NATIONAL BLOOD LEAD LEVEL SURVEY

Ministry of Health
2024

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National Blood Lead Level Survey: 2024

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FOREWORD

With immense pride and a profound sense of responsibility, we present the National Blood Lead Level Survey 2024 report. This report represents a crucial step forward in assessing and addressing lead exposure among Bhutan's youngest citizens, specifically children aged 1 to 6 years. It provides essential insights that will guide our future strategies, policies, and interventions focused on protecting and promoting children's health.

Even trace levels of lead exposure can accumulate in a child's body over time, impacting brain development, organ function, and overall health. Such exposure is associated with reduced cognitive abilities, learning challenges, and various physical health issues. In later years, these effects can extend to a higher likelihood of hypertension, kidney disorders, cardiovascular diseases, and early mortality. The significance of these findings underscores the timely necessity of this study.

The survey was conducted as a component of the 2023 National Health Survey, employing both structured interviews to identify lead-related risk factors and blood sampling to measure levels of lead (Pb) and hemoglobin (Hgb). This survey also tested blood lead levels (BLLs) in pregnant or breastfeeding women and children from monastic institutions under 13 years of age.

The completion of this survey reflects the commitment, diligence, and expertise of our healthcare professionals, statisticians, field staff, and all involved stakeholders. We extend our sincere gratitude to the respondents whose willingness to participate made this report possible. We also acknowledge the invaluable financial and technical contributions of our development partners, whose support was integral from the survey's planning phase through to the final report.

Looking to the future, these findings will be instrumental in guiding resource allocation, formulating effective health policies, and implementing targeted interventions to improve health outcomes. We call upon all stakeholders, from policymakers and healthcare providers to community leaders and individuals, to actively engage with this report and work together towards our shared vision of a Bhutan where every child can thrive in a safe, lead-free environment.

Tandin Wangchuk
Health Minister

List of Abbreviations

BCDST	: Bhutan Child Developmental Screening Tool
BLL	: Blood Lead Level
BLRV	: Blood Lead Reference Value
CAPI	: Computer Assisted Personal Interview
CDC	: Center for Disease Control and Prevention
CLIA	: Clinical Laboratory Improvement Amendments
ECCD	: Early Childhood Care and Development
FNPH	: Faculty of Nursing and Public Health
g/dL	: Grams per Deciliter
g/L	: Grams per Liter
GDP	: Gross Domestic Product
HFC	: High Frequency Check
Hgb	: Hemoglobin
ILAC	: International Laboratory Accreditation Cooperation
IPSAHD	: International Partnership for Sustainable Advances in Health and Development
IQ	: Intelligence Quotient
LMIC	: Low- and Middle-Income Countries
LOD	: Level of Detection
µg/dL	: Micrograms per Deciliter
MoH	: Ministry of Health
NBLLS	: National Blood Lead Level Survey
NHS	: National Health Survey
OR	: Odds Ratio
Pb	: Lead
ppm	: Parts Per Million
pXRF	: Portable X-ray Fluorescence
RBC	: Red Blood Cells
TWG	: Technical Working Group
UNICEF	: United Nations Children's Fund
WHO	: World Health Organization

EXECUTIVE SUMMARY

Introduction

Lead is a naturally occurring heavy metal that humans have used in numerous products and applications for centuries. However, it is extremely toxic and can impact nearly every organ system, with blood lead levels above 150 micrograms per deciliter (µg/dL) posing a fatal risk.

According to WHO, UNICEF, and CDC, there is no safe level of lead exposure for the human body. Children are particularly vulnerable, absorbing 4 to 5 times more lead than adults. Even low amounts can accumulate in a child's body, and may lead to reduced IQ, poor academic outcomes, and a range of health problems. In later life, lead exposure is linked to increased risks for high blood pressure, kidney disease, cardiovascular conditions, and premature deaths, among others.

There is no treatment for lead poisoning except chelation therapy to reduce blood lead levels above 45 micrograms per deciliter. The chelation therapy, however, does not reverse the damage from lead poisoning. Therefore, preventing exposure to lead is of the utmost importance. The first steps in addressing this issue are to assess the extent of lead poisoning in the population, identify the sources of exposure, and then take preventive actions.

Prior to this survey, Bhutan had no data on blood lead prevalence at the national level. Lead prevalence data were limited to one facility-based study that found a high prevalence of elevated blood lead levels in children in Thimphu and Phuentsholing. In 2024, the Ministry of Health, with support from FNPH, IPSAHD, UNICEF and WHO conducted the National Blood Lead Level Survey to determine the national prevalence of lead poisoning among Bhutanese children and identify potential sources of lead exposure.

Objectives of the Survey

- To assess the blood lead levels in children in Bhutan.
- To identify the potential sources of lead in children’s environments.

Methods

The survey was a subset of the National Health Survey (NHS) 2023. The methods included questionnaire-based interviews to assess lead-related risk factors and collection of blood samples to measure lead (Pb) and hemoglobin (Hgb) levels. A total of 2,959 children between the ages of 1 and 6 years were tested. The survey also collected blood lead level (BLL) data from 124 pregnant/breastfeeding women and 207 children under 13 years old from monastic institutions. The data collection was carried out from April 19 to June 13, 2024. Using capillary blood sampling, the BLLs were tested using LeadCare II analyzers, and the hemoglobin levels were screened using the HemoCue® Hb 301 System. Sources of exposure were investigated in 67 households, six ECCDs, and four schools using two Olympus Vanta C Series portable XRF analyzers.

Key Survey Findings

- More than 3 out of 4 (75.9%) children tested had a BLL of 3.5 micrograms per deciliter or higher.
- Around 3 out of 5 (58.9%) of the pregnant and breastfeeding mothers tested had a BLL of 3.5 micrograms per deciliter or higher.
- More than 4 out of 5 (86.0%) children tested in monastic institutions had a BLL of 3.5 micrograms per deciliter or higher.
- Male children exhibited a higher prevalence of BLLs at or above 3.5 micrograms per deciliter (79.9%) compared to females (71.7%).
- Lead poisoning was extensive in all dzongkhags, in both rural and urban areas, and among households of all income levels.
- Anemia & developmental delays were found to be associated with BLLs.
- Among the source samples tested, lead exceeding the reference threshold was found in 44.2% of *Jinlab*, 20.0% of spices and foods, 21.5% of kitchen items, 9.1% of toys, 3.3% of soil, and 0.8% of paints tested.
- Children ever taking *Jinlab* and the recency of taking *Jinlab* were both associated with having a BLL ≥3.5 µg/dL.
- While 75.2% of religious and traditional Bhutanese objects and 47.2% of household hardware contained lead, the risk of exposure is currently unknown for these items.

Conclusions

There is a high prevalence of lead poisoning in Bhutan, with multiple sources of exposure, posing a significant public health and economic threat in the country.

A whole-of-government and whole-of-society approach is critical to address lead poisoning.

CHAPTER 1

Introduction and Health Effects from Lead

Background

Lead is a naturally occurring soft metal/element which has been used extensively in many ways. Lead, however, is a toxic poison and is detrimental to human health. It is especially harmful to children, infants, and even during fetal development. There is no known level of lead in the blood that is safe.(1)

The potential sources of lead are extensive. Lead has been used in many different applications. As a soft, malleable metal, it has been used in plumbing, cookware and as an alloy with other metals. While lead has been eliminated from most petrol, its use in pigments and paints means that lead can be found in toys, spices, cosmetics, kitchenware, pottery and many other consumer goods. Lead is also an essential component of lead-acid batteries and electronics.

