unicef for every child

Tool 1

Lead-Free Future Toolkit

Understanding childhood lead poisoning levels and sources

March 2025

END CHILDHOOD LEAD POISONING

PARTNERSHIP FOR A LEAD-FREE FUTURE

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Acknowledgements

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Disclaimer

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The tool will be revised as new information and contributions become available and posted on the Partnership for a Lead-Free Future website.

Suggestions and comments are welcome and may be sent to ceh@unicef.org.

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Contents

Acronyms and abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BLL	blood lead levels
IHME	Institute for Health Metrics and Evaluation
LMICs	low- and middle-income countries
µg/dL	microgram per decilitre
OHAT	Office of Health Assessment and Translation
UNICEF	United Nations Children’s Fund
UNSDG	United Nations Sustainable Development Group
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

I. Introduction

1.1 Lead background

Lead is a naturally occurring bluish-grey metal with multiple commercial and industrial applications. Exposure to lead can result in an array of adverse health outcomes, including lifelong neurological impacts in children and cardiovascular disease in adults. Symptoms are typically subclinical with poisoning best confirmed through blood testing.

Lead can compromise neurological, cardiovascular and reproductive systems in various ways, including increased risk of high blood pressure and kidney damage later in life. Lead's chemical composition mimics calcium, which allows it to be stored in bones over time. During pregnancy, lead is transferred in utero to the fetus. After birth, maternal lead can be transferred to the infant through breast milk (ATSDR, 2020).

Sources of lead exposure in low- and middle-income countries (LMICs) include the irregular use of lead in consumer products such as spices, paints and dyes, cookware and ceramics, cosmetics, toys, leaded glass, jewellery, ammunition and fishing weights. Other potential sources include water contaminated by lead pipes and fittings, residual pollution from leaded petrol, light aviation fuel, e-waste recycling and some traditional medicines and ceremonial powders.

Lead is a main component of lead-acid batteries in vehicles and other industrial applications on a global scale. Almost all the lead in lead-acid batteries can be recovered and recycled. In LMICs, however, substantial numbers of waste lead-acid batteries are recycled in informal and/or substandard settings that contaminate the air, water and soil in the surrounding communities.

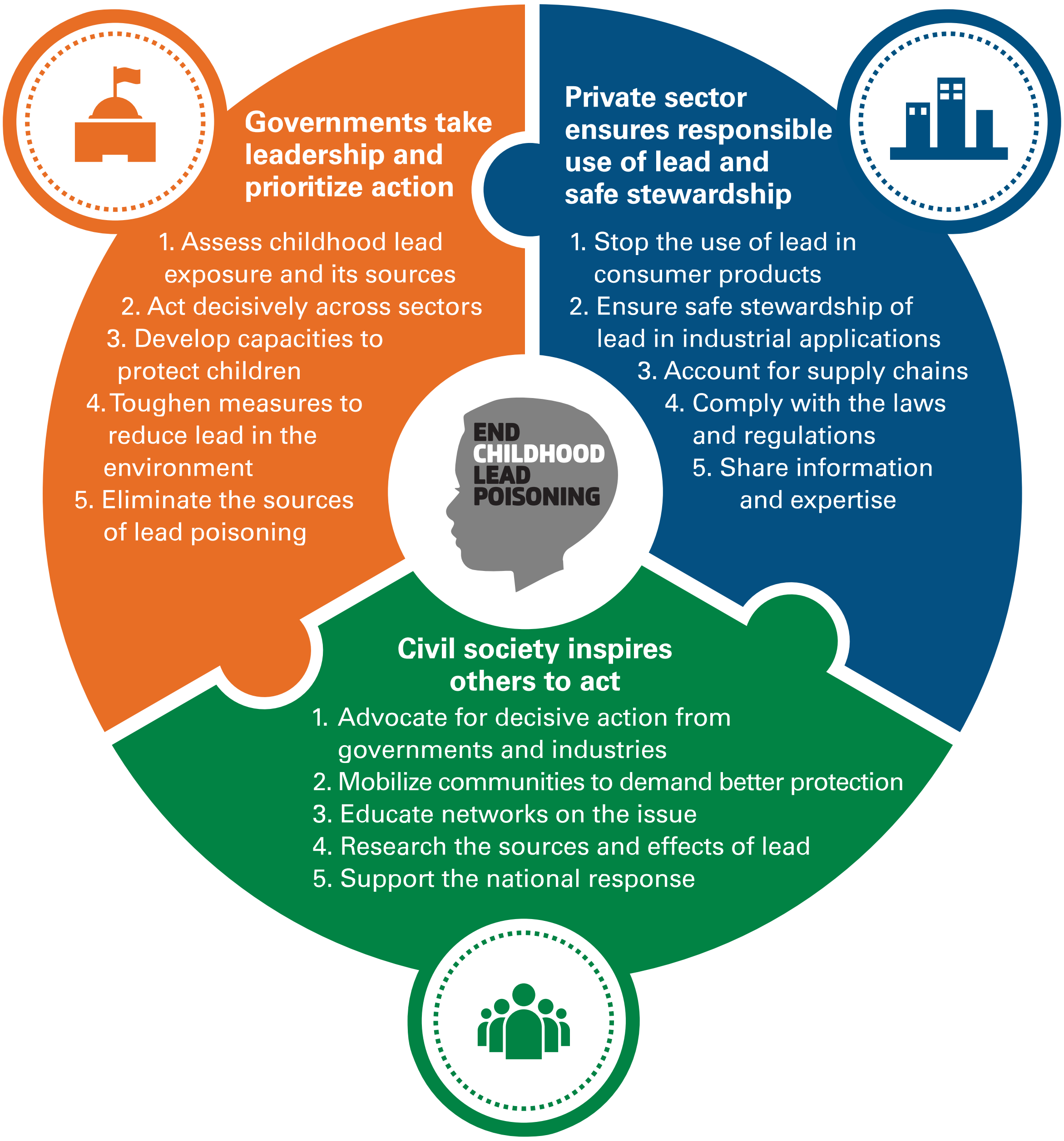
A recent UNICEF/Pure Earth joint report notes that an estimated one in three children globally have blood lead levels (BLLs) exceeding the World Health Organization (WHO) reference value of 5 µg/dL. The economic burden of decreased productivity owing to these exposures has recently been quantified as equivalent to 1.6 per cent of global gross domestic product, or US$1.38 trillion (2019 PPP).

