives a good overall picture of exposure risk, even while individual analyses can be criticized. We have indicated where there are issues with a note in Strength of Assessments column.

Source type	Source	Country	Estimated % of total available burden	Strength of assessment	Details	Journal article
Food — total diet studies						
Food	Whole diet (TDS 2024)	Cuba	78% (39–118%)	Reasonable, with caveats	A3.1	[6]
Food	Whole diet (2021)	Brazil	171% (85–258%); exceeds IHME baseline	Shows Limitations of TDS /IHME. Not reliable.	A3.3	[4]
Food	Whole diet (TDS 2020)	Nigeria	58% (29–87%)	Reasonable (caveats)	A3.4	[10]
Food	Whole diet (TDS 2020)	Iran	55% (27–83%)	Not representative (caveats)	A3.5	[11]
Food	Whole diet (2005)	India (Kanpur)	56% (28–85%) on the ICMR baseline; 105% on IHME	Old, lacking adequate sample size.	A3.6	[12]
Food	Whole diet (TDS 2022)	China	27% (14–41%). Notable reductions from earlier TDSs	Strong (caveats)	A3.2	[7] [8]
Food	Rice	India (Odisha)	48% at lowest slope; about 96% at midpoint	Too small sample size. Unreliable.	A3.7	[13]
Food — spices						
Spices	Lead-adulterated turmeric (birth cohort)	India (Bihar).	12–58% of birth-cohort burden (9–48% on IHME or ICMR baselines). Other states shows much lower burden.	Strong	App. B	[21]
Cookware						
Cookware	Lead-glazed ceramics	Mexico	5% (5–25%)	Strong (caveats)	C1	[22, 26, 27, 2, 29, 30]
Cookware	Artisanal aluminum pots	Cameroon	9% (4.5–28%)	Significant uncertainties regarding leaching	C2	[31, 32, 22, 24, 25]
Eyeliner and kohl						
Consumer products	Leaded eyeliner (infants)	Morocco	0.8–3.3% of birth-cohort burden	Uncertainties re primary data source	App. D	[37]
Consumer products	Leaded eyeliner (infants)	Egypt	0.8–2.2% of birth-cohort burden	Uncertainties re primary data source	App. D	[37]
Consumer products	Leaded eyeliner (infants)	Pakistan	0.7–1.7% of birth-cohort burden	Uncertainties re primary data source	App. D	[37]

Source type	Source	Country	Estimated % of total available burden	Strength of assessment	Details	Journal article
Consumer products	Kohl (women 15+)	Iraq	2–10% nationally	Unadjusted; 2002 Basrah clinic data, high-exposure era. Unreliable	App. D	[57]
Paint						
Housing	Lead paint in homes	India.	0.13% nationally (0.05–0.27%); 0.9% of under-fives (0.4–1.8%)	Exposures not known. Modeled results with Claude assistance	App. E	[56]
Tobacco smoke						
Household	Secondhand smoke (children 6–19)	USA	2–3% nationally (1–4%)	Nationally representative; likely confounded by housing and paint.	App. J	[58]

Each result is detailed in its own appendix. General assumptions are in Appendix F; worked calculations in Appendix G; and the methodology in Appendix H.

What stands out, by type

- **Food.** Diet is the largest source wherever it has been measured. In Cuba, Nigeria, Iran and Brazil the whole diet is above 50% of available burden at the central estimate, and in Kanpur and Odisha (rice alone) it is around half on the most conservative readings. China is lower, at 27%, and its earlier 2000 study shows dietary intake falling by two-thirds or more as blood lead fell — evidence that dietary lead can be brought down, likely driven by mitigation efforts on battery recyclers. Brazil exceeds IHME's entire baseline, which says as much about the baseline as the diet. The highest-burden countries — India, Pakistan, Bangladesh, Indonesia — have no recent national total diet study.
- **Spices.** In Bihar, lead-adulterated turmeric accounts for an estimated 12–58% of the available burden among the youngest children, based on a peer-reviewed study modeling a 2–3-year-old eating turmeric at the state's typical lead level. The youngest children are both the most exposed and the most vulnerable. Interventions are cheap and fast, certainly good investments. Other states in India are not nearly as problematic as Bihar, and while turmeric shows contamination above India's limit in 25 of the 34 cities sampled in eastern India [55], burdens in the low single digits. Questions regarding other spices and intentional contamination in other countries need further review.
- **Cookware.** Lead-glazed ceramics in Mexico are a tractable target at 5.4% and more (up to 25% under broad use definitions). Artisanal aluminum pots may be comparable (9% in Cameroon) but the estimate is modeled from published leaching tests and an unpublished adjustment from acid to real food.
- **Eyeliner.** Leaded eyeliner accounts for under 3.5% of the infant burden in Morocco, Egypt and Pakistan — small at population scale, though serious for individual infants and potentially cost effective to act on. Data is from a PowerPoint slide for a study presented in the CGD conference in London in 2026, and underlying information not used. In a 2010 study among adult women in Iraq, kohl may account for 2–10% nationally. The estimate rests on an unadjusted, high-exposure study; a market survey of kohl products. Better studies are needed.

- **Housing paint.** As a modeled illustrative example using LEEP's estimate of the blood lead increase from living in a lead-painted home, lead paint in India is about 0.1% of national burden and about 1% of the under-five burden. India-specific joint measurements are needed before it can be ranked with confidence. This burden estimate is the least reliable of the group.
- **Secondhand smoke.** In US children aged 6–19, secondhand smoke accounts for about 9% of blood lead, or 1–4% of the national available burden — small, and probably inflated by confounding with old housing. This first high-income example also shows a limit of the method: these children are already below the 10 µg/L floor.

A Note on Units

As in all GRIT guidances, blood lead levels are expressed in micrograms per liter (µg/L) [2]. One unit of lead burden (1 cpBLL) [3] is one person raised by 1 µg/L. The high-income benchmark used as the floor for "available" burden is 10 µg/L [1, 4]. This number is suggested by acknowledging that North American BLLs are at about 14 µg/L and leaving some room for improvement.

Thoughts on next steps

This assessment points to food as the largest pathway for lead exposure; a hypothesis needing to be tested in many countries, especially those with large burdens from lead such as India Indonesia, Nigeria, Bangladesh, Pakistan and more. Total diet studies are needed.

But another important question follows that one. How is food being contaminated? Options include soil, airborne particulates, fertilizers, water, processing equipment and storage. Our hypothesis (from review of the literature in China) is that airborne emissions from industry are the main source of lead exposure for food. This idea is currently being tested in a series of studies underway in India and Africa using farm sampling and isotopic analysis, conducted by GRIT, GAHP, Columbia University, and local partners. Early results are expected in mid 2027.

Appendix A: Food — Total Diet Studies

A1. Why total diet studies matter

A total diet study (TDS) buys the foods that make up a population's ordinary diet, prepares them as eaten, analyses them, and multiplies measured concentrations by how much of each food people consume. The output is an average daily lead intake, usually reported in µg per kg body weight per day. It is the most direct measure available of the dietary pathway as a whole and can also give details of individual loading from one food at a time.

Recent work pooling 25 TDS across 46 countries estimates that population-weighted dietary lead intake for children in LMICs (32.0 µg/day) is more than three times that in high-income countries (9.3 µg/day), and that diet may account for 40–50% of BLLs in LMICs [5]. Vegetables and cereals are the largest contributors on average, pointing to environmental uptake into crops as the main driver.

The weakness is coverage. Of the 15 LMIC TDS identified, only four are national in scope, and none of the national LMIC studies reports child-specific intake. About a third of the global lead burden (34.5%) is in countries — India, Pakistan, Bangladesh, Indonesia — with no recent national TDS at all.

A2. The studies used here

The studies below are taken from those compiled by Kinally, Hu and Fuller [5], China's most recent TDS, and a single-food example for rice in Odisha.

