Technical Package on Lead Poisoning Prevention - overview

Draft for consultation

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Contents

Executive summary

Every year, lead poisoning kills an estimated 3.5 million people, accounts for more than 71 million disability-adjusted life years, and costs the world an estimated $6 trillion—roughly 7% of global GDP—yet it remains vastly underfunded and under-addressed relative to its burden. The costs fall hardest on low- and middle-income countries, where children's blood lead levels are three times higher than in wealthy nations and cognitive losses may reduce lifetime earnings by up to 12%. Interventions to reduce lead poisoning are cost-effective, with benefits outweighing costs for most sources by 10 to more than 2,000-fold.

PREVENT, the WHO Technical Package on Lead Poisoning Prevention, translates existing evidence into a practical, prioritized framework for action. The six key actions of this technical package are structured to guide governments' efficient and effective implementation of lead poisoning prevention measures:

- **P**rioritize sources and measure exposures
- **R**espond to elevated blood lead and address ongoing exposures
- **E**ngage partners, private sector, and the public to increase and sustain momentum
- **V**erify that regulations align with best practices to protect health
- **En**force regulations to ensure compliance
- **T**rack progress: evaluate implementation and impact on exposure

This technical package gives governments a practical, evidence-based path to reduce and ultimately eliminate lead exposure as a public health threat.

Background and introduction

Exposure to lead and its compounds is known to cause serious–but entirely preventable–health problems. The World Health Organization (WHO) recognizes exposure to lead as an issue of major public health concern, and the World Health Assembly Resolution (WHA78.27 2025) has committed the organization to strengthen its role in lead poisoning prevention at national, sub-regional, regional and global levels, including through the development of guidance and technical support.

In response to this commitment, and given the significant public health and economic impact of lead exposure globally, WHO is developing a technical package on lead poisoning prevention. This document provides an introduction to the technical package, including an overview of the interventions and actions needed to reduce the burden of disease from exposure to lead. It is intended for policy makers, public health officials, and others engaged in lead poisoning prevention efforts at national and sub-national levels.

Lead is a heavy metal that is toxic to humans. Its widespread and continued use is responsible for extensive environmental contamination and health problems. Lead mining, smelting, refining, recycling; the use of lead compounds in consumer products and industrial processes; and historical lead use (e.g., household paint) causes harmful and avoidable human exposure.

The Institute for Health Metrics and Evaluation estimates that 3.5 million deaths globally can be attributed to exposure to lead each year, primarily due to cardiovascular effects (1). Additionally, exposure to lead is estimated to account for 71 million lost disability-adjusted life years (DALYs) worldwide (1).

Globally, lead poisoning costs an estimated $6 trillion in 2019, about 7% of global gross domestic product (GDP), with $4.6 trillion due to cardiovascular disease and the remainder due to cognitive effects. Impaired cognitive development and loss of learning potential in the first five years of life for children in low- and middle-income countries (LMICs) may reduce lifetime earnings by up to 12%. Furthermore, costs of lead poisoning are inequitably distributed, accounting for 10% of GDP in LMICs compared to 5% in high-income countries (2). Among individual LMICs, costs of lead poisoning make up at least 3%—and well over 10% in many cases—of a country's GDP (3). These costs are likely underestimated given recent increases in burden estimates.

Health effects from lead poisoning

Lead poisoning—including clinical or subclinical impacts of exposure to lead in the human body—often goes unnoticed even by health practitioners and can develop insidiously given its non-specific symptoms (4). There is no safe level of lead exposure: even low levels can have serious consequences for health in children and adults despite often presenting without symptoms. In children, lead affects brain development, resulting in cognitive delays, behavioral changes such as reduced attention span, and increased antisocial behavior. In adults, lead increases the risk of cardiovascular disease, while also affecting kidney function and reproductive health (4,5).

Acute adverse health effects can follow short-term exposure to high doses of lead. Acute exposure may cause gastrointestinal disturbances, hepatic and renal damage, hypertension and severe neurological effects, such as encephalopathy, that can lead to convulsions and death (4).

Lead accumulates in the body with continued exposures. Chronic lead exposure can cause a wide range of health issues including anemia, neurological disturbances (headache, irritability, depression, lethargy, etc.), gastrointestinal disorders, and kidney dysfunction. Over the long term, this is associated with increased risk of hypertension, ischemic heart disease and stroke (4). Exposure to even low to moderate levels of lead among pregnant women—via acute or chronic exposure—is associated with miscarriage, stillbirth, premature birth, and other effects on both the mother and developing fetus (4,5).

Populations at greatest risk

Children and pregnant women are particularly vulnerable to low levels of lead exposure. Compared to adults, children have more frequent hand-to-mouth behavior (increasing the risk of exposure), absorb a greater proportion of lead than adults, and are therefore more susceptible both to the acute toxic effects and long-term cognitive impacts. Their early and often continuing exposure also puts them at high risk for other health impacts in adulthood. In pregnant women, lead previously stored in bone is subsequently released into the bloodstream. On its own or combined with acute exposures in pregnancy, this can impact both the woman (e.g., causing anemia) and cross the placenta to affect the developing fetus (4,5).