1.2 Five actions to eliminate childhood lead poisoning

In 2023, UNICEF laid out an overarching framework to guide its efforts on lead exposure called *Five Actions to End Childhood Lead Poisoning*. It provides clear actionable measures that governments, the private sector and civil society can take to end childhood lead poisoning. Distinct steps are set out for each group of stakeholders.

With regard to governments, the framework first encourages a stocktaking exercise of existing knowledge on lead poisoning in their countries and regions. This includes literature review and expert consultation. This baseline evaluation is then supplemented by primary data collection in the form of BLL studies and environmental assessments (see Tool 2 for more information). Next, a whole-of-government approach is taken – one that includes engaging multiple ministries to develop sectoral approaches in line with a national strategy. Capacities are strengthened and regulatory frameworks are adopted to eliminate dangerous applications of lead and promote best practices. Finally, existing exposure sources – such as contaminated land – are eliminated.

Figure 1: **Five actions to end lead poisoning**



This Toolkit has been developed to support the implementation of the 'Five Actions'. A basic outline of the topics of the tools in the Toolkit is provided below. For more information, visit <www.leadfreefuture.org>.

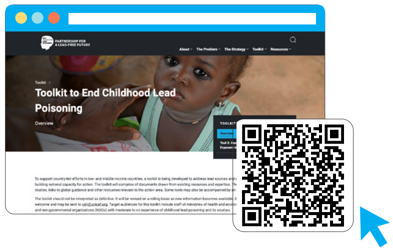


Table 1: **Lead-Free Future Toolkit outline**

Action areas	Tools
#1. Assess childhood lead exposure and its sources	**Tool 1: Understanding childhood lead poisoning levels and sources**
	Tool 2: Collecting data
	Tool 3: Assessing environmental lead exposure
#2. Act decisively across sectors	**Tool 4: Developing a country-specific strategy**
	Tool 5: Communication
#3. Develop capacities to protect children	**Tool 6: Health systems capacity**
	Tool 7: Lead surveillance system
#4. Toughen measures to reduce lead in the environment	**Tool 8: National environmental standards, laws and regulations**
	Tool 9: Environmentally sound management of lead
	Tool 10: Environmental protection capacity
#5. Eliminate the sources of lead poisoning	**Tool 11: Addressing unsafe and informal recycling**
	Tool 12: Remediation

1.3 Purpose of this tool

The purpose of this tool is to familiarize readers with key concepts of assessing and mitigating childhood lead poisoning and its sources. The tool also includes guidance on conducting a foundational lead assessment, involving a preliminary mapping of sources of exposure and institutional capacity.

In addition, this tool is intended to be used as part of the Lead-Free Future Toolkit, the purpose of which is to provide guidance and tools to help end childhood lead exposure. This tool and the rest of the Toolkit should not be taken as representing the views of the authors or the organizations with which they are affiliated, nor should it be viewed as definitive. It will be revised on a rolling basis as new information becomes available.

Target audiences include staff members of ministries of health and environment, international organizations and non-governmental organizations with moderate to no experience in working on childhood lead poisoning and its sources.

This tool is organized sequentially, proceeding from a summary of the knowns and unknowns on the extent of lead poisoning in LMICs, to initial steps required to improve understanding of the problem, and finally to a framework on how to mitigate it. Some additional detail is presented in the annexure.

This is Tool 1 of 12 in the Toolkit covering various topics related to lead poisoning. Together the tools form a complete primer on identifying, assessing and mitigating paediatric exposure. The Toolkit does not itself constitute adequate guidance for the development and implementation of such programmes. Rather, key considerations are outlined, and a preliminary list of possible actions is presented. Further guidance should be sought from experienced organizations or experts before designing or executing the work described.

II. Basic assessment: Primer on blood lead level estimates and disease burden knowns, unknowns and assumptions

Biological monitoring of human lead exposure is most commonly done through BLL measurements, though it can also be quantified through assessments of bone. Other biological media have not been evaluated to the same extent (US EPA, 2013). The half-life of lead in whole blood has been estimated to be 30 days, thus BLLs capture the level of exposure proximate to the time of extraction (Rabinowitz, Wetherill and Kopple, 1976; Chamberlain et al., 1978; ATSDR, 2020). This contrasts with bone lead measurements, which are better suited for assessments of chronic exposure; lead accumulates in bone, where it can reside for decades (Rabinowitz, 1991). Because of this, lead level declines in soft tissue can be replenished by deposits in bone. Thus, after chronic exposure has been mitigated, an initial rapid decline in BLLs is expected, followed by a much slower rate of clearance (Hu et al., 2007).

Elevated BLLs are associated with cognitive deficits, cardiovascular disease, liver and kidney disease, hearing loss, gout and multiple other adverse health impacts (US EPA, 2013).

In high-income countries, BLLs and sources of exposure for the general population are relatively well understood. In the most rigorous case, the US Health Resources and Services Administration in 1998 adopted the recommendation of the American Academy of Pediatrics to conduct regular BLL testing and risk assessment of children (Raymond, Wheeler and Brown, 2014). At present, these recommendations call for risk assessment by primary care physicians of all children at 9 months, followed by BLL screenings at 12 and 24 months (Hagan, Shaw and Duncan, eds., 2017).

This data collection is supplemented by a more comprehensive biomonitoring regime in a representative sample of the US population through the National Health and Nutrition Examination Survey, which has been carried out since the 1960s and examines approximately 5,000 people each year (National Center for Health Statistics, 2017). Other high-income countries regularly carry out similar nationally representative BLL testing, albeit to different extents (WHO/Europe, 2007; Health Canada, 2013).

2.1 Very few LMICs have nationally representative BLL studies

By contrast, very few LMICs have carried out comparable assessments of BLLs in the population. In the most robust case, a 2020 study of 31,373 children in China (< 7 years old) reported a geometric mean BLL of 2.67 µg/dL in the population (Li et al., 2020). In Mexico, a survey of children (1–4 years old) in mid-sized cities was conducted, finding that 21.8 per cent of children in the national sample had BLLs exceeding 5 µg/dL (Téllez-Rojo et. al., 2019).