Informal recycling of lead-acid batteries and e-waste can result in lead contamination of the environment. Lead is an element and therefore does not degrade. Proper disposal of lead is essential to prevent it from contaminating soil and water and posing a risk to the health of all living creatures. Strict regulation of the use and proper disposal of lead is lacking in many countries.

Children, infants, and pregnant and breastfeeding women are at the greatest risk from lead as their bodies require higher amounts of micronutrients. This increases the amount of lead their bodies absorb if they ingest or breathe in dust containing lead. Children and infants absorb 4-5 times more lead than a non-pregnant adult will.(1)

When a young child or infant ingests lead, it is absorbed and deposited primarily in the child's brain, followed by bones and other soft tissues. The neurological damage caused from the lead results in cognitive challenges, decreased IQ, poor school performance, and behavior changes.(1–3) The lead deposited in the brains of infants and children remains there permanently, causing lifelong consequences.(1,3)

Regardless of age, lead is also deposited in soft tissue, bones, and other body systems, causing multiple medical problems. Lead has been linked to cardiovascular, renal, reproductive, immunological, and endocrine problems.(4–7) A Lancet Public Health article concluded that low-level environmental lead exposure is an overlooked risk factor for high blood pressure, strokes, and death.(8)

When lead exposure is pervasive in a country, the consequences affect many aspects of life. A 2023 Lancet Planetary Health article estimated that in 2019, globally, lead caused a loss of 765 million IQ points in children less than 5 years of age and 5.5 million cardiovascular deaths. Over 90% of these losses occur in low- and middle-income countries (LMICs). The study also estimated the total cost of lead poisoning connected to cardiovascular disease and premature death. The combined cost from both of these as a percent of GDP is over 9% in South Asia and LMICs.(9) Using these estimates, Bhutan is potentially losing 22 billion Ngultrum ($260 million USD) annually, based on Bhutan's 2023 GDP.

As there is no level of lead in the blood that is safe, preventing lead exposure is essential and possible. The first step is to gather robust local data on both the prevalence and severity of lead poisoning and on the potential sources of lead.

In the first pediatric lead study, conducted in 2018 among 531 children ages 2-59 months old in Thimphu and Phuentsholing, 44% of those tested had a BLL greater than or equal to 5 µg/dL, and 80% had a BLL of 3.3 µg/dL or higher.(10)

The first X-Ray Fluorescence (XRF) study in Thimphu tested paint on walls, furniture, and toys in ECCD, healthcare facilities, and playgrounds searching for potential sources of lead in children's environments. Lead was detected only in lead-based paint in some playground equipment and on one plastic item.(11) These sources of lead however do not account for the high percentage of infants and children having lead in their blood.

Data on the prevalence and severity of BLLs and the potential sources of lead in the environment have been limited in Bhutan. Thus, this multi-phase National Blood Lead Level Survey (NBLLS) provided nationally represented data on the prevalence and severity of BLLs in Bhutan and investigated associations and the potential sources of lead in the environments of children. In addition, the first-ever data on BLLs in pregnant and breastfeeding women, as well as children under 13 years old in monastic institutions, were collected using convenient sampling.

Health Effects

Lead has been used for thousands of years. Symptoms of overt lead poisoning have been recognized for just as long. In the 20th century the use of lead in industrialized countries skyrocketed.(12) During that same time evidence increased showing how damaging lead was to the body.

In 2012, the United States' Centers for Disease Control and Prevention (CDC) recognized that no level of lead in a person was acceptable. That year the CDC lowered the US blood lead reference value (BLRV) to 5 µg/dL. This value is not a value that is considered "safe", but is a value set with national level data to identify the children whose BLL is in the top 2.5% of US national data. Exceeding this BLL prompts interventions to identify, reduce, and eliminate the sources of lead. In 2021, the US CDC again lowered the BLRV from 5 to 3.5 µg/dL.(12)

The WHO agrees that "there is no level of exposure to lead that is known to be without harmful effects." In 2023, the WHO published the third edition of Exposure to lead: a major public health concern which states, "subtle effects on intelligence quotient (IQ) can be associated with blood lead concentrations below 3.5 µg/dL". It went on to state that no threshold for the adverse effects of lead had been found.(13)

The damaging effects from lead increase as the level of lead increases. Very high levels of lead exposure may even cause death. However, most lead exposure is from lower-level exposure. Since lead is a cumulative toxin, long-term exposure to low levels of lead will build up in the body over time. This slow insidious accumulation of lead over time might take years or decades to show health effects.(1)

The effect of lead on children's health is primarily through damage to the developing nervous system. However, lead's impact continues throughout life. Behavioral and mental health issues can appear in childhood and early adulthood. As a person ages, lead's health effects connected to pregnancy, cardiovascular, and renal systems appear.(1-3)

The following table lists BLLs and the health conditions associated with them.

Effects of Blood Lead Level on Children and Adults

Blood Lead Level in micrograms per deciliter (µg/dL)		Effects on Children & Adults
	Less than 5 µg/dL	• Decreased IQ, cognitive performance, and academic achievement • Increased incidence of behavioral problems and diagnosis of attention deficit/hyperactivity disorder (ADHD) • Reduced fetal growth (based on maternal blood lead level) • Impaired renal function • Contributes to anemia
	Less than 10 µg/dL	• Delayed puberty • Developmental delay • High blood pressure • Increased cardiovascular-related mortality • Spontaneous abortion • Preterm birth
	Over 20 µg/dL	• Anemia
	Over 30 µg/dL	• Reduced nerve conduction velocity
	Over 40 µg/dL	• Peripheral neuropathy • Neurobehavioral effects • Abdominal colic
	Over 50 µg/dL	• Severe neurological features
	Over 90 µg/dL	• Encephalopathy
	Over 105 µg/dL	• Severe neurological features
	Over 150 µg/dL	• Death

Source: Adapted from the World Health Organization. (14)

Lead Absorption

Lead's primary route into a body is by ingestion and inhalation. Infants and children absorb 4-5 times more lead than non-pregnant adults. Pregnant and breastfeeding women also absorb more lead than a non-pregnant adult due to their increased nutritional requirements.(1)

The absorption of lead in the gut is directly related to nutrition. Because lead exists as a 2+ ion, the body confuses it with other 2+ ions such as calcium and iron.(12) When a malnourished person is exposed to lead, their body will actively absorb lead instead of necessary micronutrients. Lead poisoning, malnutrition, and anemia are all interconnected. A person with anemia will absorb more lead. High levels of lead can contribute to anemia also.

Lead Deposition

When lead enters the body, it is deposited in different places depending on the person's age. During fetal development and the early years of life (predominantly before 5 years old), lead is deposited between brain cells, in the bones and teeth, and in soft tissues including the kidneys, heart, and blood vessels. In children, 72% of lead is retained in bones.(15)

After early childhood, the blood brain barrier over the brain and nervous system matures and limits lead from being deposited there. However, the lead which was deposited in the brain earlier remains there permanently, causing problems for the rest of the person's life.