Study	Published	Scope	Adult lead intake used
Cuba — González-Pérez de Medina et al. [6]	2024	First Cuban TDS; 450 adults, 107 foods in 17 groups; national	118.5 µg/day (1.98 µg/kg bw/day)
China, Sixth TDS — Zhao et al. [7]	2022	National; 24 provinces, sampled 2016–2019	19.1 µg/day (0.318 µg/kg bw/day, adult male)
Brazil — Vasconcelos Neto et al. [9]	2021	National exposure assessment	91.8 µg/day (1.53 µg/kg bw/day)
Nigeria — Sub-Saharan Africa TDS, Ingenbleek et al. [10]	2020	Two centres (Lagos, Kano); foods prepared as consumed	57.6 µg/day (0.96 µg/kg bw/day)
Iran — Heshmati et al. [11]	2020	As compiled in Kinally et al.	67.0 µg/day (1.12 µg/kg bw/day)
Kanpur, India — Sharma et al. [12]	2005	City (subnational); adults and children; raw foods	114 µg/day adults; 50 µg/day children
Odisha, India — rice only [13]	2025	Single food; 12 rice samples, western Odisha	234 µg/day. Above Codex

A3. Results by study

Each estimate follows the method in Appendix H: intake converted to µg/day at 60 kg, multiplied by the JECFA adult intake-to-blood slope (lower 0.23, midpoint 0.465, upper 0.70 µg/L per µg/day) [14], and compared with the national headroom above 10 µg/L from IHME GBD 2023 [4]. Child values are shown for reference using the JECFA child range (0.5–1.0) and FDA (1.6) [15].

A3.1 Cuba — First Cuban Total Diet Study (published 2024)

Adult intake	118.5 µg/day (1.98 µg/kg bw/day), derived from the Kinally compilation
Child intake (7 y, 22.6 kg)	44.6 µg/day (adult per-kg rate applied)
BLL increase, adult (JECFA)	Lower 27.3 · Midpoint 55.1 · Upper 82.9 µg/L
BLL increase, child	JECFA 22.3–44.6 (midpoint 33.5) · FDA 71.4 µg/L. AALM in Kinally et al.: 42.8 µg/L
IHME 2023 baseline	80.6 µg/L (95% UI 50.6–119.6); population 11.3 million
Headroom	70.6 µg/L; available burden 798 million cpBLLs
Source burden	308 · 623 · 937 million cpBLLs
Share of available burden	39% · 78% · 118%

Summary: above 30% even at the most conservative reading. Cuba is a case where the TDS and the IHME baseline are mutually consistent and both high. Identifying which foods drive intake is the next step.

Worked calculations are in section G1 of Appendix G.

A3.2 China — Sixth TDS (2016–19, published 2022)

Adult intake, Sixth TDS	0.318 µg/kg bw/day (provincial range 0.103–0.746) = 19.1 µg/day [7]. Kinally et al. use 0.29.
Main contributors	Cereals 43.5%, vegetables 29.0%, beverages and water 9.8%
Child intake (7 y, 22.6 kg)	7.2 µg/day (adult per-kg rate applied)
BLL increase, adult (JECFA)	Lower 4.4 · Midpoint 8.9 · Upper 13.4 µg/L
BLL increase, child	JECFA 3.6–7.2 (midpoint 5.4) · FDA 11.5 µg/L. AALM in Kinally et al.: 6.3 µg/L
IHME 2023 baseline	42.5 µg/L (95% UI 14.6–86.6); population 1.43 billion
Headroom	32.5 µg/L; available burden 46,500 million cpBLLs
Source burden	6,300 · 12,700 · 19,100 million cpBLLs
Share of available burden	14% · 27% · 41%

For comparison, China's Third TDS, sampled in 2000, found intakes of 54.9–112.7 µg/day across ten age–sex groups, with cereals and vegetables supplying 72–80% of the total [8]. That is three to six times the 19.1 µg/day of the Sixth TDS. At the JECFA midpoint, the dietary BLL increment fell from 25.5–52.4 µg/L to 8.9 µg/L, a fall of 65–83%.

Measured against the burden of the time, diet's share has changed less than its absolute size: about 19–38% of the 2000 headroom at the JECFA midpoint (28% at the middle of the intake range), compared with 22–27% today, depending on the baseline year used. National blood lead fell in step with dietary intake. That is consistent with diet being a major driver of BLL throughout, and with China's pollution controls and phase-out of leaded petrol lowering both together.

Measure	Third TDS (2000)	Sixth TDS (2016–19)	Change
Dietary lead intake (2000: ten age–sex groups; 2016–19: adult men)	54.9–112.7 µg/day	19.1 µg/day	−65% to −83%

Measure	Third TDS (2000)	Sixth TDS (2016–19)	Change
BLL increase, JECFA midpoint	25.5–52.4 µg/L	8.9 µg/L	−65% to −83%
IHME mean BLL, all ages (contemporaneous)	147 µg/L (2000)	50 µg/L (2018); 42.5 µg/L (2023)	about −70%
Share of available burden, JECFA midpoint	19–38% (28% mid-range)	22% (2018 base); 27% (2023 base)	broadly stable

Summary: a meaningful target in the 10–30% band at the midpoint, reaching above 30% at the upper slope. Because China's population is so large, this is the largest absolute dietary burden of the studies here despite the lowest per-person intake. Provincial intakes vary sevenfold, so a provincial analysis would sharpen targeting. The Sixth TDS sampled adult men only. The 2000 comparison shows that national dietary lead can be cut substantially within two decades.

Worked calculations are in section G2 of Appendix G.

A3.3 Brazil — National Dietary Lead Exposure Assessment (published 2021)

Adult intake	1.53 µg/kg bw/day [9] = 91.8 µg/day; vegetables 53.7 µg/day and beverages 21.8 µg/day [5]
Child intake (7 y, 22.6 kg)	34.6 µg/day (adult per-kg rate applied)
BLL increase, adult (JECFA)	Lower 21.1 · Midpoint 42.7 · Upper 64.3 µg/L
BLL increase, child	JECFA 17.3–34.6 (midpoint 25.9) · FDA 55.3 µg/L. AALM in Kinally et al.: 33.1 µg/L
IHME 2023 baseline	34.9 µg/L (95% UI 8.9–63.6); population 212 million
Headroom	24.9 µg/L; available burden 5,280 million cpBLLs
Source burden	4,480 · 9,050 · 13,600 million cpBLLs
Share of available burden	85% · 171% · 258%

As with Odisha rice and Kanpur, the dietary estimate exceeds the whole available burden. The intake figure is not obviously the problem: an independent meta-analysis of lead in Brazilian food gives 1.59–1.83 µg/kg bw/day, slightly higher. That points to IHME understating Brazilian BLLs, the linear slopes overstating the BLL response at this intake, or both.

Summary: above 30% on every reading. Even if the true share were half the lower bound, diet would remain a high-priority target in Brazil.

Worked calculations are in section G3 of Appendix G.

A3.4 Nigeria — Sub-Saharan Africa Total Diet Study (published 2020)

Adult intake	0.96 µg/kg bw/day = 57.6 µg/day, Nigerian centres (Lagos and Kano) [10, 5]
Main sources	Cereals and tubers; children at the 95th percentile in Kano estimated to lose 8.8–13.3 IQ points
Child intake (7 y, 22.6 kg)	21.7 µg/day (adult per-kg rate applied)
BLL increase, adult (JECFA)	Lower 13.2 · Midpoint 26.8 · Upper 40.3 µg/L

BLL increase, child	JECFA 10.8–21.7 (midpoint 16.3) · FDA 34.7 µg/L. AALM in Kinally et al.: 20.8 µg/L
IHME 2023 baseline	56.1 µg/L (95% UI 35.0–99.8); population 245 million
Headroom	46.1 µg/L; available burden 11,300 million cpBLLs
Source burden	3,250 · 6,560 · 9,880 million cpBLLs
Share of available burden	29% · 58% · 87%

The Nigerian centres are an urban coastal city and a northern state, not a national sample. The study prepared foods as consumed, using inert utensils and distilled water, so cookware lead is excluded.

Summary: above 30% at the midpoint and close to it at the lower slope — a high-priority target. Sub-national variation, and which crops and sources drive it, should be investigated.

Worked calculations are in section G4 of Appendix G.

A3.5 Iran — Total Diet Study (published 2020)

Adult intake	1.12 µg/kg bw/day = 67.0 µg/day [11, 5]
Child intake (7 y, 22.6 kg)	25.2 µg/day (adult per-kg rate applied)
BLL increase, adult (JECFA)	Lower 15.4 · Midpoint 31.1 · Upper 46.9 µg/L
BLL increase, child	JECFA 12.6–25.2 (midpoint 18.9) · FDA 40.4 µg/L. AALM in Kinally et al.: 24.2 µg/L
IHME 2023 baseline	66.3 µg/L (95% UI 24.2–139.7), from the GBD 2023 file release Y2025M11D12 — to be confirmed against the current release
Headroom	56.3 µg/L
Share of available burden	27% · 55% · 83%

Summary: above 30% at the midpoint, just below it at the lowest slope.

Worked calculations are in section G5 of Appendix G.