UNICEF has recently begun providing assistance to LMICs to carry out BLL studies, often in the context of their existing Multiple Indicator Cluster Survey programme. A 2019 study in Georgia found that 41 per cent of children (2–7 years old) had BLLs exceeding 5 µg/dL (National Statistics Office of Georgia, 2019). A similar effort in Bhutan reported that 51 per cent of children (1–6 years old) exceeded this threshold (Bhutan Ministry of Health, 2024). Subnational studies in Bangladesh (1–18 years old) and Ghana (< 5 years old) found 40 per cent and 53 per cent of children exceeding 5 µg/dL, respectively (UNICEF Ghana, 2023; UNICEF Bangladesh, 2023). A subnational UNICEF study in Mongolia, which utilized a more conservative threshold of 3.5 µg/dL, found that 46 per cent of children (< 5 years old) exceeded this value.

2.2 Others have BLL studies that were not designed to be nationally representative

In the absence of nationally representative BLL surveys, researchers have relied on other data to draw conclusions about likely BLLs in a given country. The most common approach has been to simply infer results for the broader population based on smaller samples. This is typically done using case-control studies, with the 'control' population being taken as nationally representative, or cohort studies covering smaller geographic areas. Where multiple studies exist, the results are pooled to calculate a representative BLL (Fewtrell, Kaufmann and Prüss-Üstün, 2003; Attina and Trasande, 2013; Ericson et al., 2021).

2.3 Interpolating missing data

In cases with no existing BLL studies, researchers have interpolated nationally representative BLLs based on known values from nearby countries. At its most basic, this value is a regional average of BLL estimates in nearby countries (Fewtrell, Kaufmann and Prüss-Üstün, 2003; Attina and Trasande, 2013). Others have tried to improve on these estimates through the use of proxies. The Institute for Health Metrics and Evaluation (IHME) uses a bespoke spatio-temporal Gaussian process regression methodology for all risk factors in its Global Burden of Disease (GBD) study, including lead exposure. The robust multistage approach relies on four covariates to adjust estimates derived from the literature review: urbanicity, socio-demographics, leaded petrol phase-out and vehicles per capita.

How Data Drives Solutions in the Global Burden of Disease Study
Healthy Tomorrows

2.4 Disease burden estimates

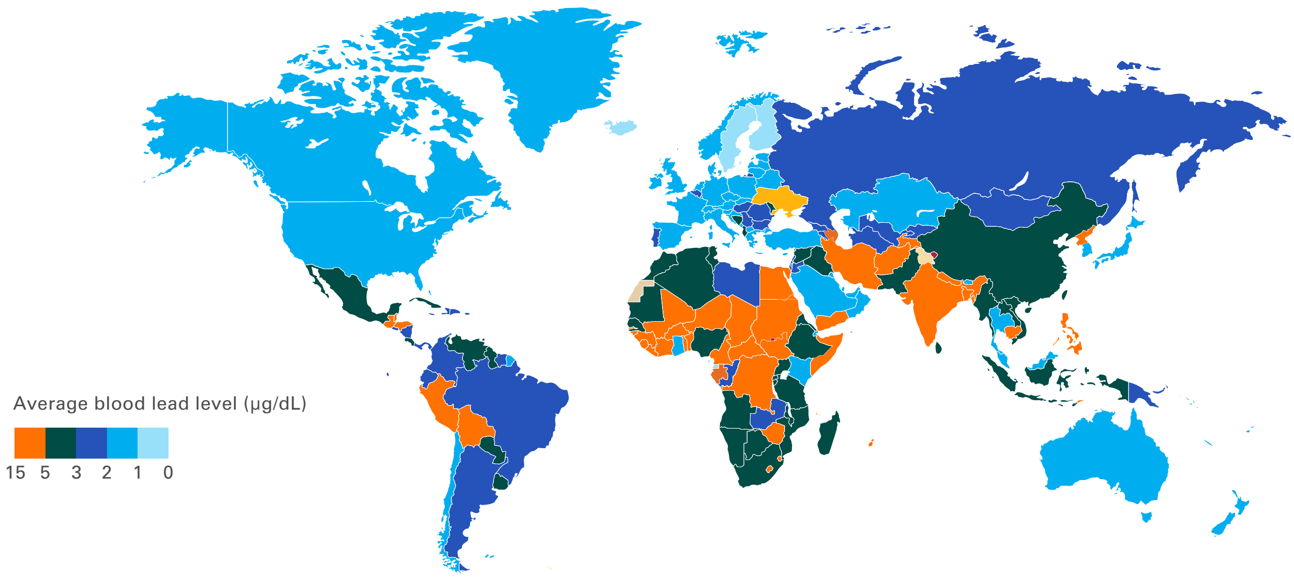
Paediatric lead exposure has been associated with a number of adverse health impacts, including anaemia, neurological decrement and, in severe cases, death (ATSDR, 2020). Lead in the digestive tract is treated by the body as calcium, with up to 50 per cent being absorbed and distributed in the bloodstream. Lead can then cross the blood-brain barrier, impeding the development of grey matter in the brain (ATSDR, 2020). Thus, children exposed to lead tend to have lower IQs and less earning potential, and exhibit more antisocial behaviour than their non-exposed counterparts (Talayero et al., 2023; Nevin, 2000).

Multiple studies have evaluated the societal implications of paediatric lead exposure. Mielke and Zahran (2012) found that lead exposure could account for 90 per cent of observed differences in aggravated assault rates across districts in six US cities. Most notably, a recent study found that the cost of IQ decrement attributable to paediatric lead exposure was equivalent to 2.2 per cent of the GDP of LMICs (Larsen and Sánchez-Triana, 2023).