Those working in lead-related industries, particularly those in unregulated and informal settings, have the highest levels of exposure. In addition, wearing contaminated work clothes home can expose family members, including children (5).

Blood lead levels

Lead is absorbed primarily through inhalation and ingestion. Inhaled lead particles and fumes are efficiently taken up through the lungs, while ingested lead is absorbed through the gastrointestinal tract. Once absorbed, lead enters the bloodstream and is distributed to soft tissues (brain, liver, and kidney) and bones, where it accumulates over years. Bone can store >90% of lead in adults and >70% in children, representing cumulative exposures over long periods; however, it is not generally measured clinically due to challenges in measurement reliability and interpretation, among others (4,6). Blood lead levels (BLLs) are the biomarker upon which clinical decisions and health risk assessment of populations are routinely based and represent an important metric of the effectiveness of public health and environmental prevention and control measures.

WHO recommends that for an individual with a Blood Lead Level (BLL) greater than or equal to 5ug/dL, the source(s) of lead exposure be identified and appropriate action taken to reduce or eliminate exposure (7). However, since there is no safe level of exposure, prevention of any exposure to lead is particularly important (5).

In 2021, only 27% of LMICs had data on general population exposures and only 25% had data on exposures in children. Almost half of children's BLLs in LMICs exceeded 5 ug/dL; they were also more than three times higher than those in high-income countries (2,8).

Sources of lead exposure

The sources of lead exposure vary by location and over time. Lead was once widely used as an antiknock agent in petrol. Elimination of lead from petrol, which began in the 1970s and was completed in all countries in 2021, saved >1.2 million lives and $2.45 trillion annually (9–11). Ongoing exposure occurs through ingestion of lead-contaminated dust, soil, food (including spices and foods cooked, served, and/or stored in lead-contaminated cookware), traditional medicines, cosmetics, and lead-based paint, among others. Inhalation of lead fumes or particles is a major occupational route of exposure.

Industrial sources: These include formal and informal battery recycling (particularly used lead-acid batteries: ULABs (12)), lead smelting, electronic waste disposal (as well as open burning of electronic and other waste), and mining activities. Lead-acid batteries are critical to the current global automobile industry—as well as off-grid solar power systems—and are the most common, rechargeable batteries in the world. Almost all lead can be recovered from these batteries and reused; however, insufficient controls in handling, packaging, transport, and recycling—and inadequate source, process, and emissions controls—can expose workers and contaminate surrounding communities (13). Globally, more than 615 million people in LMICs (about 20% of people living in LMICs) live within 5km of a ULAB site (14).

Lead smelting – the process of extracting lead from ore or recycled materials – creates major risks to workers and communities if conducted without proper controls (15). Electronic waste often contains lead in components such as solder and circuit boards; improper dismantling, burning, or informal recycling can expose workers and contaminate surrounding communities (12). Substantial lead exposures also occur through mining other ores, as lead frequently co-exists with them in the earth's crust. Workers' industrial exposures are principally through inhalation although ingestion and family member exposure can also take place if lead dust is inadvertently taken home on work clothes. Communities are exposed to lead from industrial sources through contaminated air, soil, and water, as well as indirect environmental contamination (e.g., food).

Consumer products: Despite increasing evidence of the danger, lead compounds are still used in many consumer products. In paint and some toys and plastics, lead compounds serve multiple roles as pigments (e.g., lead chromate for yellow color), drying agents, heat stabilizers, and anti-corrosive primers. In ceramics, lead-based glazes can be fired at lower temperatures, reducing costs. In cookware, scrap metal containing lead is often reused to make metal pots and pans; lead solder is still used in some canning practices. Lead can be present in resin-based (e.g. melamine) plates as well as metal utensils and storage containers. Traditional eyeliners, such as kohl and surma, are often made primarily from ground galena (lead sulfide). More broadly, lead has been found in a wide range of cosmetic products — including skin-lightening creams, nail polish, lipstick, and eyeshadow — as well as in traditional medicines (16,17). Spices can be adulterated with lead to enhance color or weight (18–24).

Indirect pathways of exposure: While people can be directly exposed to the sources above, lead can also contaminate water, food, and air, greatly increasing the population exposed to harmful levels of lead.

Water systems: In piped water systems, lead used within solder and fixtures for pipes, the pipes themselves, and even faucets can leach into water when water quality changes or pipes corrode. Additionally, onsite water sources, such as wells, and surface water, are vulnerable to contamination from pump equipment and from nearby industrial activities.

Food: Food, including crops such as staple grains, vegetables, and fruit, can become contaminated with lead based on where it is grown (both airborne lead deposition and lead contamination of soil), how it is processed, packaged, stored, cooked, or seasoned. Contamination may come from industrial emissions that deposit onto soil and crops, from lead-soldered cans, from cookware that leaches lead, and from adulterated spices (25).