After childhood, lead is deposited in soft tissues including the kidneys, heart, blood vessels, and liver. In adults, 94% of retained lead is stored in bones.(15) Lead deposited in the bones is quite stable in adults, with a half-life of around 25 years.(14) This, however, creates a reservoir for a slow continual release of lead back into the bloodstream for the rest of life.

Lead in the blood has a shorter half-life of 30-40 days.(14) This means that if a person has lead in their blood and is exposed to absolutely no additional lead, their blood lead level (BLL) will decrease to ½ the original BLL in 30 days, ¼ the original BLL in 60 days, and so on. The half-life of lead in bones depends on age. Because children's bones are growing rapidly, the estimated half-life of lead in the bones is three months at birth, around 4 years in teenagers, and 25 years in adults.(14) Since there is no level of lead in the body that is safe, and lead in adults' bones persists for decades, the prevention of lead exposure at all ages is critical.

Neurodevelopmental, Learning, & Behavioral Issues

During fetal development and the early years of life, lead can be deposited between brain cells. The lead deposited in the brain interferes with the cellular communication between brain cells, causing problems with learning, planning, and impulse control that continue into adulthood. Lead is also linked to ADHD, increased psychiatric and social problems, conduct disorders, school delinquencies, and violent/criminal behaviors later in life.(1) Lead can decrease IQ by up to 9 IQ points, depending on the amount of lead deposited.(2)

Childhood exposure to lead is connected to lower academic achievements, higher dropout rates from school, and lower lifetime earning potential. Loss of IQ points occurs disproportionately more at BLLs below 10 µg/dL compared to BLLs above 10 µg/dL.(16) Research has shown that neurodevelopmental effects occur even at BLLs <3.5 µg/dL, and that an estimated 20 percent or more of the learning gap between rich and poor countries can be attributed to elevated blood lead levels in children's blood.(17)

Pregnancy Issues

During pregnancy and breastfeeding, there are two potential sources of lead for the woman. First, she can ingest or inhale lead. Secondly, lead in a woman's bones deposited earlier in life can come out through a remodeling process of the bones that naturally occurs during pregnancy and breastfeeding.

During pregnancy, higher BLLs increase the risk of pre-eclampsia (hypertension in pregnancy) which increases the risk of maternal and/or fetal death. Lead in pregnancy also increases the risk of having a stillbirth/miscarriage, poor fetal growth, premature birth, and having a low-birth-weight baby.(1,18) For every 1 µg/dL increase in the mother's BLL, there is a 70% increase in the risk of preterm delivery. Low vitamin D levels combined with lead exposure increases the risk of a preterm delivery by a factor of three.(19) Concerningly, a study at Jigme Dorji Wangchuck National Referral Hospital in 2023 found low vitamin D levels in women.(20)

Cardiovascular Issues

Lead exposure is a leading risk factor for cardiovascular morbidity and mortality. This includes hypertension, atherosclerosis/coronary artery disease, heart attacks, and strokes. Studies have shown associations between BLLs and all-cause and cardiovascular mortality.(6,8,12) Studies show a significant increase in coronary artery calcification with BLL increases of as little as 1 µg/dL.(21)

With the reduction of lead use in the United States starting in the 1970s, mean BLLs in the US have dramatically decreased. A significant reduction in the rates of hypertension and cardiovascular deaths during the same period are attributed to the reduction in lead exposure.(12) In contrast, lower- and middle-income countries have seen the rates of cardiovascular morbidity and mortality increasing over the past decades. Lead is a likely contributor to this ever-increasing problem globally.

Research continues to strive to understand the duration of lead exposure that is necessary for cardiovascular morbidity and mortality. Clearly, however, the cumulative exposure to lead is very important. Chronic low level lead exposure may be as bad as brief exposures to higher levels of lead. Research from the US acknowledges that without efforts to further reduce lead exposure in the US, it will be challenging to further reduce cardiovascular morbidity and mortality.(8)

Renal Issues

Lead exposure, even at low levels, is a known risk factor for chronic kidney disease. Studies have shown that adults having a BLL between 2.4 – 3.3 µg/dL or higher have approximately a 50% higher risk of chronic kidney disease compared with adults with a BLL ≤1.1 µg/dL.(22,23) As Bhutan has a large and increasing number of renal transplant patients, those on dialysis, and those with chronic kidney failure, this is an area of concern.

Diagnosis of Lead Poisoning

The symptoms of lead poisoning are vague and nonspecific, making a clinical diagnosis impossible. A blood lead level test is necessary to diagnose the condition.(1)

Treatment Options

Treatment of lead poisoning through chelation of lead from the blood can be done. However, due to complications and risks from chelation, treatment is currently limited to individuals with a BLL ≥45 µg/dL.(14) Even if chelation treatment is given to reduce the amount of lead in the blood, it does not reduce any neurodevelopmental consequences or reduce the lead stored in bones.

Preventing the exposure of lead to everyone is critical!

CHAPTER 2

Survey Methodology and Materials

Survey Design

The National Blood Lead Level Survey (NBLLS) 2024 is a subset of the National Health Survey (NHS) 2023, making it a two-stage, household-based survey. The first stage, NHS 2023, was designed by the National Statistics Bureau and the Ministry of Health to generate key health indicators for all 20 dzongkhags and four thromde in Bhutan. The second stage, NBLLS, selected all households from the NHS 2023 with a child aged 1-6 years. The survey employed a rigorous sampling design to ensure that the findings could be generalized to the entire population of children 1-6 years old.

Phases of the Survey

The NBLLS comprised two concurrent phases:
Phase 1: Nationally representative data on blood lead levels (BLLs) and hemoglobin (Hgb) in children aged 1-6 years were collected, along with developmental screening data for children 1-5 years old. As a secondary objective, BLL were gathered from pregnant and breastfeeding women in the selected households.

Phase 2: Households of children with the highest BLL in Phase 1 were revisited the following day to test other household members and conduct environmental testing for potential lead sources.

General Research Objectives

1. To assess the blood lead levels in children in Bhutan.
2. To identify the potential sources of lead in children's environments.

Specific Research Objectives

Phase 1:

1. Determine the range of BLLs and the national prevalence of BLLs greater than or equal to (≥) 3.5 µg/dL in children 1 – 6 years old.
2. Study the association between BLLs ≥3.5 and ≥5 µg/dL and select risk factors.
3. Examine the impact of BLLs on children, focusing on their association with hemoglobin (Hgb) levels and developmental delays.

Phase 2:

1. Identify the extent of blood lead levels among household members of children with the highest BLLs from Phase 1.
2. Identify potential sources of lead in the home, creche, ECCD centers, and pre-school environments of children with the highest blood lead levels.

Secondary Objectives

1. Determine the prevalence of BLLs ≥3.5 µg/dL among women who were pregnant and/or breastfeeding within 6 months of delivery in the selected households of phase 1.
2. Determine the prevalence of BLLs ≥3.5 µg/dL in children less than 13 years old in monastic institutions.

Phase 1

Sample Size Determination

A multi-stage cluster sampling method was used to select a nationally representative sample for the NHS 2023. Since the NBLLS 2024 was a subset of NHS 2023, the required sample size of children aged 1–6 years for the NBLLS 2024 was calculated in three steps with the following sample size calculation assumptions:

Step 1: Initial calculation

$$n=\frac{Z^2_{1-a}\,p(1-p)}{d^2}$$

Where:

Z = Level of confidence. This describes the level of uncertainty in the sample prevalence as an estimate of the population prevalence. For a 95% confidence level with α = 0.05, for this study Z = 1.96.