2.5 Current knowledge of lead toxicity globally

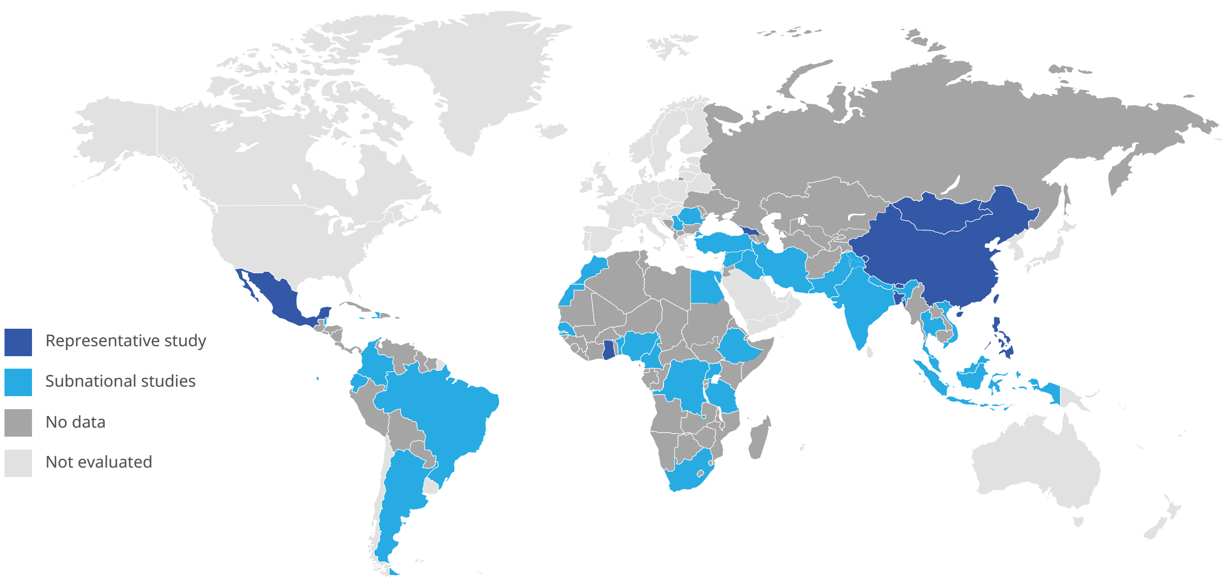
Current data indicate that one in every three children have lead poisoning, indicated by a BLL exceeding 5 µg/dL (UNICEF and Pure Earth, 2020). Figure 2 below presents current BLL estimates by country. Importantly, the majority of these data are interpolated using a very limited set of studies. For example, at present only 4 of the 136 LMICs (i.e., Bhutan, China, Georgia and Mexico) have nationally representative BLL surveys based on data collected in the past 10 years. Only 34 additional LMICs have subnational datasets collected at least one year after their leaded petrol phase-out date. No data on the remaining countries are available. Figure 3 presents the LMICs with nationally representative data, those with subnational studies reporting BLLs, and those with no data at all.

Figure 2: Estimated mean BLLs of children



Source: UNICEF and Pure Earth, 2020.

Figure 3: Existing studies of children's BLLs



Disclaimer: The boundaries and the designations used on these maps do not imply the expression of any opinion whatsoever on the part of UNICEF concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Lines on maps represent approximate border lines for which there may not yet be full agreement.

III. Potential sources of lead exposure

A fundamental concept to understanding lead exposure is the difference between 'hazard' and 'risk'. A hazard is a potential source of harm, while a risk is the probability and severity of harm. A hazard becomes a risk when humans have an increased likelihood to be exposed to it. A plastic toy may contain elevated concentrations of lead and is thus a hazard. Without a human exposure pathway, however, that toy may not pose a risk. Well-maintained lead-based paint presents a hazard; it becomes a risk when that paint is damaged or disturbed and converted to dust which can be inhaled and ultimately ingested. 'Severity' refers to the dose, which is in turn mediated by the concentration and frequency of exposure.

In this context, risk assessment is the process of identifying and characterizing lead exposure risks in children's environments. A risk assessment of environmental media is required to identify likely sources of exposure; BLLs confirm that the pathway is complete.

Most forms of lead are not readily absorbed through the skin, thus the majority of exposure occurs through ingestion and, to a much lesser extent, inhalation. Incidental ingestion of lead-contaminated soil and dust is a common human exposure pathway where environmental contamination has occurred (e.g., from paint or industrial sources). Ingestion of lead-contaminated medicines and foods is also common in many settings. While lead is sparingly soluble in water, particles can enter water through contaminated supply or distribution systems (Champion et al., 2022; Fisher et al., 2021; Buerck et al., 2023). Inhalation of respirable lead particles is uncommon outside of industrial settings. Children both take in and absorb proportionally much more lead than adults, owing to their behaviour and physiological differences (ATSDR, 2020).

Sources of lead exposure are diverse and tend to be regionally specific. Even leaded petrol – the largest single historical contributor to elevated BLLs – affected certain populations more than others. Indeed, perhaps 80 per cent of all leaded petrol produced before 1970 was used in the United States, due to larger vehicles and longer distances travelled (Nriagu, 1990). Lead-adulterated spices, with some exceptions, seem to be concentrated in South Asia (Hore et al., 2019; Forsyth et al., 2019). Lead-glazed ceramics, while fabricated in various countries, are uniquely prevalent in Mexico (Téllez-Rojo et al., 2019). Other sources of exposure are diverse. There is a dearth of research in this area, and new significant sources of exposure continue to be identified. Thus, it is key that researchers remain curious when identifying different sources of lead exposure.

IV. Fundamentals for assessing levels of lead poisoning

As noted above, biological monitoring of human lead exposure is most commonly done through BLL measurements. Blood can be collected through various methods, including capillary tubes, venous extraction and blood spot methods. Once collected, these samples can be analysed using a range of methods, including anodic stripping voltammetry, electrothermal or flame atomic absorption spectrometry, multi-collector inductively coupled plasma mass spectrometry, or inductively coupled plasma mass spectrometry. Each of these approaches offers certain advantages such as field portability, accuracy and cost. Tool 2 in this Toolkit provides a summary and evaluation of each approach.

BLL assessments can be carried out for multiple purposes. Collection and analysis from children known to have an elevated exposure – such as those living near a contaminated site – can be essential to inform mitigation or treatment approaches. Samples collected from a randomly selected and representative subset of children in a region or country are essential to understanding the extent and severity of lead exposure. Such studies carried out on a periodic basis – and coupled with an environmental assessment component – can form a robust monitoring and surveillance system to identify and support the control of sources of lead exposure. Tools 2 and 7 explore these concepts in detail.