A3.6 Kanpur, India — Dietary and Inhalation Intake Study (published 2005)

Adult intake	114 µg/day as published [12]; about 98 µg/day as compiled by Kinally et al.
Child intake	50 µg/day as published; 41.9 µg/day for a 7-year-old in Kinally et al.
BLL increase, adult (JECFA, 114 µg/day)	Lower 26.2 · Midpoint 53.0 · Upper 79.8 µg/L
BLL increase, child (50 µg/day)	JECFA 25–50 (midpoint 37.5) · FDA 80 µg/L. AALM in Kinally et al.: 40.2 µg/L
Baseline	ICMR pooled mean for Indian children, 104 µg/L [16] (headroom 94); IHME 2023 India all ages 60.4 µg/L (headroom 50.4)
Share of available burden	ICMR baseline: 28% · 56% · 85%. IHME baseline: 52% · 105% · 158%

Kanpur is a single industrial city studied two decades ago, before the full effect of unleaded petrol and with foods analyzed raw. It is the only Indian whole-diet study in the compilation and should be read as an indication of what an Indian TDS might find, not a current national estimate. The ICMR

baseline is used for the central estimate, as for Odisha, because the IHME baseline makes diet exceed the whole burden at the midpoint.

Summary: above 30% at the midpoint on either baseline. The finding underlines the case for a national Indian TDS.

Worked calculations are in section G6 of Appendix G.

A3.7 Lead in rice, Odisha, India (single-food example)

This example, first published in the August guidance [1], applies the method to a single staple rather than the whole diet. Odisha combines among the highest rice consumption of any Indian state, published field measurements of lead in locally grown rice, and a large, mostly rural population eating rice grown where they live. It would need further study to validate; treat it as an illustration of the method, not as definitive.

Population of Odisha (2026)	47.2 million (Census 2011: 41.97 million, 83.3% rural; projection for 2026) [17]
Mean BLL used	104 µg/L — ICMR pooled mean for Indian children aged ≤14 years, 95% CI 95.5–112 µg/L, 51 studies [16]; used as a proxy for all ages
Headroom and available burden	94 µg/L; 4,437 million cpBLLs
Lead in rice, western Odisha	0.98 mg/kg = 980 µg/kg (n=12; Sambalpur, Bargarh and Subarnapur) [13]
Rice consumption	0.30 kg per person per day, from all-India rural per capita cereal consumption of 9.4 kg/month [18]
Daily lead from rice	294 µg/day; Codex-compliant counterfactual 60 µg/day [19]; attributable increment 234 µg/day
BLL increase, JECFA adult range	Lower 53.8 · Midpoint 108.8 · Upper 163.8 µg/L
Affected population	Rural Odisha ≈ 83% × 47.2 million = 39.2 million, taken as those eating locally grown rice
Source burden	2,109 · 4,265 · 6,421 million cpBLLs
Share of available burden	48% · 96% · 145%

Measuring the increment above a Codex-compliant baseline may be contentious: compliant food eaten in ordinary quantities can itself raise BLLs substantially, and Codex levels clearly need revisiting. Excluding the Codex counterfactual would make the result higher still.

Running the AALM [20] for 234 µg/day in food gives an average BLL of about 100 µg/L, with adults higher than children — at the Indian average and at the JECFA midpoint. That would imply rice is responsible for all lead exposure in Odisha, which is unlikely given leafy vegetables and consumer goods are also known sources. The likely culprit is sparse data: 12 samples cannot characterise a state, and results are dry weight (husked grain, oven-dried at 60 °C).

Summary: above 30% even at the lowest slope — an extremely high-priority target, and most likely the largest single source of lead poisoning in the state. The result is indicative only. The next question is how lead gets into rice and whether it can be stopped.

Worked calculations are in section G7 of Appendix G.

A4. Diet results compared

Study	Year	Adult intake (µg/day)	BLL increase, JECFA mid (µg/L)	Baseline (µg/L)	Share of available burden (range)	Band
Cuba	2024	118.5	55.1	80.6	78% (39–118%)	Above 30%
China	2022	19.1	8.9	42.5	27% (14–41%)	10–30%
China	2000	54.9–112.7	25.5–52.4	147 (2000)	48% (38–72%)	Above 30%
Brazil	2021	91.8	42.7	34.9	171% (85–258%)	Above 30%; exceeds baseline
Nigeria	2020	57.6	26.8	56.1	58% (29–87%)	Above 30%
Iran	2020	67.0	31.1	66.3	55% (27–83%)	Above 30%
Kanpur, India	2005	114	53.0	104 (ICMR)	56% (28–85%)	Above 30%
Odisha rice	2025	234 (rice only)	108.8	104 (ICMR)	96% (48–145%)	Above 30%

Three patterns stand out. First, wherever a recent LMIC TDS exists, diet is a large share of the burden — consistent with the 40–50% pooled estimate in Kinally et al. Second, several estimates reach or exceed 100% of the baseline at the upper slope which implies data quality issues. IHME's national estimates may be lacking, relying on projections where representative baseline studies have not been done. TDS data can also be inadequate and non-representative. In addition, the linear JECFA slopes will overstate BLL response at high intakes. All these issues can lead to significant uncertainties; all requiring better data. But most importantly, the countries carrying the largest share of the global lead burden — India, Pakistan, Bangladesh and Indonesia — have no recent national TDS, so the most important estimates cannot yet be made.

As the single-source guidance notes, a large share does not by itself make a source investable. Sizing the dietary pathway says nothing about where the lead in food comes from — atmospheric deposition from smelters and battery recyclers, soil, irrigation water, or processing — and the intervention depends on that answer. The investment should be proportional to the benefit, with investments that can achieve the largest reduction in cpBLLs prioritized. China's experience between its 2000 and 2016–19 studies show that national dietary lead can fall substantially once those sources are controlled.

Appendix B: Food — Lead-Adulterated Turmeric in India

Turmeric is adulterated with lead chromate to brighten its color. Market surveys across South Asia have found lead above 1,000 µg/g in turmeric from Patna, Bihar [21], and household testing in Bihar found spice lead significantly associated with elevated child BLL (adjusted odds ratio 1.35 for each doubling) [22]. Unlike staple foods, spice adulteration is deliberate, traceable to a few supply chains, and has been stopped quickly elsewhere — Bangladesh cut turmeric adulteration sharply within a few years [57].

B1. Source data

A study of turmeric adulteration across five eastern Indian states [55] collected 503 turmeric samples from 34 cities in 2021–2023 and interviewed 128 people along the supply chain. Thirty percent of samples exceeded India's 10 µg/g limit, with the highest levels in Bihar (geometric mean 48 µg/g, maximum 6,416 µg/g). Lead chromate is added mainly to brighten the color of turmeric roots and to hide insect damage after long storage.

The authors model a young child aged 2 to 3 eating turmeric at Bihar's typical lead level every day: the geometric mean for turmeric powder, 51 µg/g, compared with turmeric below the limit. They assume about 0.7 g of turmeric a day and 43% bioaccessibility. Three models give a blood lead increase of 7.7–38.0 µg/L using either a simple intake slope (0.52 µg/L per µg/day), the AALM or the IEUBK. Because the input is a statewide average concentration, the increase applies to every young child, not only those in households holding heavily adulterated turmeric.

The paper frames children's ages in three ways: the exposure model uses a child of 2–3 years, the population comes from the 2011 Census count of 18.6 million children aged 0–6 in Bihar, and the economic estimate uses a child aged 3. Following the paper, the burden here is framed on a single birth cohort, like the eyeliner analysis in Appendix D. The 18.6 million children aged 0–6 imply a cohort of about 2.7 million. Mean child blood lead is 76 µg/L, from a statewide Bihar study cited by the authors.

The 0.7 g a day intake — about a quarter of a teaspoon — comes from national household spending survey data [21] and is plausible. In Bihar, turmeric goes into dal, vegetable dishes and khichdi, the main weaning food, at most meals. A 2-year-old eats roughly 5–9% of a six-person household's food, so across two or three turmeric-spiced dishes a day a toddler plausibly takes 0.3–0.8 g, with 0.7 g toward the upper end. Turmeric milk, a common home remedy for children's colds, can add a larger dose on the days it is given.