P = Baseline level of the indicator. This was taken as the percentage of children who had a blood lead level (BLL) of 3.3 µg/dL or higher, based on a 2018 hospital-based study (P = 0.8).

d = Margin of error. This is the expected half-width of the confidence interval. A margin of 0.05 was used for this study.

$$n=\frac{1.96^2 \times (0.8 \times (1-0.8))}{0.05^2} = 245.8624$$

Step 2: Survey domain and design effect

The number of survey domains was set at six age groups of children, ensuring adequate representation for each of the six sub-groups. A design effect of 2 was applied to address the impact of cluster sampling.

$$n= 245.8624 \times 2 \times 6 = 2950.3488$$

Step 3: Adjustment for expected non-response

An 80% response rate was anticipated, and the sample size was adjusted to account for expected non-response.

$$n= 2950.3488/0.8 = 3687.936 \approxeq 3688 \text{ (rounded)}$$

Given that the NHS 2023 included 3,627 children, the Technical Working Group (TWG) of the NBLLS decided to include all eligible children aged 1–6 years from the NHS 2023 in the NBLLS 2024.

For the secondary objectives, all women in the selected households who were either pregnant or who were breastfeeding and had delivered within the prior 6 months were included. For gathering preliminary data on blood lead levels (BLLs) among monastic children under 13, the field teams selected 0-3 monastic institutions per dzongkhag as time permitted. This purposive sampling approach provided valuable initial insights into BLL prevalence within the group.

Inclusion Criteria

1. All children greater than or equal to 12 months of age through 6 years of age (<84 months) who were listed in NHS 2023 data. If a child turned 7 years old during the data collection they were still included.
2. Women of any age who were pregnant and/or breastfeeding within 6 months of delivery in the selected households of phase 1.

Exclusion Criteria

1. Children who were not present on the day of the household visit. (Reasonable attempts were made to contact and include all eligible children).
2. Children 1 through 6 years of age who were currently living in the household, who however, had not been living in the household at the time of the NHS 2023.
3. Households where the family living there had changed since the NHS 2023 data were originally collected.

Questionnaire Design and Data Collection

The questionnaire for the National Blood Lead Level Survey (NBLLS) was designed after reviewing international and regional literature on the potential sources of lead. Information on lead risk factors was also available from Bhutan's 2018 hospital-based study as well as suspected sources of lead within Bhutan from pre-survey portable X-ray fluorescence (pXRF) testing. The questionnaire was validated by the technical working group (TWG). Data for this survey were collected digitally using Survey Solutions software on tablets. This allowed for accurate and efficient data capture directly in the field, reducing errors and streamlining the data collection process.

Training of Enumerators

Three days of comprehensive training were provided to all enumerators, including guidance on translating complex questions. A glossary of technical terms was distributed in the predominant local languages. Interviews were conducted in the language or dialect most familiar to participants, as determined by the interviewers. To minimize the risk of mistranslation, all the interviewers were health workers with experience in conducting surveys and with regional language competency. During data collection, each team was accompanied by a supervisor, and members of the NBLLS technical working group were available to assist with any queries, ensuring standardized procedures across all sites.

Data Collection Protocol

Following the identification of eligible households from the NHS 2023 roster, trained enumerators visited the selected homes. At the onset of each household visit, the survey was explained to the adult caregiver, and written informed consent was obtained for participation.

The initial step involved confirming the demographic details of all children aged 1 - 6 years. Next, a series of household-related questions, which pertained to all household members, were asked. Subsequent questions focused on assessing child-specific risk factors. In households with pregnant women or women who had delivered within the past 6 months and were breastfeeding, a limited set of questions was administered to gather additional data.

Upon completion of the questionnaire, all children between 1 and 5 years of age underwent developmental screening using the Bhutan Child Developmental Screening Tool (BCDST). The BCDST is a set of tools validated and used in Bhutanese children aged 2 months to 5 years of age.

Next, two capillary blood samples were collected from all children and women for BLL and Hgb analysis. Enumerators followed a protocol to minimize environmental lead contamination during sample collection. Samples for BLL testing were collected for later analysis. Hemoglobin testing was performed in the home immediately on a HemoCue Hb 301 analyzer carried by each enumerator.

Following the Hgb test, the results were recorded in the computer assisted personal interview (CAPI) system. Hemoglobin results were interpreted based on WHO 2024 anemia guidelines and reassurance, nutritional advice, or a referral to the nearest healthcare facility was provided. Finally, a colored educational lead flyer, printed in both English and Dzongkha, was explained and left with each household. The flyer provided information and recommendations to reduce lead exposure. The complete protocol for Phase 1 data collection is provided in appendix 1.

Blood Handling and Lead Testing Protocol

BLL blood samples were transported daily to a central testing location in each dzongkhag for testing. Testing of samples typically occurred on the evening they were collected. For samples from more remote areas for which testing could not happen within 48 hours, the blood samples were kept in a cold box and tested within seven days.

Blood lead levels (BLLs) were analyzed by trained enumerators using four LeadCare II analyzers. All central testing sites were selected to be at elevations below 8,000 feet (2,438 meters), which is the LeadCare II approved limit.

In some remote areas which required days of trekking to reach, Phase 1 and Phase 2 XRF enumerators traveled together. Two blood samples were collected for BLL testing. One sample was tested immediately to direct Phase 2 household and XRF testing. The second sample of blood was stored in a cold box and transported to an elevation below 8,000 feet for testing on the LeadCare II analyzer. The second value was considered the participant's true BLL for entry into CAPI and for data analysis. The protocol for BLL testing is provided in appendix 2, and the rationale for using the LeadCare II for BLL testing is provided in appendix 3.

Blood Lead Level Results and Phase 2 Selection

The BLL results were reviewed daily. The enumerator who collected the blood contacted the parent, guardian, or participant to inform them of the test results. All children with a BLL ≥20 µg/dL in Phase 1 were included in Phase 2 testing. If no child had a BLL ≥20 µg/dL on a day of testing, the household with the child having the highest BLL ≥10 µg/dL was selected for Phase 2.

Phase 2

Household Members' Blood Lead Level and Lead Source Testing

Households for Phase 2 were selected based on the child's BLL in Phase 1. Three attempts were made to contact the parent or guardian for Phase 2 testing. If a household selected for Phase 2 testing could not be contacted or the household declined to be in Phase 2, the household with the child with the next highest BLL was substituted.

Inclusion Criteria

- All household members ≥2 months of age who were present at the time of the visit.
- Any child or woman tested in Phase 1 with a BLL ≥30 µg/dL

Exclusion Criteria

- Any child or woman who was previously tested by the NBLLS enumerators in Phase 1 AND whose BLL was <30 µg/dL.

Data Collection Protocol

Phase 2 teams consisted of two to three enumerators, at least one of whom had additional XRF safety and testing training. Each Phase 2 team traveled to the households with a LeadCare II analyzer, HemoCue Hb 301 analyzer, and a portable X-ray fluorescence (pXRF) analyzer.