Researchers carrying out BLL surveys should engage stakeholders at national and local levels to facilitate testing and sharing of results. It is essential that a risk communication strategy be developed in advance of any programme. The purpose of risk communication is to enable people at risk to make informed decisions about their health (WHO, n.d.; US EPA, 2024). Further information on risk communication is provided in Tool 5. Any testing on human subjects always requires institutional review board approval. Further information on the institutional review board process is available in Tool 2.

V. Conducting a foundational assessment of lead exposure

5.1 Preparing a summary report on the current status of lead toxicity in the country

In cases where lead exposure has been identified by country governments as a priority, it is necessary to conduct a foundational national assessment. For UNICEF, the goal of such an assessment is to build the basis for country-driven leadership to end lead poisoning. The assessment should include a review of existing information on the scale and severity of lead toxicity in the country, as well as associated adverse economic and social outcomes.

Where possible, known or suspected sources of lead should be identified, including industrial sources and lead-containing products. Finally, it should include a mapping of stakeholders, existing capacity and any previously existing or planned programmes. Annex A provides a potential outline for such an assessment. Key considerations for completing a foundational national assessment are provided below.

5.2 Estimated BLLs, burden of disease and economic impacts: Utilizing existing tools

Much of the existing data on BLLs have been made available in publicly accessible websites. These include UNICEF's Children's Environmental Health Country Profiles as well as IHME's GBD Results tool. Each of these tools and their basic functionality are summarized below.

Children's Environmental Health Collaborative Country Profiles: UNICEF has compiled a range of country-disaggregated environmental health data on children and made them publicly available and queryable. Country profiles offer snapshots on multiple parameters, including climate and health data and disease burden risk factors and causes – all disaggregated by age group.

IHME's GBD Results tool: IHME is a leading public organization focused on quantifying the burden of various health outcomes. Their periodic GBD studies – published in *The Lancet* – report on 282 causes of morbidity and mortality in 195 countries. The results, which rely on a combination of real-world data and modelling, are reported in terms of disability-adjusted life years and deaths. Their fully queryable database is publicly available after registration.

PubMed: The US National Institutes of Health maintains the world's largest database of peer-reviewed health studies published in English. The database – which contains more than 37 million citations – is keyword searchable. Users can then filter results by dozens of parameters including country, sex, species, age and study year.

Other tools: WHO maintains a range of useful databases on multiple topics. Pure Earth's Global Lead Pollution Map is easily searchable and presents data on lead exposure from Pure Earth's Toxic Site Identification Program, a recent World Bank study, and IHME's GBD study.

5.3 Identifying key sources

Owing to the significant variation of exposure sources between and within countries, a geographically specific investigation is essential to understanding exposure. A simple investigation can be comprised of literature review and expert consultation, with findings being presented in a summary report. Further field-based assessments (i.e., the collection of primary data through biological and environmental assessment) are more resource intensive but are almost always necessary to fully understand sources of lead exposure. Field-based assessments are described at length in Tool 3 of this Toolkit.

5.4 Literature review

Literature review is the process of identifying and synthesizing research that has already been conducted. In the context of lead exposure, literature review can provide investigators with necessary country- and/or region-specific information as the basis for further work.

A formal literature review typically contains six distinct steps: formulating the research question(s) and objective(s); searching the extant literature; screening for inclusion; assessing the quality of primary studies; extracting data; and analysing and synthesizing data (Templier and Paré, 2015). Researchers do not necessarily need to conduct a formal literature review to gain an understanding of sources of exposure in their country or region; nonetheless, these steps provide a useful list of considerations when engaging in this type of research. At a minimum, researchers should collect reports of lead exposure from multiple sources, assess them for quality and synthesize their major findings. Annex B provides additional instruction on conducting a literature review. A related tool – a scoping review – is not discussed in this document but can assist in landscape and gap analysis (Munn et al., 2018).

5.5 Expert consultation

In addition to the published literature, the cumulative experience of experts can provide an invaluable resource. Local academics, non-governmental organizations working on chemicals, government agencies or departments and WHO Collaborating Centres (the global database) are all possible sources of information. These contacts can also help individual researchers identify data in the 'grey literature' – the collective body of works published outside of commercial or academic channels, or unpublished entirely.

After the research is conducted, it is essential that it be summarized in a single document. At a minimum, this document should state the objective of the research, the methods used and the key findings. Such a document can serve as an annex to the foundational assessment.

5.6 Regulatory assessment

An initial regulatory assessment can provide important information on the current laws, regulations and standards relating to known sources of lead exposure in the country, including lead-based paint and other consumer products as well as industrial emissions from mining activities and substandard recycling of lead-acid batteries.

Features of a regulatory assessment may include: a review of existing national laws, policies and standards related to lead, such as regulations for lead in paint, water, food and consumer products; an identification of gaps or inconsistencies with international standards; a comparison of national regulations with best practices recommended by international organizations such as WHO, the United Nations Environment Programme (UNEP) and other relevant bodies; and an assessment of whether internationally recommended lead limits (e.g., < 90 ppm lead content in paint) have been adopted in domestic regulations.

The regulatory assessment could also review compliance with international agreements (e.g., the Basel Convention), the leaded petrol phase-out date, and any guidance on the clinical management of lead poisoning.

The evaluation of specific regulations across key sectors, including housing, environment, industry, health and trade, can help determine whether adequate controls exist to address lead at every critical stage. Assessing institutional capacity, penalties, inspection mechanisms and compliance levels is critical to understanding the effectiveness of enforcement for existing regulations. Additionally, evaluating how industries – including paint manufacturers and battery recyclers – are involved in current mitigation efforts can help to determine whether voluntary programmes or corporate social responsibility initiatives related to lead reduction could complement regulatory solutions.