B2. Birth-cohort estimate for Bihar

Birth cohort, Bihar	2.7 million (from 18.6 million children aged 0–6, Census 2011)
Mean child BLL	76 µg/L; headroom 66 µg/L
Available cohort burden	178 million cpBLLs
Turmeric lead, Bihar powder	51 µg/g geometric mean; about 0.7 g/day per child; 43% bioaccessible
BLL increase from turmeric	7.7–38.0 µg/L, applied to every child in the cohort
Turmeric burden	21–103 million cpBLLs

Share of available cohort burden	12–58% (9–42% on the IHME under-20 Bihar baseline of 99.6 µg/L; 10–48% on the ICMR Bihar mean of 89.9 µg/L)

The authors estimate that ending adulteration would gain 0.3–2.3 IQ points per child, worth US$ 239 million to 1.6 billion a year in future earnings in Bihar alone, rising by a further US$ 430 million to 2.8 billion a year if reductions in cardiovascular deaths are included.

Summary: 12–58% of the available burden among Bihar's youngest children — the 10–30% band at the lower end of the model range and above 30% at the upper end. Even on the higher IHME and ICMR baselines the share stays above 8%. The youngest children are both the most exposed and the most vulnerable, and turmeric adulteration is a supply-chain and enforcement problem with precedent for rapid resolution, as in Bangladesh. This makes it a high-priority, low-cost target.

Worked calculations are in section G8 of Appendix G.

Appendix C: Cookware — Lead-Glazed Ceramics and Aluminum

Most total diet studies prepare food in a laboratory with stainless steel or glass, deliberately excluding lead that migrates from household pots. Of the 14 LMIC TDS compiled by Kinally et al., eight did not describe preparation in enough detail to rule cookware in or out, but the working assumption is that laboratory preparation excludes it. Lead from cookware is therefore largely additive to the dietary burden in Appendix A, not part of it.

Two kinds of cookware matter most in LMICs: artisanal aluminum pots cast from mixed scrap, and traditional lead-glazed ceramics. The evidence for each is very different. For lead-glazed ceramics there are measured blood lead differences between users and non-users. For aluminum there are none yet; every blood lead estimate is modeled from leaching tests.

C1. Lead-glazed ceramics in Mexico

Low-fired traditional pottery glazed with lead oxide releases lead into food, especially acidic dishes, stews and anything stored in the pot. The best evidence comes from Mexico, where barro vidriado is still widely used, but contaminated ceramics are not confined to Mexico or to artisanal ware: in a 25-country market screen, 45% of 308 ceramic foodware samples exceeded 100 ppm lead, including mass-produced pieces [23].

Evidence on blood lead increase

Study	Setting and sample	Use prevalence	Blood lead finding
Farías et al. 2014 [24]	Schoolchildren, Morelos	≈48% of households	Users 79.8 vs non-users 65.8 µg/L: +14 µg/L for cooking; +23.9 µg/L where food was stored in the ware.
Terrazas-Meraz et al. 2015 [25]	387 indigenous schoolchildren	82%	Medians 145 vs 61 µg/L; adjusted difference +39 µg/L (52% higher).
Pantic et al. 2018 [26]	1,963 mother–child pairs, five Mexico City cohorts 1988–2015	36% overall (23–47% by cohort)	Use associated with 11% higher child BLL, consistent across the whole period even as leaded petrol was phased out.
Téllez-Rojo et al. 2019 [27]	1,431 children aged 1–4, national survey of localities under 100,000	34.5% in past 3 months; 17.9% at least weekly	Elevated BLL (≥50 µg/L) in 40.8% of users vs 11.9% of non-users; frequent use RRR 8.06 (95% CI 3.02–21.49).
Hernández-Avila et al. 1991 [28]	99 women, Mexico City	70% (69 of 99)	Dose–response with frequency of eating LGC-prepared food; 58% of elevated BLLs attributable to LGC.
Cantoral et al. 2026 [29]; Betanzos-Robledo et al. 2026 [30]	Mexico	—	Increase of 16 µg/L associated with lead-glazed ceramic use; used in GRIT's primary estimate.

Taken together, use of lead-glazed ware raises BLL by roughly 14–39 µg/L in rural and peri-urban Mexico, less in urban Mexico City where use is lighter. Storage and frequent use move results toward the upper end.

GRIT's primary estimate takes the narrower, better-defined group of weekly users — 18% of Mexicans, about 24 million people — and a 16 µg/L increase. That gives 380 million cpBLLs, or 5.4% of Mexico's 7.1 billion available cpBLLs. Broader definitions of use (any use in the past three months) and larger increments increase the share to 12–25%.

Summary: The primary estimate (5.4%) lead-glazed ceramics in Mexico is in the 5–10% band, rising into the 10–30% band under broader use definitions — a meaningful target with a known, viable intervention (lead-free glazes, which Mexico has promoted for decades). Because the national survey covered only localities under 100,000, applying its use rate nationally may overstate prevalence.

Worked calculations are in section G9 of Appendix G.

C2. Artisanal aluminum cookware in Cameroon

Aluminum pots cast by small foundries from scrap — engine parts, radiators, cans, cable — are the everyday cooking pot for lower-income households across much of sub-Saharan Africa and South and Southeast Asia. Product testing consistently finds high lead; what is missing is any measured blood lead difference between users and non-users in an LMIC.

Evidence on lead content and leaching

Study	Sample	Finding
Weidenhamer et al. 2014 [31]	29 pots, Cameroon	Lead leached under simulated cooking; a typical serving exceeded California's 0.5 µg/day MADL roughly 200-fold. Artisanal pots described as the most commonly used in Cameroon.
Weidenhamer et al. 2017 [32]	42 items, 10 countries	15 items released ≥1 µg lead per 250 mL serving; one Vietnamese pot released over 1,000 µg per serving in repeat tests.
Weidenhamer et al. 2023 [33]	Pots cast from seven scrap streams, Ghana	Engine-block pots released no detectable lead; mixed-metal pots averaged about 37 times FDA's child reference level (3 µg a day) per serving, and the worst serving was 139 times.
Fellows et al. 2022 [34]	40 pots, US (15 from Afghan refugee families, 25 bought new)	23 of 40 exceeded the FDA child IRL; all 15 donated family pots did; one pressure cooker 650-fold after 24 hours of storage.
Sargsyan et al. 2024 [23]	520 metal foodware items, 25 LMICs	51% above 100 ppm lead; 69% of contaminated items were pots and pans, and 57% were aluminum.
Binkhorst et al. 2025 [35]	113 aluminum pots, 25 LMICs	Total lead averaged 1,600 ppm; only 22% below 100 ppm. Leachate averaged 100 µg/L (4% acetic acid, 2 h boil); about 10% exceeded 250 µg/L.
Nash et al. 2025 [22]	150 children, eight districts of Bihar	95% of homes had metal foodware above 100 ppm, but foodware lead was not significantly associated with child BLL (aOR 1.09, 95% CI 0.88–1.36). Spices were (aOR 1.35).

The Nash study in Bihar is the only study that tested cookware against measured blood lead in an LMIC household survey, and it did not find an effect. That does not rule one out, but it argues against the higher modeled estimates. The leaching tests also overstate real exposure: 4% acetic acid boiled for two hours is far more aggressive than rice, maize, cassava or millet cooked in near-neutral water.

Converting leachate to a BLL increase therefore needs several assumptions: how much food is cooked in the pot, how much less real food leaches than acid [36], and how many people use high-lead pots. Users of high-lead pots are taken to gain 10, 15 or 35 µg/L; applied to Cameroon with 50–90% of people using such pots, this gives 4.5%, 9% and 28% of available burden.

Summary: artisanal aluminum cookware falls in the 5–10% band at the central estimate, with a range from below 5% to near 30%. The width of that range comes almost entirely from not knowing the real-world BLL increase. A single well-designed user/non-user comparison, or a switch-out trial replacing aluminum with stainless steel and measuring BLL before and after, would sort out this uncertainty and is the next step.

Worked calculations are in section G10 of Appendix G.

C3. Cookware compared

Cookware	Basis of BLL estimate	BLL increase in users (µg/L)	Use prevalence	Share of available burden	Band (central)
Lead-glazed ceramics (Mexico)	Measured, six studies; one modeled	14–39 (16 primary)	18–35%	5.4% (5–25%)	5–10%
Artisanal aluminum (Cameroon)	Modeled from leaching; one null BLL study	10–35	50–90%	9% (4.5–28%)	5–10%

Appendix D: Use of Kohl and Eyeliners

Leaded Eyeliner in Infants

Traditional eye cosmetics — kohl, surma, kajal — can contain very high levels of lead and are often applied to newborns and infants. A study presented at the 2026 CGD lead conference in London [37], examined birth cohorts, so the analysis is framed on live births rather than the whole population.

The available burden is therefore the birth cohort's: live births × (infant mean BLL − 10 µg/L), using IHME estimates for infants. Shares in this appendix are of that infant burden, not the national total.