A listing of household members willing to participate in the survey was entered into the CAPI from oldest to youngest, along with age and sex. Next, all eligible household members had their capillary blood collected in a process identical to Phase 1, with a few exceptions. If the household was below 8,000 feet elevation the BLLs were tested at the home. For households at higher elevations, blood samples were collected and transported to a central testing location below 8,000 feet. For infants under 12 months of age, blood collection was performed via a heel stick.

If anyone from Phase 1 or during Phase 2 had a BLL ≥30 µg/dL, a repeat blood sample was collected from a different finger after thorough cleaning and tested. The lower of the two BLLs was considered the correct result. A referral to a healthcare facility was provided for anemia like in Phase 1, and a referral to a healthcare facility was given for any BLL ≥30 µg/dL.

Protocol for the X-Ray Fluorescence Environmental Testing

After completing the household BLL and Hgb testing, environmental testing for lead was conducted using an Olympus Vanta C series portable X-Ray Fluorescence (pXRF) analyzer. In each home, teams tested paint on walls, toys and other items used by the child, kitchenware used for preparing and eating food, spices, soil, and any other high touch items.

Portable XRF (pXRF) testing was conducted at each of the households selected for Phase 2 testing. In addition, pXRF testing was conducted at the creche, early childhood care and development center (ECCD), or pre-primary school where the child from the household attended. Additionally, as time permitted, one household from each dzongkhag with a child having a BLL (<3.3 µg/dL) was selected for Phase 2 XRF source testing, but no additional blood testing of household members was done.

If pXRF testing identified items with a high risk of lead exposure, recommendations were given according to protocol. The same lead flyer provided in Phase 1 was again discussed and provided to the household. Phase 2 testing protocol is provided in appendix 4.

Data Management

The data from Phase 2 were entered into the CAPI. The CAPI data from pXRF testing were merged with the data downloaded directly from the pXRF analyzers at the end of the survey.

Protocol for Testing the Blood Lead Levels and Hemoglobin in Young Monastic Children

During the National Blood Lead Level Survey (NBLLS), visits were arranged to monastic institutions selected through purposive sampling. At each institution, the purpose of the study was explained to an adult decision-maker, and consent was obtained. Verbal assent was also secured from each participating child before data collection began.

Each child’s name and age were recorded in CAPI. Next, blood samples were collected following the same protocol as used in Phase 1. The child’s Hgb was tested on-site using a HemoCue Hb 301 analyzer. All BLL samples were transported to a central location for testing, as was done in Phase 1.

Information on each child's Hgb level was provided to a responsible person at the monastic institution, and appropriate actions were taken. Additionally, each institution received a colored handout outlining steps to reduce lead exposure. The monastic data collection protocol is provided in appendix 5. No pXRF source testing was conducted at monastic institutions.

Ethical Review, Approvals, and Informed Consent

Risks:

For participants of blood testing:

- They experienced a small prick to the finger or heel (in infants) to draw a few drops of blood and possibly mild soreness.
- There was a very small chance of an infection to the prick site. No reports of any infections were reported to the survey team.
- Knowing they or their child had lead in their blood may have caused psychological stress, however no specific incident of this was reported to the survey team.

For sites of pXRF testing:

- The pXRF analyzer produces X-ray radiation, which could cause harm to the user or those around them if used improperly. However, only enumerators with training in the safe use of the pXRF analyzer conducted testing. This minimized any risk.
- There was the potential of psychological stress created by lead being found in items which were tested. No instances of stress were reported to the survey team.

Administrative clearance was obtained from the Ministry of Home Affairs, and ethical clearance was granted by the Ministry of Health, Bhutan.

Prior to participation, individuals were briefed about the purpose and scope of the survey, including the confidentiality of the information, and were informed that they had the right to withdraw at any time. During all phases, informed written consent, verbal assent and/or written assent was sought as required. During Phase 2, informed consent to conduct XRF testing of items was taken from the head of the household or an adult decision maker in the household. If no adult was available at the house, creche, ECCD, or pre-primary school, testing was not conducted at that site. All consents and assents were provided in English and in Dzongkha. All enumerators involved with the survey were trained on this topic.

Duration of the Data Collection

The data collection was conducted between April 19th and June 13th, 2024.

Limitations

Due to limited laboratory testing capability in Bhutan, the survey could not do venous blood confirmation of high BLLs from the LeadCare II analysis. Neither was lead testing possible in water samples, leach testing in kitchen items, or dust wipe testing for lead possible.

Data Management

The answers to all questions were entered directly into a tablet (CAPI). Parameters for acceptable values and alerts were used to minimize errors. The Hgb values were recorded in the tablet in the homes. The BLL results were recorded into the tablet as soon as they were tested. The electronic data were kept secure by the MoH/NBLLS team.

Data processing and Data Analysis

During the data collection, an independent consultant conducted periodic spot checks and verification of data known as High Frequency Checks (HFC). During the analysis, a series of data management processes (cleaning, sorting, processing and imputations) were performed by the NBLLS technical working group. Sampling weights for child responses were generated and attached to the files before the analysis, and weighted analysis was carried out for all the indicators related to children 1-6 years old. Statistical analyses were performed using Stata/MP 18.0 (StataCorp LLC, College Station, TX, USA).

The data from the NBLLS were integrated with the National Health Survey 2023 (NHS 2023) to enhance the dataset with additional household and individual-level demographic characteristics. Specifically, household-level variables, such as income quintile and rural/urban classification were combined with individual-level data, including maternal demographic information. The integration of these datasets was facilitated through the use of a Unique Identifier (ID) that was consistently generated across both the NBLLS and NHS 2023 datasets. This Unique Identifier (ID) was also utilized to merge the combined NHS 2023 and NBLLS dataset with ancillary data sources collected during the survey.

Specific Equipment and Materials Used

<u>LeadCare II analyzer & reagents</u>
Meridian Bioscience, USA
LeadCare II is a portable analyzer which uses anodic stripping voltammetry to determine the amount of lead in a capillary blood sample. The analyzer is US Food and Drug Administration (FDA) approved and Clinical Laboratory Improvement Amendments (CLIA) waived. Reporting range is from 3.3-65 µg/dL.

<u>HemoCue® Hb 301 analyzer & cuvettes</u>
HemoCue AB, Sweden
This is a portable automated point-of-care device for measuring hemoglobin in 10 microliters of capillary whole blood. The measurement range is 0 to 26 g/dL.

Olympus Vanta C portable XRF analyzer & accessories
Evident / Olympus Scientific Solutions, USA
A portable X-Ray Fluorescence (pXRF) analyzer with a silver (Ag) anode was used. The analyzer included software specific for lead testing and included necessary attachments. The level of detection (LoD) for lead is around 2 parts per million (ppm), depending on the testing method used.

D-Wipe Towels
ESCA Tech, USA
These are pre-moistened towels with a pH balanced solution designed to lift and bind metal dust for quick removal from the skin without rinsing.

D- Lead Surface Wipes
ESCA Tech, USA
These are large disposable pre-wet wipes designed to lift and bind metal dust for surface cleaning.

MiniCollect® Safety Lancets
Greiner, Austria
Three sizes of age-specific lancets were obtained: Blade width 1.5 mm x 1 mm depth, width 1.5 mm x 1.5 mm depth, and 1.5 mm x 2 mm depth.