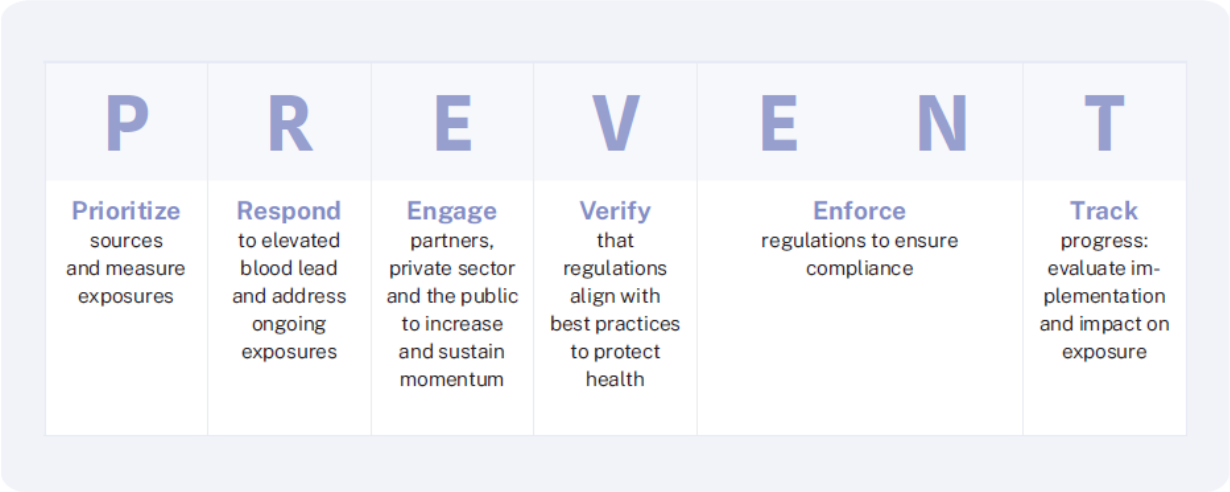
Air: Lead emitted from ULAB facilities is estimated to expose individuals living within 5 km (14). Lead from smelting may be present in fine particulate matter < 2.5 µm (PM2.5), which can travel >1,000 km (12,17).

Other lead sources: Smoking, direct consumption of lead-contaminated soil or clay, and consumption of wild game shot with (or other interaction with) lead gunshot all pose risks of lead exposure (17).

Impacts on BLL by source: The relative impacts of lead sources on BLLs are the subject of active investigation, given limited data on BLLs and source-specific exposures. A systematic review from 2025 found that, globally, industrial sources accounted for the largest increases in BLLs (>4 ug/dL for people living near sites, >3 ug/dL for occupational and take-home exposures). Other exposures associated with elevated BLLs were paint, traditional medicines and cosmetics, ceramic and melamine plates, smoking, food, and direct ingestion of soil (17).

Individual studies have found associations with other sources, depending on the region or country. For example, lead-containing spices originating in South Asia and Georgia have been associated with significant BLL increases locally and in other countries via exports (18–24,26–28). Lead soldered cans have also been associated with BLL increases in two countries, while metal cookware has been found to contain lead, and simulated cooking studies suggest significant exposures associated with leaching (17). Contaminated water was associated with increased BLLs in Bangladesh, and about 25% of all water sources tested in LMICs exceeded the WHO provisional guideline value of 10ug/L (29,30). Overall, both systematic reviews and individual studies used to determine relative, source-specific contributions to BLLs reflect significant concern of bias due to nonrandom, and often purposive, sampling to identify potential sources and are highly region- and country-specific, underscoring the need for context-specific data to drive national prioritization.

PREVENT: The Technical Package on Lead Poisoning Prevention



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Effective environmental health programs include technical, regulatory, inspection, enforcement, and stakeholder engagement capacities. Each of these areas require clear leadership, mandates, and responsibilities, as well as commitment to strong coordination to accomplish the shared goals of a whole-of-government effort on lead. The six action areas within the technical package provide an evidence-based framework for governments to prevent lead poisoning through reducing and eventually eliminating lead exposures. Although presented successively, these key action areas are part of a connected, comprehensive approach rather than discrete steps.

PRIORITIZE sources and measure exposures

Given resource constraints, it's important to prioritize lead sources that are both high risk and amenable to intervention within the country-specific context. This requires assessing not only the relative contribution of particular lead exposures and the anticipated impact of source interventions, but also cost, feasibility and policy readiness (31,32). Interventions for all sources return favorable benefit-to-cost ratios, with those targeting consumer products returning the highest (ranging 10 to >2,000-fold (3)).

Prioritization relies on:

- Assessing policy and regulatory responsibilities across government agencies, identifying relevant existing consumer and environmental protection regulations, and investigating gaps in current policies (33)
- Consolidating existing data on BLLs and lead in sources to assess relative public health risks (32,34,35)
- Assessing environmental health capacities to implement and enforce prevention measures relative to costs, among other factors (33)

The health sector can initiate this process, but should facilitate coordination and shared leadership between health, environment, and other key government agencies while ensuring the approaches protect public health (35,36). If systematic data on BLLs and sources are not available, previous investigations into lead exposures in the country and in countries with potentially similar routes and preponderance of exposures, existing data on major industrial and manufacturing activities and population demographics, and targeted screening of sources using field-ready methods may inform prioritization of sources (16,34).