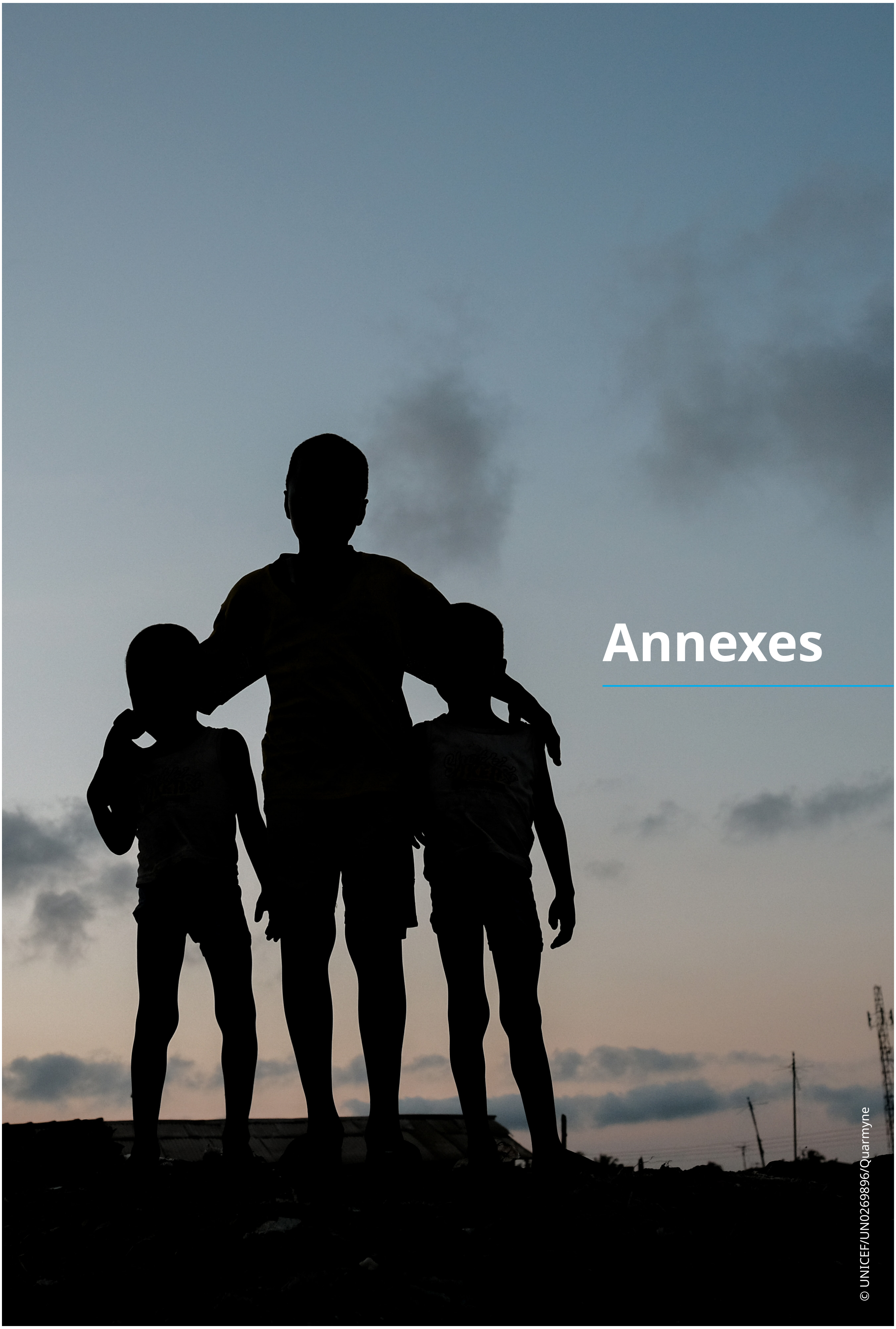
5.7 Institutional capacities

The effective management of childhood lead poisoning requires coordination across various ministries to address the diverse sources and impacts of lead exposure. Each ministry contributes unique expertise, regulatory power and outreach capabilities, creating a comprehensive strategy to prevent, manage and eliminate lead poisoning risks. Collaboration among these entities, coupled with adequate resources and public awareness, is essential to effectively protect children's health and well-being.

A table has been provided in Annex C that can be adapted to local country context, outlining the ministries, departments and agencies that should be playing a role in addressing childhood lead poisoning and what that role should be. A capacity gap analysis is a useful step to understand the barriers to ensuring multisectoral ownership and leadership, as well as implementation bottlenecks from the national to the local level.

5.8 Stakeholder mapping

Stakeholder mapping is the exercise of identifying and analysing individual stakeholders and their relevant differences in experience, influence and power in the context of the project. UNICEF and WHO, among others, provide detailed guidance on stakeholder mapping and engagement (WHO and UNICEF, 2020). Other considerations include the resources each stakeholder brings to the project and their responsibilities within the context of the project. Stakeholders can come from a range of sectors including government agencies, health clinics, community organizations, non-governmental organizations and donors.



Annexes

Annex A

Suggested structure and content of a foundational lead assessment

The table below provides a suggested structure for foundational assessments of lead exposure in individual countries. Researchers are encouraged to modify as needed.

Sections	Guiding questions	Possible resources
1. Country background information (general) a. Geography and demographics b. Socio-economic status: GDP and level of development c. Political and governance structure	What are the general geographical and sociopolitical characteristics of the country?	Children's Environmental Health Assessment Government reports
2. Existing knowledge of national health and economic impacts from lead a. Primer on lead exposure and associated health risks b. Known or estimated childhood blood lead levels (national and subnational if available) c. Available burden of disease data associated with lead exposures d. Deaths, disability-adjusted life years and IQ decrement (if available) attributable to lead e. Economic impacts from lead exposures	How significant of an issue is childhood lead exposure suspected to be in the country?	IHME 2021 Global Burden of Disease Results tool Children's Environmental Health Collaborative Country Profiles Literature review (see Annex B for guidance on conducting a literature review)
3. Known and suspected sources of lead exposures a. Industrial sources i. Formal sector ii. Informal sector b. Lead-containing products c. Confirmed or suspected contaminated sites	What are the suspected sources of lead exposure in the country, and to what extent are they being mitigated? Which sources can be addressed immediately, e.g., with existing best practices? For which sources is more information needed?	Literature review (see Annex B for guidance on conducting a literature review) Expert interviews