Country	All-ages BLL (µg/L)	Infant BLL (µg/L)	Infant headroom (µg/L)	Live births (million)	Available infant burden (million cpBLLs)	Eyeliner burden (million cpBLLs) and share
Morocco	49	34	24	0.5	12	0.1–0.4 (0.8–3.3%)
Egypt	104	76	66	2.1	139	1.1–3.0 (0.8–2.2%)
Pakistan	146	116	106	5.92	627	4.2–10.6 (0.7–1.7%)

Averaged across all newborns, users and non-users alike, eyeliner adds roughly 0.2–0.8 µg/L in Morocco, 0.5–1.4 µg/L in Egypt and 0.7–1.8 µg/L in Pakistan.

Summary: under 5% of the infant burden in all three countries — a small, proportionate share of resources at population scale. Leaded eyeliner can still cause severe poisoning in individual infants, and product bans are cheap, so it may remain worth acting on where the intervention is simple.

Worked calculations are in section G11 of Appendix G.

Kohl Use in Adult Women — Iraq

This analysis covers adult women, using the one study found that compares blood lead in adult users and non-users within the same sample [57].

I1. Source data

Al Naama et al. measured blood lead in 602 people aged 9–79 attending 17 primary health centers in central Basrah between July and December 2002 [57]. Kohl use was recorded for women only.

Measure	Finding
Sample	602 primary health center attendees, central Basrah, 2002; 382 women
Kohl users	98 of 382 women (25.6%)
Mean BLL, kohl users	139.1 µg/L
Mean BLL, women not using kohl	98.8 µg/L

Measure	Finding
Difference	+40.3 µg/L ($p < 0.0001$; unadjusted)
Other findings	Men 132.5 vs women 101.0 µg/L; occupational exposure 153.0 vs 111.2 µg/L; smokers 138.1 vs 109.3 µg/L; paint exposure not significant

Strengths. One of very few studies to measure BLL in adult kohl users against non-users in the same sample. The kohl group is reasonably large, and the difference is large and consistent in direction with case reports and studies in children.

Weaknesses. The comparison is unadjusted, so smoking, occupation, age and residence could confound it. Participants were clinic attendees, not a population sample. The lead content of the kohl was not measured, and frequency and duration of use were not recorded. The setting was high-exposure: the study mean of 112.6 µg/L is well above IHME's estimate for Iraqi women in 2002 (66.5 µg/L), and Iraq was among the last countries to phase out leaded petrol.

I2. Burden estimate for women 15+

The baseline is IHME GBD 2023 for Iraq [4]. Nationally, 44.18 million people at a mean of 43.7 µg/L give an available burden of 1,488 million cpBLLs. Women aged 15 and over number 14.27 million at a mean of 47.4 µg/L, an available burden of 534 million cpBLLs. Kohl burden is the number of women using kohl × the BLL increase from kohl. Two prevalences (10% and the study's 25.6%) are crossed with two increases (a cautious 20 µg/L and the study's 40.3 µg/L).

Prevalence	BLL increase (µg/L)	Users (million)	Kohl burden (million cpBLLs)	Share of women 15+ burden	Share of national burden
10%	20	1.43	28.5	5.3%	1.9%
10%	40.3	1.43	57.5	10.8%	3.9%
25.6%	20	3.65	73.1	13.7%	4.9%
25.6%	40.3	3.65	147.2	27.6%	9.9%

The 20 µg/L rows allow for confounding and for the fall in general exposure in Iraq since 2002. Children and infants who are also given kohl are not counted here; Appendix D treats them separately on a birth-cohort basis, so the two should not be added.

Summary: a meaningful target in the 10–30% band among adult women at the central readings (14–28%), falling to about 5% at the low reading; about 2–10% of Iraq's national burden. The 28% figure is an upper bound, because it assumes the 2002 Basrah prevalence and effect still hold. Current prevalence of use and the lead content of kohl sold in Iraq are the two data gaps; a market product survey with a short use survey would firm up both more cheaply than a new blood lead study.

Worked calculations are in section G13 of Appendix G.

Appendix E: Lead Paint in Homes in India

Lead paint is a different kind of source from food or cookware. It reaches children mainly through household dust: peeling, flaking and chipping paint, and friction at doors and windows, generate lead-bearing dust and fragments that young children ingest through ordinary hand-to-mouth activity. Exposure depends on the paint's lead content, how much of it is deteriorating, cleaning, nutrition and time spent at home — and dust lead can also come from soil, industry and other sources.

India set a 90 ppm limit for household and decorative paints, effective 2017 [38]. That restricts new paint; it does nothing about legacy paint already on walls.

This modeled analysis was assisted by Claude Opus 5.5 in mid-October 2026. It is not based on field measurements. Comments and edits are welcomed. We also note that interventions to mitigate lead in paint have been modeled to be enormously cost effective.

Evidence on blood lead increase

There is no measured average BLL increase from "crumbling paint" in India, or anywhere, that can be applied directly. The relationship is better described through dust:

- **US NHANES 1999–2004.** Dixon et al. analyzed 2,155 children aged 12–60 months. Population-weighted geometric mean BLL was 20 µg/L; for children in pre-1978 homes with floor dust lead of 12 µg/ft², the model predicted a geometric mean of 39 µg/L, with 27% above 50 µg/L. These are modeled total BLLs, not paint-attributable increments [39].
- **Pooled dust and soil studies.** Lanphear et al. pooled 12 epidemiologic studies linking household dust and residential soil lead to children's BLLs; Gaitens et al. examined housing determinants of dust lead [40, 41]. Together they support modeling paint exposure through measured dust rather than assigning one effect to every painted home.
- **Renovation and remediation.** Interior renovation has been associated with roughly 12% higher mean BLL, and 17% where renovation occurred in the past month — about 6 µg/L at a 50 µg/L baseline. Remediation studies in previously poisoned children report subsequent declines, but in selected populations [42, 43, 44].

Evidence from India

Study	Finding
Toxics Link and IPEN 2025 [45]	51 solvent-based decorative paints bought February–May 2023: 90% above 90 ppm, 76% above 10,000 ppm. Selected products and smaller brands, so not a household prevalence.
Historical paint survey 2013 [46]	148 paints tested; 45% above 90 ppm.
Nash et al. 2025, Bihar [22]	Detectable lead in at least one paint reading in nearly 80% of households measured; about 4% exceeded 500 µg/cm² and one exceeded 1,000 µg/cm². Establishes lead on surfaces, not deterioration or dust release; not a national sample.
Delhi homes, 2009 [47]	33 homes (99 floor samples): geometric mean floor dust lead 19.7 µg/ft², windowsill 75.5 µg/ft². Shows a dust pathway.
Census 2011 housing condition [48]	41.5% of homes "livable", 5.35% "dilapidated". Too broad to combine with paint testing without joint data.
Nagpur and Delhi BLL studies [49, 50]	Lead-painted housing or peeling paint associated with elevated child BLL; associations and odds ratios, not an attributable increment.

Illustrative increments and exposure scenarios

The blood lead increase is taken from LEEP's cost-effectiveness model of its paint programs [56], which estimates that growing up in a home with lead paint raises a child's BLL by 17 µg/L on average (intuitive 90% range 7–30 µg/L). The central figure is the median of three US abatement-based estimates (Dixon dust–BLL modeling and the HUD hazard-control program); the lower bound comes from the HOME randomized trial and the upper from combined dust and soil estimates in the American Healthy Homes Survey. Exposure is therefore defined as living in a lead-painted home, not only a visibly deteriorated one. The increase is likely to be higher where paint is more leaded or more deteriorated, as the indicative ranges below suggest:

Housing condition	Assumed attributable increase (µg/L)
Intact lead paint	0–5
Some deteriorated or peeling lead paint	10–20
Substantial deterioration with contaminated dust	20–50
Severe deterioration or paint-chip ingestion	50–200+

Exposure prevalence is not measured, but modeled: 2% (low), 5% (central) and 10% (high) of India's roughly 115 million children under five [51], or 2.3, 5.75 and 11.5 million children. LEEP's market-based approach offers a check. About 43% of Indian homes would count as painted (75% of urban and 25% of rural homes, with roughly 35% of people urban). If 80% of newly painted homes use colored solvent-based paint, as LEEP assumes, and 10–40% of that paint is leaded, then 3–14% of children live in lead-painted homes.