Country actions:

- *Designate (or leverage existing) national coordinating mechanism to define a clear roadmap to prevent lead exposure*
  - *Sensitize key government decision-makers on health risks of lead exposure*
- *Identify and review existing laws, regulations, and standards for water, air, soil, food, consumer products, and occupational exposure to:*
  - *Map legal responsibilities across government*
  - *Assess whether lead-specific standards exist and how effectively they can protect health*
- *Identify and review existing data on lead exposure (e.g. blood lead levels) and sources*
  - *As resources allow, conduct additional systematic or targeted blood lead level and environmental source investigations to fill gaps in data to inform prioritization*
- *Integrate the relevant data and policy review to prioritize and select sources by impact, feasibility, and actionability for policy implementation*

RESPOND to elevated blood lead and address ongoing exposures

Establish surveillance systems: country capacity to test and report BLLs within surveillance systems is essential to protect pregnant women, children, and other populations from lead exposure. Countries may require different approaches to BLL surveillance to fit their needs and resources. Regular testing of BLLs, for example during clinical visits, is key to detect, investigate, and respond to chemical events (36–39). Proactive surveillance via national surveys or biomonitoring cohorts at household level (e.g., the Multiple Indicator Cluster Survey (MICS)) can help identify common exposures, establish national BLL benchmarks, and monitor program impacts (5,24,26).

Priority populations for BLL monitoring include young children, pregnant women, and workers in lead-related industries (36). Surveillance systems must be supported by standardized case definitions and action levels, designated responsible actors, quality-assured laboratory capacity within connected laboratory networks, and trained personnel. The ability to respond quickly and effectively requires connections to other systems, including investigations and inspections, to rapidly identify and contain exposures (32,35,40).

Establish response mechanisms (39,41):

- **Investigate exposures**: When surveillance systems identify elevated BLLs, rapid response teams then investigate quickly using an integrated approach to identify sources of lead contamination and exposure routes, manage exposed individuals, and take action to prevent further human exposure (36,37,39).

- **Communicate to the public and key stakeholders:** Engaging the public and other key stakeholders can increase awareness of lead risks, identify effective, short-term precautions, and improve prevention measures to avoid recurrence of exposures (36).

- **Clinical management**: Healthcare practitioners should have the skills and resources to diagnose and manage lead poisoning (36). Health systems should establish clear clinical guidelines; train health care workers on screening, diagnosis, and management of lead poisoning; ensure essential medicines are available; and define referral pathways for confirmatory testing, environmental investigation, and specialized care. Countries should develop capacity for diagnostic testing, chelation therapy to treat very elevated BLLs, and follow-up monitoring, with reporting mechanisms to public health authorities to trigger investigation and control measures (4,36).

- **Implement interventions to prevent future occurrence:** In contaminated soil or other environments, remediation can prevent continued exposures. Remediation reduces BLLs by 2.1 µg/dL on average (42) and returns 50-100% more than its cost (3). Due to its high cost, it should be considered as a complement to prevention efforts and financed by the industry responsible for the contamination (33,36). In cases of contaminated consumer products, investigation to identify the root causes of contamination is warranted, with subsequent removal of products from circulation, following similar principles to addressing violations of chemical regulations (33).

Country actions:

- *Standardize case definitions, action thresholds, and other criteria for investigation and response to lead poisoning*
- *Establish or enhance surveillance system for monitoring BLLs, especially among high-risk populations (children, pregnant women, and workers in lead-related industries)*
- *Develop accredited, quality-controlled laboratory capacity for biomonitoring and environmental monitoring, while also supporting field testing in communities*
- *Investigate cases and clusters of elevated BLLs to address current and prevent future exposures*
- *Support clinical management of lead poisoning – including guideline development, training health care workers, facilitating referrals to care, improving capacity of poison centers and securing essential medicines (e.g. chelating agents)*
- *Address ongoing exposure from identified sources*

ENGAGE partners, private sector, and the public to increase and sustain momentum

Lead poisoning prevention requires multisectoral engagement across ministries (e.g., health, environment, import/export, agriculture, among others), public and private sectors, national and state levels, and with the public in order to pass, implement, and enforce robust policies. To make rapid progress, governments will need to cultivate a strong network and have the capacity to engage diverse stakeholders. While enacting regulations is a key component of prevention, many substantial sources are generated by informal sectors, which must be engaged during policy creation, passage, and implementation to avoid loopholes and comprehensively prevent lead exposure (12). Public engagement is also essential to help sustain and amplify government efforts (43).

Encouraging industry change: country progress on managing ULABs has required industry responsibility (e.g., extended producer responsibility) through legislation and has been encouraged via market or other incentives (44). These efforts have generally focused on supporting formal recycling, even when batteries are collected informally (40).

Reformulating products: to eliminate lead, changes in production of consumer and household products, such as paint, may require technical assistance and ancillary support (e.g., identifying supply chains and product reformulation) (45–47).

Improve public awareness: engaging the public, as consumers of products, about the risks of lead exposure, dangers of lead-containing products, and ways to protect themselves can improve awareness of lead risks, inform choices of lead-free products, and change public practices (36,43).