Sections	Guiding questions	Possible resources
4. Stakeholder mapping a. Relevant government agencies b. Civil society c. International organizations d. Donor agencies	Who are the relevant actors with regard to lead exposure mitigation?	*Integrating Stakeholder and Community Engagement in Quality of Care Initiatives for Maternal, Newborn and Child Health* (WHO and UNICEF, 2020) Tool 4 of this Toolkit
5. Institutional capacity assessment	What capacity exists in the country to mitigate lead exposure?	Institutional capacity assessment guidance (see Annex C)
6. Regulatory assessment a. Existing regulatory framework, including a summary of relevant laws and regulations b. Gap assessment	Which laws, regulations and standards exist to mitigate lead exposure? Which laws, regulations and standards are needed to mitigate lead exposure?	Expert interviews Literature review (see Annex B for guidance on conducting a literature review) Desk study
7. Information gaps	What key information was not available for the preparation of this assessment?	
8. Recommendations	What key recommendations follow from this assessment to mitigate childhood lead exposure?	Expert interviews
9. References		

Annex B

Conducting a literature review for a preliminary national assessment of lead exposure

Summary

A literature review is the process of identifying and synthesizing research that has already been conducted. In the context of lead exposure, a literature review can provide investigators with necessary country- and/or region-specific information as the basis for further work.

A formal literature review typically contains six distinct steps: formulating the research question(s) and objective(s); searching the extant literature; screening for inclusion; assessing the quality of primary studies; extracting data; and analysing and synthesizing data (Templier and Paré, 2015).

Researchers do not need to conduct a formal literature review to gain an understanding of sources of exposure in their country or region. These steps nonetheless provide a useful list of considerations when engaging in this type of research. At a minimum, researchers should collect reports of lead exposure from multiple sources, assess them for quality and synthesize their major findings.

Using online resources

Online databases are an essential component of any literature review. These databases can be divided into three main categories: metadata resources, full-text aggregators and publishers. Metadata resources primarily provide citations and, on occasion, links to full-text resources, while full-text aggregators and publishers provide either open or paid access to full-text resources. In nearly all cases, abstracts are available free of charge. Abstracts alone can often provide enough information to rule out or include individual articles.

With regard to metadata resources, PubMed is likely the most robust search engine for health data published in the English language and is often a key resource in literature reviews on lead exposure. The database – which contains more than 37 million citations – can be searched by keyword and filtered by dozens of parameters including country, sex, species, age and study year. Google Scholar is much larger in its breadth, with over 300 million citations, though is somewhat less customizable. Web of Science is commonly accessed by researchers in exposure and environmental sciences.

Full-text aggregators include Internet Archive Scholar, PubMed Central, Europe PubMed Central and ResearchGate. Each offer their own advantages including regional specificity and/or the ability to connect with authors to access their research or seek their advice. For instance, message boards on sites like ResearchGate are often used by researchers to ask methodological questions to a global community of experts on a range of subjects. Questions and responses are public and searchable, allowing users to access thousands of exchanges on various topics.

Publishers include ScienceDirect and SciELO. Like those resources above, each have different advantages, including access to non-English-language journals and search functionality.

Whichever online resources are utilized, it is essential that results are filtered by relevant criteria, such as date and geography. Sources of lead exposure change over time and place. Much of the exposure risk posed by leaded petrol, for instance, has abated while new sources of exposure, such as used lead-acid battery recycling, are becoming more significant.

Steps for conducting a literature review

The text below offers an example of a stepwise approach to conducting a literature review in the context of a preliminary national assessment on lead exposure.

Step 1. Formulate the research question(s) and objective(s)

In the present context, the objective of the study is to identify the extent and sources of paediatric lead poisoning in the target country. Thus, the research questions are: 'What are children's blood lead levels in [country or region]?' and 'What are the sources of lead exposure in [country or region]?'

Step 2. Search the extant literature

Researchers should define their search terms and strategy. Here, this includes determining the keywords and databases to be searched. In the case of PubMed, MeSH (Medical Subject Headings) terms are a limited vocabulary used for indexing articles. Keywords for searches in PubMed should be drawn from this list: <https://meshb.nlm.nih.gov/search>. This is necessary to ensure each search returns relevant results. The term 'exposure', for instance, is not currently a MeSH term. The terms 'blood', 'lead', and 'child' all are. Country names in English are also MeSH terms.

As a practical example, a PubMed search in October 2024 for 'blood lead Pakistan' returned 674 results. After filtering these results by age (child: birth–18 years), the list was reduced to 129 articles. Further filtering by publication date (within the last 10 years) brought the results to 69 relevant articles. Each of these articles must now be reviewed for relevance.

Step 3. Screen for inclusion

The study objectives and research questions were defined as part of step 1. In this step, the results are screened across inclusion criteria. These could include parameters relating to study design, such as capillary versus venous samples, number of participants, or whole blood versus plasma. They could also include criteria somehow missed by earlier screenings, such as animal studies being erroneously included.

To complete this step, the abstract of the study, and often the full text, must be reviewed by researchers. Studies not meeting the inclusion criteria must be excluded from subsequent steps.

Step 4. Assess the quality of primary studies

Quality assurance and control is the process of reviewing studies to determine whether enough confidence can be placed in their results to draw meaningful conclusions. This is typically done through a 'bias assessment', or a short list of questions relating to design, methods and results of each study. Various approaches are available from different organizations, or researchers may opt to develop their own (OHAT, 2019). The bias assessment is one of the more labour-intensive steps in the process, as it involves reading much of the full text of each study. Articles performing poorly in the bias assessment are excluded.

Step 5. Extract data

Researchers must select, extract and organize data in a uniform way. This can include data related to the methods as well as outcome variables. Most importantly the data must be organized in a consistent format using standard units. Conversions are often necessary at this stage. For example, blood lead level results can be reported in various units (e.g., µg/mol, µg/L, µg/dL). These must all be converted to the same type of unit to enable comparison.

Step 6. Analyse and synthesize data

Once the data are extracted, they can be analysed to determine what reasonable conclusions can be drawn. This can include both qualitative and quantitative assessment. For instance, a review of the narratives can give the researcher a sense of the types of studies being carried out, including which regions and sources they tend to focus on, which sources they tend to evaluate and so on. A more quantitative approach can evaluate numerical data using statistical software.

The results of the analysis are then synthesized in an effort to answer the research questions outlined in step 1. Researchers should consider summarizing their main results in simple tables and figures. A flow chart of the literature review process including steps taken at each stage (e.g., number of articles excluded or included) is typically included.