Exposed population	Children 0–4 only: 2.3 · 5.75 · 11.5 million (2% · 5% · 10%)
BLL increase in exposed children	17 µg/L (LEEP; range 7–30 µg/L)
IHME 2023 baseline, India	60.4 µg/L all ages (95% UI 23.5–108.4); population 1.44 billion; available burden 72,600 million cpBLLs
Source burden	39 · 98 · 196 million cpBLLs
Share of national available burden	0.05% · 0.13% · 0.27%
Share of under-five available burden	0.4% · 0.9% · 1.8% (using the ICMR pooled child mean of 104 µg/L [16])

Summary: under 5% on every scenario tested, at national or under-five scale. Even the most pessimistic combination — 15% of under-fives at LEEP's upper 30 µg/L — reaches about 4.8% of the under-five burden and 0.7% nationally. But given the uncertainties in this model, that conclusion should be held loosely. LEEP's increment comes from US homes with mostly intact paint and well-nourished children; Indian paint is often far more leaded and more deteriorated, which argues toward the upper end. India-specific joint measurements — paint lead, paint condition, floor dust lead and children's venous BLL in the same homes — are needed before paint can be ranked with confidence.

Worked calculations are in section G12 of Appendix G.

Appendix J: Secondhand Tobacco Smoke — US Children

Tobacco smoke carries lead, both inhaled directly and deposited in household dust. This appendix is the document's first high-income example. It uses a nationally representative US analysis of secondhand smoke (SHS) and blood lead in children [59], and it raises a method question the LMIC examples have not: what to do when the exposed population is already below the 10 µg/L floor.

J1. Source data

Obeng et al. analyzed 2,815 non-smoking children and adolescents aged 6–19 in NHANES 2015–2018 [58]. SHS exposure was measured by serum cotinine; anyone above 10 ng/mL was excluded as an active smoker. Geometric mean BLLs were adjusted for age, sex, race/ethnicity, central obesity, household education and income.

Serum cotinine group	Weighted share	Adjusted geometric mean BLL (µg/L)	Increase over low group
Low (< 0.03 ng/mL)	44.3%	4.1 (3.8–4.3)	—
Intermediate (0.03–3 ng/mL)	52.3%	4.8 (4.5–5.1)	+0.7 µg/L (+18%)
Heavy (> 3 ng/mL)	3.4%	5.2 (4.6–5.9)	+1.1 µg/L (+29%)

Strengths. Nationally representative and survey-weighted; exposure measured by biomarker and a significant dose–response (p-trend < 0.001).

Weaknesses. No adjustment for housing age or paint condition — the obvious confounder, since smoking is concentrated in poorer households that are more likely to have deteriorating lead paint. The intermediate group spans trace to substantial exposure and covers half of all children. The overall association is weak ($R^2 = 0.11$), the design is cross-sectional, and children under 6 are excluded because their cotinine was not measured.

J2. Burden estimate

The baseline is IHME GBD 2023 [4]. The US population of 346.3 million at a mean of 13.5 µg/L gives an available burden of 1,215 million cpBLLs. Children aged 6–19 number about 59.3 million, at IHME means of 10.2 µg/L (ages 5–9), 9.1 µg/L (10–14) and 8.7 µg/L (15–19) — about 9.3 µg/L overall. The SHS burden is calculated two ways: with the paper's geometric-mean increases as measured (a lower bound), and with its percentage increases applied to IHME's arithmetic means (an upper bound).

Scenario	SHS burden (million cpBLLs)	Share of US available burden
Lower bound halved (half the effect is confounding)	12	1.0%
Paper's increases as measured (0.40 µg/L per child)	24	2.0%
Upper bound halved	26	2.1%
Percentage increases on IHME means (0.87 µg/L per child)	52	4.3%

On either reading, SHS accounts for about 9% of these children's average blood lead.

The floor problem. Because US children aged 6–19 average about 9.3 µg/L, their own available burden above the 10 µg/L floor is close to zero. Applied strictly, the method credits SHS — and nearly every other source in this age group — with no burden at all. The shares above count SHS lead against the national available burden even though it sits below the floor. For high-income countries, a share of total BLL (about 9% here) may be the more informative measure.

Summary: under 5% of the US available burden (1–4%, central 2–4%), a small, proportionate share of resources at population scale. The estimate is likely inflated by confounding with old housing, and US SHS exposure has continued to fall since 2015–2018. Smoke-free homes are already justified on other health grounds; lead adds a modest further reason.

Worked calculations are in section G14 of Appendix G.

Appendix F: Assumptions, and What Would Change the Answer

Diet (total diet studies)

Intake values. Cuban, Nigerian and Iranian intakes are derived from the 7-year-old values in the Kinally compilation. Kanpur uses Sharma et al.'s published 114 µg/day; Kinally's compiled value is about 98 µg/day. China's 2000 intakes are the reported range across age–sex groups, not a single adult-male value.

Adult rates applied to children. Most studies report adult intake only. Where both are measured, child intake per kg is consistently higher, by more than double in some studies (2.3 times in Bangladesh), so child figures are underestimates.

Conversion slopes. JECFA slopes are linear and were fitted at 100–250 µg/L. At high intakes (Cuba, Brazil, Kanpur, Odisha) they likely overstate the BLL response; for adults they ignore cumulative exposure, which the AALM captures. FDA's 0.4 µg/L factor applies to women of childbearing age and is not used for the population burden.

Baseline BLLs. IHME 2023 all-ages national means, with wide uncertainty intervals. A higher true baseline lowers the dietary share; a lower one raises it. Iran's baseline and the China 2000 and 2018 comparison values come from an earlier file release (Y2025M11D12) and should be confirmed against the current release. India uses the ICMR pooled child mean where noted.

Whole-population exposure. Diet is treated as reaching everyone at the national mean intake. In reality, intake is skewed and the highest-exposed groups carry a disproportionate share. Nigeria and Kanpur are subnational samples applied to national or state baselines.

Timing. TDS sampling years (2000–2020) are compared with 2023 baselines except in the China comparison; any trend in food lead since sampling is ignored. This matters most for Kanpur (2005).

Overlap with other sources. Food can carry lead from spices, cookware or processing. The burden here is for the dietary pathway as measured and may overlap with burden assigned to those sources in other GRIT analyses.

Lead in rice, Odisha

Concentration. The figure rests on 12 samples from three western districts, themselves in range of battery recyclers. The national mean for Indian wheat and rice is 0.12 mg/kg, about eight times lower, which is itself a reason to want state-representative sampling.

Standards context. At 0.98 mg/kg, Odisha rice is about five times India's FSSAI cereal limit (0.2 mg/kg [52]), the Codex lead ML for cereal grains (0.2 mg/kg) and China's grain limit (0.2 mg/kg [53]). It is not compliant with any lead standard that applies to it.

Consumption. 0.30 kg/day is all-India rural per capita total cereal consumption, used as a proxy for rice; conservative for Odisha, but a state-specific figure from HCES unit-level data would be better.

Baseline BLL. No Odisha-specific pooled BLL exists; the national ICMR figure for children under 14 is used for everyone. A higher state baseline would raise available burden and lower the share.

Where the lead comes from. The only lead-isotope study of Indian foodstuffs attributed 68.5–86.7% of food lead to atmospheric deposition rather than soil [54]. If confirmed for staple crops, intervention would point to industrial air-emission control rather than soil remediation.

Spices

Source figures. The Bihar estimate is a high-quality peer-reviewed study [55]. Its blood lead increase spans a fivefold range (7.7–38.0 µg/L) across three models, which is the largest single uncertainty.

Intake and concentration. The study assumes about 0.7 g of turmeric a day per child, not taken from a dietary survey of Bihari children; a household check gives 0.3–0.8 g. Applying a geometric-mean concentration to every child understates the effect of heavily adulterated batches, while episodic purchasing may overstate continuous exposure.

Population. The 2.7 million cohort is derived from the 2011 Census, and the 76 µg/L baseline from a single statewide study. Older children and adults also eat turmeric but are not counted, so the absolute burden across all ages would be larger.

Cookware

Cookware evidence. The ceramics estimate depends on measured BLL differences, mostly from Mexico, where prevalence comes from a survey of small localities. The aluminum estimate rests on acid leaching tests, an assumed 0.75 kg/day of food cooked per person, an assumed 60–70% reduction for neutral foods from acetic acid tests, and a prevalence range inferred from market screening rather than household surveys. The only measured LMIC test (Bihar) was null.

Diet and cookware overlap. Treated as additive because TDS foods are generally prepared in the laboratory. Where a TDS cooked food in local household pots, part of the cookware burden is already inside the dietary estimate.

Leaded eyeliner

Method detail. The underlying prevalence of use and per-user increment are not reproduced in the source notes and should be added before the estimates are used formally. Shares are of the birth cohort's available burden, not the national total; mothers and older children who also use eyeliner are not counted.