Country actions:

- *Engage informal and formal lead industrial sectors to promote safe recycling practices, ensure worker protections and prevent environmental contamination*
  - *Use fines, economic incentives, or other instruments to facilitate compliance with environmentally sound industrial lead practices*
- *Engage informal and formal manufacturers of consumer products to promote and facilitate elimination of lead and lead-containing ingredients*
- *Identify regulatory, market-focused, or other instruments and approaches to facilitate elimination of lead in products*
- *Build and maintain networks of key stakeholders, including health care workers, environmental experts, civil society organizations, researchers, policy makers, industry and workers, to engage with and support government's response*

VERIFY that regulations align with best practices to protect health

Legally-binding, source-specific lead standards prevent lead exposure. Starting with the highest-priority sources, standards for lead content should be enacted and aim to eliminate the use of lead where it is not needed and prevent lead exposures within industrial processes that continue to require lead (36).

Industrial sources require environmental standards; source, process, and emissions controls with clear industry responsibility, including environmentally sound handling, recycling, transport, and disposal of lead-containing materials; prohibition of unsafe processes such as burning lead-containing waste; and clear occupational standards to protect workers, including regular BLL monitoring and measures to prevent take-home exposures (3,12,36,40,48–54). Consumer products and food require content standards, especially focused on preventing adulteration and intentional use of lead (36,40). Some globally-established examples, which may act as starting points, include:

Source	Standard/Exposure Limit	Key Global Reference
Ambient air	≤0.5 µg/m^3 (average over 1 year)	WHO (3)
Drinking water	≤10 µg/L (provisional guideline)	WHO (3,55)
Recreational water	≤200 µg/L	WHO (56)
Soil	Varies by land use and proximity to children	None to-date, national standards vary (3)
Occupational exposure	Varies by country/lead type; mandatory BLL monitoring required	International Labor Organization (52,53)
Industrial emissions	Align with ambient air and water standards	
Food (non-spices)*	0.01–0.4 mg/kg	Codex Alimentarius (57)
Spices	0.6–2.5 mg/kg	Codex Alimentarius (57)
Paint/pigments	≤90 ppm	United Nations Environmental Program (58)
Cosmetics	≤10 ppm (some countries ≤2 ppm)	None to-date, currently relying on national standards (59–61)

*Global standards for cookware have not been set.

Regulations on sources can include details on inspection and monitoring authorities, penalties aligned with violations, as well as assuring sustainable funding support (e.g., ensuring fines collected from regulated entities pay for enforcement) (33,40).

Country actions:

- *Identify relevant law enforcement and inspection agencies and ensure their enforcement authority powers are clearly and legally defined for lead exposure*
- *Adopt or amend national laws and regulations to limit lead in consumer products*
- *Adopt or amend existing health, environmental, and safety standards for the manufacture, recycling, and disposal of lead and lead-containing materials*
    - *Include criteria for action to remove and protect workers*
- *Establish or reaffirm penalties for violation of applicable legal standards*
- *Standardize qualification and training criteria for inspection and enforcement authorities, especially inspection and prosecution procedures*
- *Ensure implementation and enforcement functions are financed sustainably, including from national budgets and via fees from regulated entities, where relevant.*

ENFORCE regulations to ensure compliance

Implementation of lead regulations requires national and subnational-level coordination to ensure the approach is aligned with the national policy, feasible at state, provincial or local level, and inclusive of the informal sector (31,33,36). Practically, standards to limit the use of lead have been enacted in a progressively stricter manner, providing time periods and targets for industry compliance on their way to full-scale enforcement, as in paint (58). In many cases, lead and other environmental regulations are enacted, but enforcement is uneven. Enforcement challenges arise due to limited political will, conflicts of interest, capacity limitations, overreliance on a particular regulatory approach, and lack of specificity in compliance mechanisms (62). Inspection and enforcement depend on sufficient technical, regulatory, and inspection capacity, supported by clear mandates and defined responsibilities (33). Transparency and openness, especially information about the design, conduct, and results of compliance and enforcement programs, is critical to success (33).

Conduct ambient air, soil, and water monitoring with facility audits and inspections: Enforcing industrial lead standards requires health, environmental, and safety-focused inspection to complement environmental monitoring. Monitoring of emissions and effluents complement these inspections to ensure environmental contamination does not put nearby communities at risk (3,12,33,36,40).

Inspect consumer products and food, and publicize results: Inspection of consumer products, as well as food, to determine lead content is a direct way to measure compliance and can trigger strict enforcement measures, including seizure and steep fines, to eliminate adulteration. Publicizing results also improves community awareness and consumer choices (22,24,26,33,36,40).

Remove workers from unsafe conditions: International best practices stipulate that when specific occupational exposure limits are exceeded, the workplace should be temporarily closed and workers with BLLs exceeding occupational standards removed (ideally with pay) and monitored until BLLs are below the occupational threshold. The facility should improve process controls, with increasing consequences for repeat or larger offenses. Compliance measures should also ensure action is taken to limit take-home exposures (36,52,53).

Apply proportional and escalating penalties as required: enforcement best practices include measures to ensure that repeated violations, as well as more severe compliance violations, have proportionally more severe penalties. Penalties can include the responsibility for industry to rectify damages (33).