Other considerations

Quality assurance/quality control methods: Researchers should check for human error. Decimal points will fall in the wrong place, incorrect numbers will be entered. A percentage (e.g., a random subsample of 10 per cent of all results) of each step should be repeated by a second researcher. If errors are identified, they should be corrected and the check reconducted on a wider sample (e.g., 20 per cent).

PROSPERO: This is a database of registered systematic reviews. Researchers may consult the database to identify similar efforts or register their own.

Lack of data: Sometimes there are simply no relevant studies published. For example, a search for 'blood lead Tajikistan' returns a single result. In this case, the study should be reviewed and summarized, but the literature review should be expanded in scope, perhaps to neighbouring countries.

Limitations: Researchers must identify and describe the quality of their own study, including which limitations could be controlled for and which simply had to be accepted.

Annex C

Institutional capacity assessment guidance

The effective management of childhood lead poisoning requires coordination across various ministries to address the diverse sources and impacts of lead exposure. Each ministry contributes unique expertise, regulatory power and outreach capabilities, creating a comprehensive strategy to prevent, manage and eliminate lead poisoning risks. Collaboration among these entities, coupled with adequate resources and public awareness, is essential to effectively protect children's health and well-being.

The table below can be adapted to local country context outlining the ministries, departments and agencies that should be playing a role in addressing childhood lead poisoning and what that role should be. A capacity gap analysis is a useful step to understand the barriers to ensuring multisectoral ownership and leadership, as well as implementation bottlenecks from the national to the local level. Consider a human rights-based approach during the assessment (UNSDG, 2003).

Ministry	Role: What is their specific role in ending childhood lead poisoning?	Capacity gap analysis		
		Motivation: What is their understanding of the issue and the political will to prioritize?	**Authority:** Does the stakeholder have the mandate and authority to take action on the issue?	**Resources:** Does the stakeholder have the knowledge, skills, and organizational, human and material resources? If not, what's missing?
Ministry of Health	**Surveillance and screening:** Conducting national lead screening programmes to identify children with elevated blood lead levels. **Treatment and medical care:** Developing guidelines for health-care professionals on diagnosis and management of lead poisoning; providing health-care facilities for treatment, including chelation therapy for children with high levels of lead. **Public awareness campaigns:** Educating the public about the risks of lead exposure, symptoms of lead poisoning and preventive measures.			

Ministry	Role: What is their specific role in ending childhood lead poisoning?	Capacity gap analysis		
		Motivation: What is their understanding of the issue and the political will to prioritize?	**Authority:** Does the stakeholder have the mandate and authority to take action on the issue?	**Resources:** Does the stakeholder have the knowledge, skills, and organizational, human and material resources? If not, what's missing?
Ministry of Environment	**Regulation of pollutants:** Enforcing environmental regulations to limit lead emissions from industries, mining and other sources. **Monitoring environmental lead:** Identifying and assessing risk areas to prioritize mitigation actions; testing soil, air and water for lead contamination, especially in areas where children live and play. **Remediation programmes:** Initiating clean-up projects in contaminated areas, such as removing lead-based paint or contaminated soil, or addressing polluted water sources.			
Ministry of Trade, Industry and Commerce **or** **Ministry of Food and Safety**	**Regulating lead in consumer products:** Ensuring strict limits on the amount of lead in consumer products, including paint, toys and cosmetics. **Industry compliance:** Monitoring industries that use lead to ensure they follow safe practices, such as the recycling of lead-acid batteries. **Substituting safer materials:** Promoting the use of lead alternatives in industries like paint, plumbing and electronics through policies and incentives. **Import and export controls:** Setting standards and restrictions to prevent the importation of products containing hazardous levels of lead.			

Ministry	Role: What is their specific role in ending childhood lead poisoning?	Capacity gap analysis		
		Motivation: What is their understanding of the issue and the political will to prioritize?	**Authority:** Does the stakeholder have the mandate and authority to take action on the issue?	**Resources:** Does the stakeholder have the knowledge, skills, and organizational, human and material resources? If not, what's missing?
Ministry of Education	**Educational campaigns in schools:** Integrating lessons about the dangers of lead exposure into the curriculum to raise awareness among children and parents. **Safe school environments:** Ensuring that schools are free from lead hazards, including lead-based paint, cooking utensils and contaminated soil in playgrounds. **Training for educators:** Equipping teachers with knowledge on how to identify symptoms of lead poisoning and how to educate students on preventive measures. **Educational support for children affected by lead:** Ensuring that teachers and school administrators are knowledgeable about the prevalence of lead poisoning in their districts, and that services to support affected students are available.			
Ministry of Housing and Urban Development	**Enforcing lead-free/safe construction standards:** Creating and enforcing regulations to eliminate lead-based paint and/or ensure the safe use of lead in residential housing, health facilities, schools and early childhood development facilities.			
Ministry of Water	**Ensuring clean water supply:** Setting water quality standards, testing water systems for lead contamination and replacing lead pipes and components.			

Ministry	Role: What is their specific role in ending childhood lead poisoning?	Capacity gap analysis		
		Motivation: What is their understanding of the issue and the political will to prioritize?	**Authority:** Does the stakeholder have the mandate and authority to take action on the issue?	**Resources:** Does the stakeholder have the knowledge, skills, and organizational, human and material resources? If not, what's missing?
Ministry of Labour	**Workplace safety regulations**: Establishing and enforcing rules to protect workers in lead-related industries, and implementing training programmes for workers to reduce the risk of 'take-home' lead exposure affecting their families. **Child labour monitoring:** Ensuring children are not exposed to lead through illegal child labour in lead-related industries like battery recycling or mining.			
Ministry of Finance	**Funding for prevention and treatment:** Allocating budgets to support health care, environmental protection, education and lead remediation projects. **Tax incentives and subsidies:** Providing incentives to industries to reduce or eliminate lead use in consumer products, subsidies for safer alternatives, and measures to ensure safe industrial stewardship.			
Ministry of Social Welfare	**Support for affected families:** Conducting awareness programmes and providing social support – including nutrition and health care assistance – for families of children affected by lead poisoning; offering services for children who suffer developmental delays or disabilities resulting from lead poisoning.			

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