CHAPTER 3

Response Rate and Description of Survey Participants

Background

This chapter presents the response rate for the primary target population of children 1-6 years old and describes their background characteristics. It also provides a description of three other target populations: pregnant and/or breastfeeding women, children from monastic institutions less than 13 years old, and Phase 2 household contacts.

Response Rate

Out of 3,627 eligible children identified from the National Health Survey (NHS) 2023 dataset, blood lead levels were tested on 2,959 children, resulting in an overall response rate of 81.6% (Figure 3.1). Despite a gap in time of approximately one year between the surveys and the NBLLS requiring a capillary blood test, the survey had a high response rate, exceeding expectations. As anticipated, the response rate in rural areas (84.1%) was higher than in urban areas (78.0%).

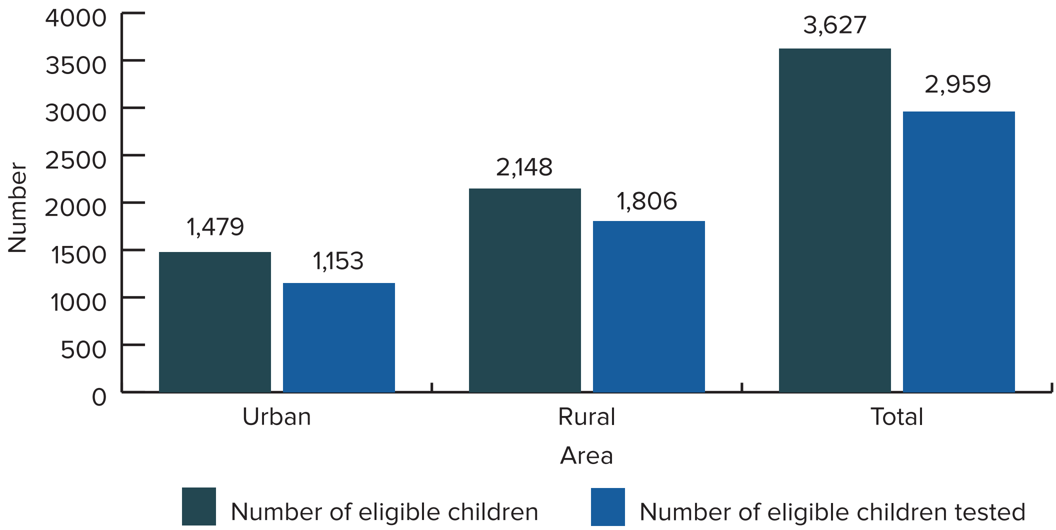

Figure 3.1: Number of children 1-6 years old who were eligible and tested for BLLs by area of residence [National Blood Lead Level Survey 2024].

Description of Survey Participants

Participants were distributed evenly by age groups, sex, and household income quintiles. The number of participants by age groups ranged from a minimum of 411 among 1-year-old children, to a maximum of 581 among 6-year-old children (Figure 3.2). The mean age of children in this group was 49 months old. Male children comprised 52.2% of the participants. The fourth highest income quintile had the most participants (21.3%) while the highest income quintile had the lowest percentage (18.7%).

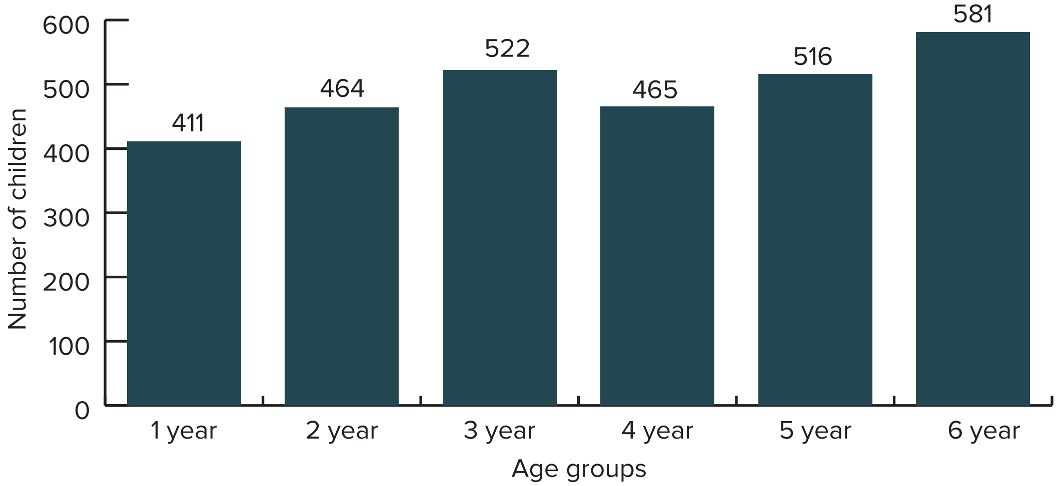

Figure 3.2: Number of children in the survey by age groups [National Blood Lead Level Survey 2024].

Although the survey was not explicitly designed to generate dzongkhag-level prevalence estimates for blood lead levels (BLLs), it had sufficient power to provide reliable prevalence data even at the dzongkhag level. The number of participants ranged from a minimum of 49 in Gasa Dzongkhag to a maximum of 457 in Thimphu Dzongkhag.

Additionally, the survey collected BLL data from 124 pregnant and/or breastfeeding women. Forty-six percent of the women were in the 15–29-year-old age group, and the remainder were in the 30-49 age range. Forty percent of the women were from urban areas, and 50% had less than a class 12 education.

Among the 207 children under 13 years of age from 17 monastic institutions, the youngest child tested was 4 years old, and the mean age of the children tested from monastic institutions was 11 years old. Most of the children tested in monastic institutions were male (male: 202, female: 5).

Among Phase 2 household members, a total of 128 household members were tested in 67 homes. They ranged in age from 7 months - 87 years old, with an average age of 31 years old. Males made up 46% of the household members.

CHAPTER 4

Lead Poisoning Prevalence

Prevalence of Lead Poisoning in Children 1–6-Years Old

Key findings

- An alarming percentage (75.9%) of children 1-6 years old had blood lead levels (BLLs) ≥3.5 µg/dL.
- A high prevalence of BLLs ≥3.5 µg/dL was observed across all age groups, ranging from 73.9% among 4-year-old children to 78.8% among 1-year-old children.
- Males exhibited a higher prevalence of BLLs ≥3.5 µg/dL (79.9%) compared to females (71.7%).
- The prevalence of BLLs ≥3.5 µg/dL was slightly higher in urban areas (77.0%) compared to rural areas (75.2%).
- The data demonstrated a high prevalence of BLLs ≥3.5 µg/dL across all income quintiles. For instance, 76.5% of children in the "Lowest" income quintile had BLLs ≥3.5 µg/dL, compared to 75.6% in the "Highest" income quintile.

Background

Lead exposure in early childhood poses significant health risks, including cognitive impairment, developmental delays, and behavioral issues. The World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC) have established that there is no safe level of lead in blood. The CDC currently has set a blood lead reference value (BLRV) of 3.5 µg/dL to identify children with a blood lead level (BLL) who may need intervention.

International literature reveals that BLLs in children vary significantly worldwide, with higher prevalence rates in low-and middle-income countries (LMICs) where environmental and industrial exposures are less regulated. Studies from South Asia, Africa, and parts of Latin America show that BLLs in children frequently exceed WHO and CDC reference levels. This is due to lead contamination in spices, aluminum cookware, glazed pottery, ayurvedic medicines, lead-based paints, contaminated water, and exposure to lead from informal industries.