Paint

Increment. The 17 µg/L central value (7–30 µg/L) is LEEP's estimate from US abatement and housing studies [56], not a measured effect in India. The US homes had mostly intact pre-1978 paint averaging 1.73 mg/cm² and well-nourished children; Indian paint is often far more leaded (76% of tested samples above 10,000 ppm) and more deteriorated, so the true increase may be higher. US dust–BLL models do not transfer directly to Indian age structure, nutrition, housing and dust.

Prevalence. No national survey measures the share of under-fives living with sufficiently leaded and deteriorated paint. Product tests describe paints sold, not homes; Bihar surface readings describe paint present, not deteriorating;

Attribution. Comparing children in dusty older homes with the general population cannot isolate paint from soil, industrial and other dust sources. Any paint increment must be integrated with background BLL and other sources to avoid double counting.

Kohl (Iraq)

Prevalence. The 25.6% comes from one city's clinic sample in 2002. Kohl use varies widely by region and generation, and no national figure exists; 10% is used as a low case.

Increment. The 40.3 µg/L difference is unadjusted and was measured against a 2002 baseline about twice today's. Kohl is a direct exposure, so its increment need not fall with the general baseline, but the lead content of current products is unknown. 20 µg/L is used as a cautious case. The increase is assumed to add to the average BLL.

Population. Only women 15+ are counted. Infants and children given kohl are covered by the birth-cohort approach in Appendix D and should not be added to this estimate.

Secondhand smoke (US)

Confounding. The paper did not adjust for housing age or paint, so part of the SHS association is likely lead paint. Halved scenarios allow for this.

Geometric and arithmetic means. The paper reports geometric means; IHME reports arithmetic means. Applying the paper's absolute increases gives the lower bound and its percentage increases the upper.

The floor. US children 6–19 are below 10 µg/L, so their own available burden is about zero. Shares are of the national available burden, and the share of children's BLL (about 9%) is reported alongside.

Timing and scope. Exposure data are from 2015–2018; SHS exposure has fallen since. Non-smoking adults exposed to SHS, children under 6, and active teen smokers are not counted.

Appendix G: Worked Calculations

Each calculation follows the same pattern: BLL increase per person × people affected, compared with population × (mean BLL − 10 µg/L). Sections are listed in the order the estimates appear in Appendices A–E.

G1. Food — Cuba total diet study

Worked logic: Cuba

Intake: 44.6 µg/day ÷ 22.6 kg = 1.98 µg/kg bw/day; × 60 kg = 118.5 µg/day.

BLL increase: 0.23 × 118.5 = 27.3; 0.465 × 118.5 = 55.1; 0.70 × 118.5 = 82.9 µg/L.

Headroom: 80.6 − 10 = 70.6 µg/L. Available burden: 11.3 million × 70.6 = 798 million cpBLLs.

Share: 27.3 ÷ 70.6 = 39%; 55.1 ÷ 70.6 = 78%; 82.9 ÷ 70.6 = 118%.

G2. Food — China total diet study

Worked logic: China, Sixth TDS

Intake: 0.318 µg/kg bw/day × 60 kg = 19.1 µg/day.

BLL increase: 0.23 × 19.1 = 4.4; 0.465 × 19.1 = 8.9; 0.70 × 19.1 = 13.4 µg/L.

Headroom: 42.5 − 10 = 32.5 µg/L. Available burden: 1.43 billion × 32.5 = 46,500 million cpBLLs.

Share: 4.4 ÷ 32.5 = 14%; 8.9 ÷ 32.5 = 27%; 13.4 ÷ 32.5 = 41%. Burden at midpoint: 1.43 billion × 8.9 = 12,700 million cpBLLs.

G3. Food — Brazil

Worked logic: Brazil

Intake: 1.53 × 60 = 91.8 µg/day. BLL increase: 0.23 × 91.8 = 21.1; 0.465 × 91.8 = 42.7; 0.70 × 91.8 = 64.3 µg/L.

Headroom: 34.9 − 10 = 24.9 µg/L. Available burden: 212 million × 24.9 = 5,280 million cpBLLs.

Share: 21.1 ÷ 24.9 = 85%; 42.7 ÷ 24.9 = 171%; 64.3 ÷ 24.9 = 258%.

G4. Food — Nigeria total diet study

Worked logic: Nigeria

Intake: 21.7 µg/day ÷ 22.6 kg = 0.96 µg/kg bw/day; × 60 kg = 57.6 µg/day.

BLL increase: 0.23 × 57.6 = 13.2; 0.465 × 57.6 = 26.8; 0.70 × 57.6 = 40.3 µg/L.

Headroom: 56.1 − 10 = 46.1 µg/L. Available burden: 245 million × 46.1 = 11,300 million cpBLLs.

Share: 13.2 ÷ 46.1 = 29%; 26.8 ÷ 46.1 = 58%; 40.3 ÷ 46.1 = 87%.

G5. Food — Iran total diet study

Worked logic: Iran

Intake: 25.2 µg/day ÷ 22.6 kg = 1.12 µg/kg bw/day; × 60 kg = 67.0 µg/day.

BLL increase: 0.23 × 67.0 = 15.4; 0.465 × 67.0 = 31.1; 0.70 × 67.0 = 46.9 µg/L.

Headroom: 66.3 − 10 = 56.3 µg/L. Share: 15.4 ÷ 56.3 = 27%; 31.1 ÷ 56.3 = 55%; 46.9 ÷ 56.3 = 83%. Because diet reaches everyone, the share does not depend on population.

G6. Food — Kanpur, India

Worked logic: Kanpur

BLL increase at 114 µg/day: 0.23 × 114 = 26.2; 0.465 × 114 = 53.0; 0.70 × 114 = 79.8 µg/L.

ICMR baseline: headroom 104 − 10 = 94 µg/L. Share: 26.2 ÷ 94 = 28%; 53.0 ÷ 94 = 56%; 79.8 ÷ 94 = 85%.

IHME 2023 baseline: headroom 60.4 − 10 = 50.4 µg/L. Share: 52%; 105%; 158%.

Using Kinally's compiled 98 µg/day instead lowers every share by about 14%.

G7. Food — rice in Odisha, India

Worked logic: Odisha rice

Baseline: 47.2 million × (104 − 10) = 4,437 million cpBLLs available.

Intake from rice: 0.30 kg/day × 980 µg/kg = 294 µg/day; Codex-compliant counterfactual 0.30 × 200 = 60 µg/day; attributable increment 234 µg/day.

BLL increase: 0.23 × 234 = 53.8; 0.465 × 234 = 108.8; 0.70 × 234 = 163.8 µg/L.

Burden: 39.2 million × 53.8 = 2,109; × 108.8 = 4,265; × 163.8 = 6,421 million cpBLLs.

Share: 2,109 ÷ 4,437 = 48%; 4,265 ÷ 4,437 = 96%; 6,421 ÷ 4,437 = 145%.

G8. Spices — turmeric in Bihar, birth cohort

Worked logic: Bihar birth cohort

Available burden: 2.7 million × (76 − 10) µg/L = 178 million cpBLLs.

Turmeric burden, low: 2.7 million × 7.7 µg/L = 20.8 million cpBLLs → 20.8 ÷ 178 = 12%.

Turmeric burden, high: 2.7 million × 38.0 µg/L = 102.6 million cpBLLs → 102.6 ÷ 178 = 58%.

Alternative baselines: IHME under-20 Bihar 99.6 µg/L → available 242 million cpBLLs, share 9–42%; ICMR Bihar 89.9 µg/L → available 216 million cpBLLs, share 10–48%.

G9. Cookware — lead-glazed ceramics in Mexico

Worked logic: GRIT primary estimate (weekly users)

Baseline: IHME 2023 mean 63.8 µg/L (95% UI 31.3–138.2); population 132 million. Headroom 53.8 µg/L; available burden 7,100 million cpBLLs.

Weekly users: 18% of 132 million = 23.8 million. BLL increase in users: 16 µg/L.

Burden: 23.8 million × 16 = 380 million cpBLLs; 380 ÷ 7,100 = 5.4% of available burden.

Worked logic: scenario range

Low: 20% of people use LGC × 14 µg/L = 2.8 µg/L per capita → 370 million cpBLLs = 5.2%.

Central: 27.5% × 24 µg/L = 6.6 µg/L per capita → 870 million cpBLLs = 12%.

High: 35% (any use in the past 3 months) × 39 µg/L = 13.6 µg/L per capita → 1,800 million cpBLLs = 25%.