Country actions:

- *Establish environmental monitoring systems for testing lead in relevant sources and ambient environments*
- *Conduct inspections and monitoring—focusing on health, environment, and safety— of hazardous industries to track compliance*
- *Inspect domestically produced and imported consumer products for lead content and seize, recall, or ban non-compliant products*
- *Apply penalties proportionate to the violation, including measures to rectify damage from noncompliance*

TRACK progress: evaluate implementation and impact on exposure

Tracking progress requires monitoring and evaluating process and outcome indicators (35,63), which may come from a mix of BLL surveillance as well as dedicated monitoring and evaluation systems. BLL surveillance, for example through repeated cross-sectional surveys, can monitor trends over time and generate estimates of average BLLs in a particular population, which can act as an outcome-level metric of the effectiveness of policies and enforcement (20,21,25). Source monitoring (e.g., within enforcement measures) is a critical component that may be more feasible than BLL surveillance (33). For example, post-market testing may enable more timely monitoring of progress towards eliminating lead from consumer products than population BLL changes (16,35,37). Process indicators and responsible entities for those indicators should be clear and aligned with outcomes, ensuring measurable progress (63). These could include number of policies passed or lead standards enacted at national and sub-national levels, completion of capacity-strengthening exercises, reach of public engagement, or number of inspections or other compliance monitoring activities conducted (40).

Country actions:

- *Establish and track progress towards an ambitious, achievable national goal to reduce lead poisoning, integrating surveillance and other monitoring systems where appropriate*

References

1. GBD 2023 Lead Collaborators. Lead-Attributable Cardiovascular Disease Burden: Global Burden of Disease Study 2023. JAMA. 2026 Mar 30. doi:10.1001/JAMA.2026.2197 PubMed PMID: 41910985.

2. Larsen B, Sánchez-Triana E. Global health burden and cost of lead exposure in children and adults: a health impact and economic modelling analysis. Lancet Planet Health. 2023 Oct 1;7(10):e831–40. doi:10.1016/S2542-5196(23)00166-3 PubMed PMID: 37714172.

3. The World Bank Group. A World Without Lead: Paving the Path to a Healthy, Productive Future [Internet]. 2025. Available from: www.worldbank.org

4. World Health Organization. WHO guideline for clinical management of exposure to lead. World Health Organization; 2021. 91 p.

5. World Health Organization. Exposure to lead: A major public health concern (Fourth edition) [Internet]. Fourth. 2025. Available from: https://iris.who.int/.

6. Barbosa F, Tanus-Santos JE, Gerlach RF, Parsons PJ. A critical review of biomarkers used for monitoring human exposure to lead: Advantages, limitations, and future needs. Environmental Health Perspectives. Public Health Services, US Dept of Health and Human Services; 2005. p. 1669–74. doi:10.1289/ehp.7917 PubMed PMID: 16330345.

7. World Health Organization. Lead poisoning [Internet]. 2024 [cited 2026 Feb 3]. Available from: https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health

8. Ericson B, Hu H, Nash E, Ferraro G, Sinitsky J, Taylor MP. Blood lead levels in low-income and middle-income countries: a systematic review. Lancet Planet Health. 2021 Mar 1;5(3):e145–53. doi:10.1016/S2542-5196(20)30278-3 PubMed PMID: 33713615.

9. UN Environmental Programme. Era of leaded petrol over, eliminating a major threat to human and planetary health [Internet]. 2021 [cited 2026 Feb 3]. Available from: https://www.unep.org/news-and-stories/press-release/era-leaded-petrol-over-eliminating-major-threat-human-and-planetary

10. Angrand RC, Collins G, Landrigan PJ, Thomas VM. Relation of blood lead levels and lead in gasoline: an updated systematic review. Environ Health. 2022 Dec 1;21(1). doi:10.1186/s12940-022-00936-x PubMed PMID: 36572887.

11. Mielke HW, Gonzales CR, Powell ET, Egendorf SP. Lead in Air, Soil, and Blood: Pb Poisoning in a Changing World. Int J Environ Res Public Health. 2022 Aug 1;19(15). doi:10.3390/ijerph19159500 PubMed PMID: 35954853.

12. World Health Organization. Recycling used lead-acid batteries: health considerations. 2017.

13. US EPA. Waste & Debris Fact Sheets | I-WASTE DST [Internet]. 2024 [cited 2026 Feb 3]. Available from: https://iwaste.epa.gov/guidance/natural-disaster/fact-sheets/types-of-waste?id=auto-batteries

14. Crawfurd L, Hu J, Mitchell T. Beyond Hot Spots: Estimating Population Lead Exposure from Battery Recycling Beyond Hot Spots: Estimating Population Lead Exposure from Battery Recycling [Internet]. 2026 Jan. Available from: www.cgdev.org

15. World Economic Forum. Closing the Loop on Energy Access in Africa. 2021 May.

16. Sargsyan A, Nash E, Binkhorst G, Forsyth JE, Jones B, Sanchez Ibarra G, et al. Rapid Market Screening to assess lead concentrations in consumer products across 25 low- and middle-income countries. Sci Rep. 2024 Dec 1;14(1). doi:10.1038/s41598-024-59519-0 PubMed PMID: 38678115.