Results

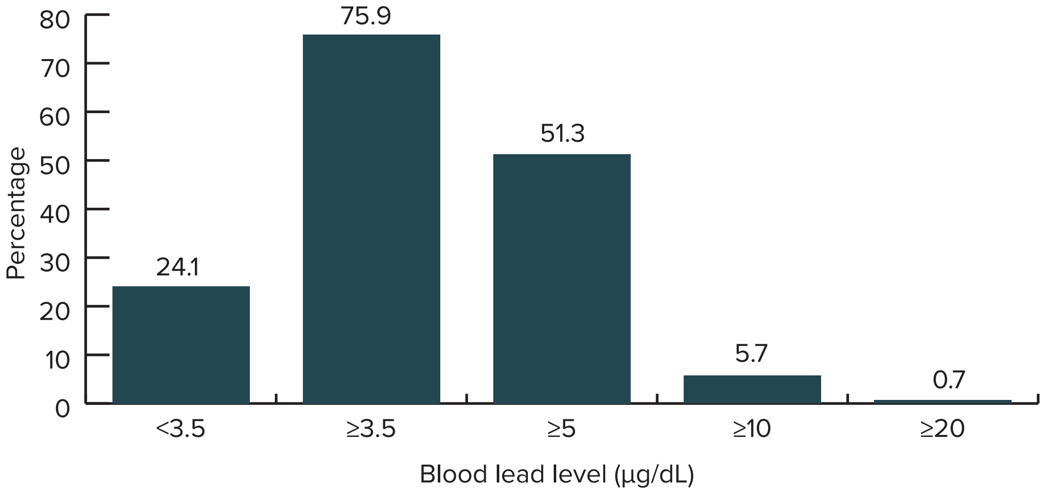

Figure 4.1: Percentage of children 1-6 years old with various blood lead levels [National Blood Lead Level Survey 2024].

Figure 4.1 shows that 75.9% of Bhutanese children had a blood lead level (BLL) ≥3.5 µg/dL, and more than half (51.3%) of the children 1-6 years old had a BLL ≥5 µg/dL. The data on BLLs of children 1-6 years old revealed a significant public health concern with lead exposure across the population. However, none of the children tested had a blood lead level above 45 µg/dL, which would have required medical chelation treatment to lower the BLL rapidly.

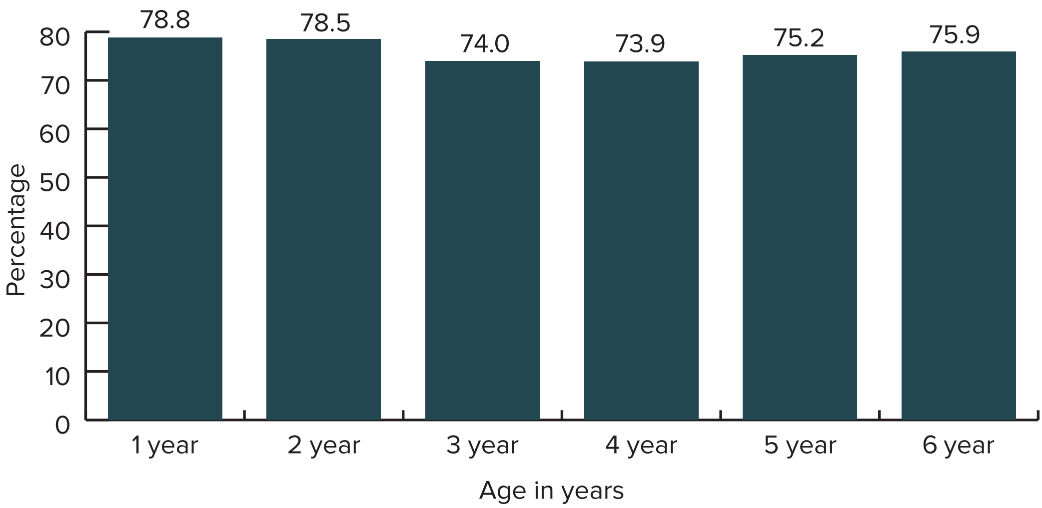

Figure 4.2: Percentage of children 1-6 years old with a blood lead level ≥3.5 µg/dL by age [National Blood Lead Level Survey 2024].

Figure 4.2 shows that a large proportion of children in all six age groups had a BLL ≥3.5 µg/dL, with percentages ranging from 73.9% to 78.8%. Notably, children 1 and 2 years old exhibited the highest percentages of BLLs ≥3.5 µg/dL, at 78.8% and 78.5%, respectively. Children one and two years old had the highest percentages of BLLs ≥3.5 µg/dL, ≥5 µg/dL, and ≥10 µg/dL.

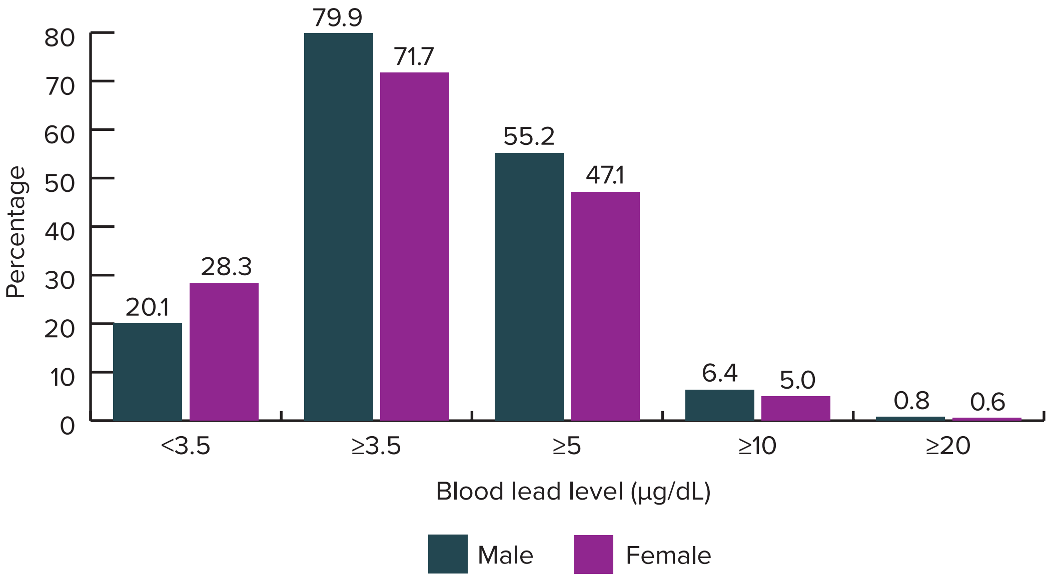

Figure 4.3: Percentage of children 1-6 years old with various blood lead levels by sex [National Blood Lead Level Survey 2024].

Overall, males were at greater risk of higher BLLs across all levels. A higher percentage of males (79.9%) had a BLL ≥3.5 µg/dL compared to females (71.7%). At more concerning BLLs, males always had higher percentages compared to females. Although the percentages of children with extremely high BLLs (≥20 µg/dL) were relatively low for both genders, males (0.8%) still showed a slightly higher prevalence than females (0.6%).