G10. Cookware — artisanal aluminum in Cameroon

Worked logic: from pot leachate to BLL increase

Acid-test scenario: an average pot (100 µg/L leachate) used for about 0.75 kg of food per adult per day → 75 µg/day → 0.465 × 75 = 35 µg/L.

Real-food scenario: neutral-pH staples assumed to leach 60–70% less → 22–30 µg/day → 10–14 µg/L.

For the burden estimate, users of high-lead pots gain 10 (low), 15 (central) or 35 (high) µg/L. These are modeled, not measured.

Worked logic: Cameroon burden

Baseline: IHME 2023 mean 121.7 µg/L; population 33.9 million. Headroom 111.7 µg/L; available burden 3,790 million cpBLLs.

Low: 50% × 10 µg/L = 5.0 µg/L per capita → 170 million cpBLLs = 4.5%.

Central: 70% × 15 µg/L = 10.5 µg/L → 356 million cpBLLs = 9.4%.

High: 90% × 35 µg/L = 31.5 µg/L → 1,070 million cpBLLs = 28%.

G11. Eyeliner — birth-cohort burden

Worked logic: eyeliner

Available infant burden = live births × (infant mean BLL − 10 µg/L).

Morocco: 0.5 million × (34 − 10) = 12 million cpBLLs; eyeliner 0.1–0.4 million → 0.8–3.3%.

Egypt: 2.1 million × (76 − 10) = 139 million cpBLLs; eyeliner 1.1–3.0 million → 0.8–2.2%.

Pakistan: 5.92 million × (116 − 10) = 627 million cpBLLs; eyeliner 4.2–10.6 million → 0.7–1.7%.

Average increase across all newborns: eyeliner burden ÷ live births, e.g. Pakistan 4.2 ÷ 5.92 = 0.7 to 10.6 ÷ 5.92 = 1.8 µg/L.

G12. Paint — lead paint in homes in India

Worked logic: exposure scenarios

Denominator: about 115 million children aged 0–4 (59.5 million boys, 55.2 million girls). The demographic year was not established in the source assessment; treat as illustrative.

Exposed children = 115 million × prevalence: 2% → 2.30 million; 5% → 5.75 million; 10% → 11.5 million; 15% (extended) → 17.25 million.

Burden = exposed children × 17 µg/L: 39, 98, 196 and 293 million cpBLLs.

National available burden: 1.44 billion × (60.4 − 10) = 72,600 million cpBLLs → shares of 0.05%, 0.13%, 0.27% and 0.40%.

Under-five available burden: 115 million × (104 − 10) = 10,810 million cpBLLs → shares of 0.4%, 0.9%, 1.8% and 2.7%.

Worked logic: LEEP market-based check

Share of homes painted: 75% of urban homes + 25% of rural homes = 0.75 × 0.35 + 0.25 × 0.65 = 43%.

Newly painted homes using colored solvent-based paint: 80% (LEEP assumption, not measured for India).

Leaded share of that paint: 10–40% (assumed range).

Children in lead-painted homes: 43% × 80% × 10–40% = 3–14%.

Prevalence and increment should be varied separately. The grid gives burden in million cpBLLs, with the share of under-five available burden in brackets:

Prevalence	+7 µg/L	+17 µg/L	+30 µg/L
2% (2.3 m)	16 (0.1%)	39 (0.4%)	69 (0.6%)
5% (5.75 m)	40 (0.4%)	98 (0.9%)	172 (1.6%)
10% (11.5 m)	80 (0.7%)	196 (1.8%)	345 (3.2%)
15% (17.25 m)	121 (1.1%)	293 (2.7%)	518 (4.8%)

These are cross-sectional scenario populations, not incident cases, and they do not identify which children carry the increment. Adults in the same homes may also be exposed, but a child dust-ingestion increment cannot be applied to all residents.

G13. Kohl — adult women in Iraq

Worked logic: kohl, Iraq

National available burden: 44.18 million × (43.7 − 10) = 1,488 million cpBLLs.

Women 15+ available burden: 14.27 million × (47.4 − 10) = 534 million cpBLLs.

BLL increase in users: 139.1 − 98.8 = 40.3 µg/L (Al Naama et al., unadjusted).

Central/high: 0.256 × 14.27 million = 3.65 million users; × 40.3 = 147 million cpBLLs → 147 ÷ 534 = 27.6% of women 15+; 147 ÷ 1,488 = 9.9% nationally.

Intermediate: 3.65 million × 20 = 73.1 million (13.7%; 4.9%). 1.43 million × 40.3 = 57.5 million (10.8%; 3.9%).

Low: 0.10 × 14.27 million = 1.43 million users; × 20 = 28.5 million cpBLLs → 5.3% of women 15+; 1.9% nationally.

G14. Secondhand smoke — US children 6–19

Worked logic: secondhand smoke, US

National available burden: 346.3 million × (13.5 − 10) = 1,215 million cpBLLs (IHME 2023; male 171.8 million at 15.2 µg/L, female 174.5 million at 11.8 µg/L).

Children 6–19: 0.8 × 20.2 + 21.0 + 22.1 = 59.3 million; mean (16.2 × 10.2 + 21.0 × 9.1 + 22.1 × 8.7) ÷ 59.3 = 9.3 µg/L — below the floor.

Lower bound (paper's increases): 0.523 × 0.7 + 0.034 × 1.1 = 0.40 µg/L per child; × 59.3 million = 24 million cpBLLs → 2.0%.

Upper bound (percentage increases on IHME mean): unexposed level = 9.3 ÷ (0.443 + 0.523 × 1.18 + 0.034 × 1.29) = 9.3 ÷ 1.104 = 8.4 µg/L. Increases: 0.18 × 8.4 = 1.5 µg/L; 0.29 × 8.4 = 2.4 µg/L. Weighted: 0.523 × 1.5 + 0.034 × 2.4 = 0.87 µg/L per child; × 59.3 million = 52 million cpBLLs → 4.3%.

Confounding allowance: halving each bound gives 12 million (1.0%) and 26 million (2.1%).

Share of children's BLL: 0.40 ÷ 4.6 = 8.8% (geometric means); 0.87 ÷ 9.3 = 9.4% (IHME means).

Under-five extension: 18.3 million × 12.6 µg/L × (1 − 1 ÷ 1.104) = 18.3 × 1.2 = 22 million cpBLLs → 1.8% nationally.

Appendix H: Method — From Exposure to Share of Available Burden

Each estimate in this document follows the same logic from the single-source guidance [1]: estimate how much a source raises BLL in the people it reaches, multiply by how many people that is, and compare the result with the burden available above a 10 µg/L floor in the same population. The available burden is population × (mean BLL − 10 µg/L), using IHME GBD 2023 unless stated otherwise.

The investment bands are those of the earlier guidance: under about 5% warrants a small, proportionate share of resources; 5–10% is worth monitoring and a low-cost intervention; 10–30% is a meaningful target; above 30% with a viable intervention is an extremely high priority.

Step-by-step

1. **Establish the baseline.** Take the national all-ages mean BLL and population for 2023 from IHME GBD 2023. Subtract the 10 µg/L floor to get headroom per person. If the population is specialised (children under 5, a birth cohort under 12 months, etc.) then data for that population is used.
2. **Choose the source.** For example, lead in the ordinary diet as measured by a TDS.
3. **Estimate the BLL increase.** From measured user/non-user differences where they exist; otherwise from intake using conversion factors or the AALM. For food, multiply the per-kg intake by body weight: 60 kg for adults and 22.6 kg for a 7-year-old. Where only adult per-kg intake is reported, it is applied to children too, which understates child intake.
4. **Estimate the affected population.** For diet, everyone eats, so the affected population is the whole population, and the share reduces to BLL increase ÷ headroom.
5. **Compute the source's burden.** BLL increase per person × affected population.
6. **Compare against available burden.** Divide by population × headroom.

Share of available burden = (BLL increase × people affected) ÷ (population × (mean BLL − 10 µg/L))

Intake-to-blood conversion factors

Source	Children (µg/L per µg/day)	Adults (µg/L per µg/day)
JECFA [14]	0.5–1.0 (midpoint 0.75, our arithmetic)	0.23–0.70 (midpoint 0.465, our arithmetic)
FDA [15]	1.6 (children 0–6)	0.4 (women of childbearing age only)

These slopes were fitted at BLLs of roughly 100–250 µg/L and are linear; they do not capture the flattening of the dose–response at high intakes, nor accumulation over a lifetime. They are a first pass, to be checked against the AALM [20] where the result matters. The adult range is used for population-wide food burdens; child values are shown for reference.

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