17. Kinally C, Fuller R, Larsen B, Hu H, Lanphear B. A review of lead exposure source attributional studies. Science of the Total Environment. Elsevier B.V.; 2025. doi:10.1016/j.scitotenv.2025.179838 PubMed PMID: 40532468.

18. Forsyth JE, Mistree D, Nash E, Angrish M, Luby SP. Evidence of turmeric adulteration with lead chromate across South Asia. Science of the Total Environment. 2024 Nov 1;949. doi:10.1016/j.scitotenv.2024.175003 PubMed PMID: 39053552.

19. Forsyth JE, Weaver KL, Maher K, Islam MS, Raqib R, Rahman M, et al. Sources of Blood Lead Exposure in Rural Bangladesh. Environ Sci Technol. 2019 Oct 1;53(19):11429–36. doi:10.1021/acs.est.9b00744 PubMed PMID: 31525910.

20. Forsyth JE, Nurunnahar S, Islam SS, Baker M, Yeasmin D, Islam MS, et al. Turmeric means “yellow” in Bengali: Lead chromate pigments added to turmeric threaten public health across Bangladesh. Environ Res. 2019 Dec 1;179. doi:10.1016/j.envres.2019.108722 PubMed PMID: 31550596.

21. Brown MJ, Patel P, Nash E, Dikid T, Blanton C, Forsyth JE, et al. Prevalence of elevated blood lead levels and risk factors among children living in Patna, Bihar, India 2020. PLOS Global Public Health. 2022 Oct 1;2(10 October). doi:10.1371/journal.pgph.0000743

22. Forsyth JE, Baker M, Nurunnahar S, Islam S, Islam MS, Islam T, et al. Food safety policy enforcement and associated actions reduce lead chromate adulteration in turmeric across Bangladesh. Environ Res. 2023 Sep 1;232. doi:10.1016/j.envres.2023.116328 PubMed PMID: 37286126.

23. UNICEF. Ending Childhood Lead Poisoning in Georgia. 2024.

24. Rylander C, Anda EE, Cirtiu CM, Jankhoteli T, Dzotsenidze N, Ghetia V, et al. Blood Lead Levels in Children 5 to 7 Years of Age from the Republic of Georgia: A Feasibility Study on

Lead Surveillance Using Volumetric Absorptive Microsampling. Environ Health Perspect. 2025 May 1;133(5). doi:10.1289/EHP15788 PubMed PMID: 40117538.

25. Kinally C, Hu H, Fuller R. Quantifying the Global Burden of Lead Exposure from Dietary Lead Intake [Internet]. 2026. doi:10.2139/SSRN.6341545

26. Rylander C, Ephadze N, Manjavidze T, Anda EE, Dzotsenidze N, Shavishvili R. Time-trends of blood lead levels from 2020 to 2023 in pregnant and breastfeeding women from Adjara, Georgia—A birth registry-based study. Int J Hyg Environ Health. 2025 Jan 1;263. doi:10.1016/j.ijheh.2024.114482 PubMed PMID: 39481238.

27. Forsyth JE, Saiful Islam M, Parvez SM, Raqib R, Sajjadur Rahman M, Marie Muehe E, et al. Prevalence of elevated blood lead levels among pregnant women and sources of lead exposure in rural Bangladesh: A case control study. Environ Res. 2018 Oct 1;166:1–9. doi:10.1016/j.envres.2018.04.019 PubMed PMID: 29804028.

28. Gleason K, Shine JP, Shobnam N, Rokoff LB, Suchanda HS, Ibne Hasan MOS, et al. Contaminated Turmeric Is a Potential Source of Lead Exposure for Children in Rural Bangladesh. J Environ Public Health. 2014;2014. doi:10.1155/2014/730636 PubMed PMID: 25214856.

29. Fisher MB, Purvis T, Seidu Z, Roy S, Baldwin-SoRelle C, Cronk RD, et al. Lead (Pb) contamination in drinking water in low-and 2 middle-income countries: a systematic review and meta-analysis (pre-print). EarthArXiv. 2026.

30. Mitra AK, Ahua E, Saha PK. Prevalence of and Risk Factors for Lead Poisoning in Young Children in Bangladesh. J HEALTH POPUL NUTR. 2012;30(4):404–9.

31. World Health Organization. Road map to enhance health sector engagement in the Strategic Approach to International Chemicals Management towards the 2020 goal and beyond WORKBOOK. 2018.

32. UNICEF. Tool 1: Understanding childhood lead poisoning levels and sources. New York; 2025 Mar.

33. UN Environmental Programme. UN Environment Guidance on Enforcement of Chemicals Control Legislation UNEP GUIDANCE Enforcement of Chemicals Control Legislation. 2019.

34. UNICEF. Tool 3: Assessing Environmental Lead Exposure in Resource-Constrained Settings. New York; 2025 Mar.

35. UNICEF. Tool 4: Developing a country strategy and action plan for a lead-free future for every child. New York; 2025 Jul.

36. World Health Organization. Compendium of WHO and other UN guidance on health and environment 2024 update. 2024.

37. Hore P, Ahmed M, Nagin D, Clark N. Intervention model for contaminated consumer products: a multifaceted tool for protecting public-health. Am J Public Health. 2014;104(8).

38. NYC Health. Investigating and Addressing Exposures to Lead-Containing Consumer Products Technical Guide. 2025.

39. World Health Organization. International Health Regulations and chemical events [Internet]. 2015. Available from: www.who.int/about/licensing/copyright_form/en/index.html

40. UNICEF. Tool 8: National legal frameworks for regulating sources of lead exposure. New York; 2025.

41. World Health Organization. GUIDELINES FOR ESTABLISHING A POISON CENTRE. 2020.

42. Dobrescu AI, Ebenberger A, Harlfinger J, Griebler U, Klerings I, Nußbaumer-Streit B, et al. Effectiveness of interventions for the remediation of lead-contaminated soil to prevent or reduce lead exposure - A systematic review. Science of the Total Environment. Elsevier B.V.; 2022. doi:10.1016/j.scitotenv.2021.150480 PubMed PMID: 34844314.

43. UNICEF. Tool 5: Clear communication to prevent and address childhood lead poisoning. New York; 2025 Mar.

44. Acosta A, Corallo A, Pon J, Candela Zaffiro Tacchetti M, Lizárraga M, Añibarro Montero C. Extended Producer Responsibility (EPR) schemes for used lead-acid batteries (ULAB) in the Latin American and Caribbean region: Second Technical Report of the Intergovernmental Network on Chemicals and Waste. 2025.

45. Lead Elimination Exposure Project. Malawi follow-up study results [Internet]. [cited 2026 Feb 2]. Available from: https://leadelimination.org/malawi-follow-up-study/

46. Peralta N, Cantoral A, Téllez-Rojo MM, Trejo-Valdivia B, Estrada-Sánchez D, Richardson-L V, et al. Lead Levels in a Potters Population and Its Association With the Use of Different Glazes: Cross-Sectional Evaluation of the Approved Pottery Program. Frontiers in Toxicology. 2022;4. doi:10.3389/ftox.2022.799633

47. Global Alliance to Eliminate Lead Paint. Module D-1 Industry Perspective: Restricting Lead Use in Paint.

48. Global Battery Alliance, World Economic Forum. Consequences of a Mobile Future: Creating an Environmentally Conscious Life Cycle for Lead-Acid Batteries. 2020.

49. UN Environmental Programme. A Guidance Manual For Policymakers and Regulators for the Environmentally Sound Management of Waste or Used Lead Acid Batteries in Africa [Internet]. 2022. Available from: http://www.un.org/Depts/

50. Wilson B, Manhart A. Standard Operating Procedures for Environmentally Sound Management of Used Lead-acid Batteries Turning waste into resources for development SRI builds capacity for sustainable recycling in developing countries With contributions from Gilbert Adie. 2021.

51. Manhart A, Adjei F, Weber F, Adogame L, Addie G, Onuoha S, et al. Partnership for Responsible Battery and Metal Recycling (ProBaMet) – Project Summary Report. 2025.

52. International Labor Organization. Exposure to lead in the world of work: Impacts for occupational safety and health.

53. International Labor Organization. Exposure to hazardous chemicals at work and resulting health impacts: A global review. 2021.

54. Occupational Safety and Health Administration. Lead - Overview [Internet]. [cited 2026 Feb 2]. Available from: https://www.osha.gov/lead

55. World Health Organization. Guidelines for drinking-water quality: Fourth Edition. 2022.

56. World Health Organization. Guidelines on recreational water quality. Volume 1, Coastal and fresh waters. World Health Organization; 2021. 138 p.

57. Food and Agriculture Organization of the United Nations, World Health Organization. Codex Alimentarius: General standard for contaminants and toxins in food and feed. 2025.

58. UN Environmental Programme. Model Law and Guidance for Regulating Lead Paint [Internet]. 2018 [cited 2026 Apr 29]. Available from: https://wedocs.unep.org/items/e37b821c-1fd9-47be-8a4a-caa484d929f0

59. European Chemicals Agency. Cosmetics-restricted-substances - ECHA [Internet]. [cited 2026 Feb 2]. Available from: https://echa.europa.eu/cosmetics-restricted-substances

60. US Food and Drug Administration. Lead in Cosmetics | FDA [Internet]. [cited 2026 Feb 2]. Available from: https://www.fda.gov/cosmetics/potential-contaminants-cosmetics/lead-cosmetics#

61. Health Canada. Guidance on Heavy Metal Impurities in Cosmetics - Canada.ca [Internet]. [cited 2026 Feb 2]. Available from: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/industry-professionals/guidance-heavy-metal-impurities-cosmetics.html

62. Ole NC, Omotuyi OY, Herbert EB, Omukoro DE. Environmental laws and enforcement: Prospects and challenges. Environmental Pollution and Public Health. 2024 Jan 1;305–26. doi:10.1016/b978-0-323-95967-4.00006-4

63. World Health Organization. Monitoring, Evaluation, and Review of National Health Strategies: A country-led platform for information and accountability. 2011.