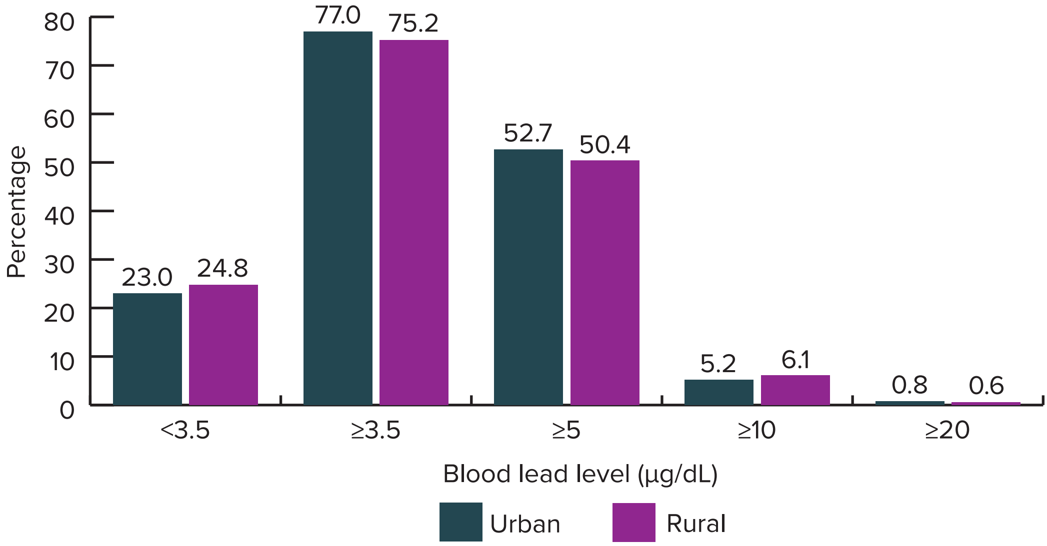

Figure 4.4: Percentage of children 1-6 years old with various blood lead levels by area [National Blood Lead Level Survey 2024].

The BLL data for children 1-6 years old revealed some differences between urban and rural settings. In urban areas, 77.0% of children had a BLL ≥3.5 µg/dL, slightly more than in rural areas (75.2%). At all BLLs, urban areas had higher percentages than rural areas, except for BLLs ≥10 µg/dL where rural areas had a higher percentage.

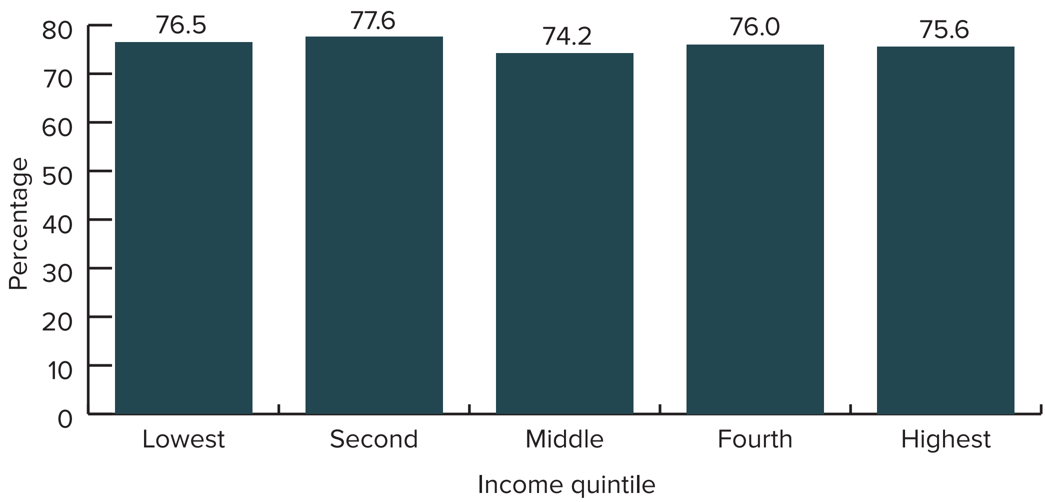

Figure 4.5: Percentage of children 1-6 years old with blood lead levels ≥3.5 µg/dL by family income quintiles [National Blood Lead Level Survey 2024].

Across all quintiles, a consistently high percentage of children had a BLL ≥3.5 μg/dL, ranging from 74.2% to 77.6%. The second income quintile (77.6%) and lowest income quintile (76.5%) had slightly higher percentages of children with BLLs ≥3.5 μg/dL compared to other quintiles.

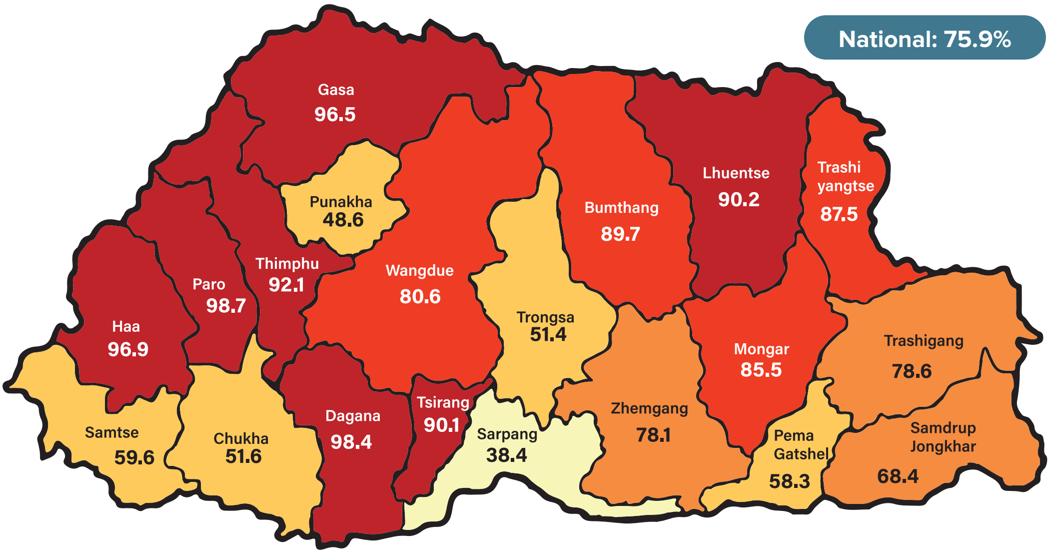

Figure 4.6: Percentage of children 1-6 years old with blood lead levels ≥3.5 μg/dL by dzongkhags [National Blood Lead Level Survey 2024].

The analysis of blood lead levels in children aged 1-6 years across various dzongkhags and regions in Bhutan revealed significant variation (Figure 4.6). The highest percentage of blood lead levels ≥3.5 μg/dL was observed in Paro (98.7%) and other dzongkhags in the northwest. In contrast, the lowest percentage of children aged 1-6 years with blood lead levels ≥3.5 μg/dL was found in Phuentsholing Thromde (an urban area under Chukha Dzongkhag), where 13.3% of children had a level ≥3.5 μg/dL, followed by Gelephu Thromde (an urban area under Sarpang Dzongkhag) at 20.2% and Sarpang Dzongkhag at 38.4%.

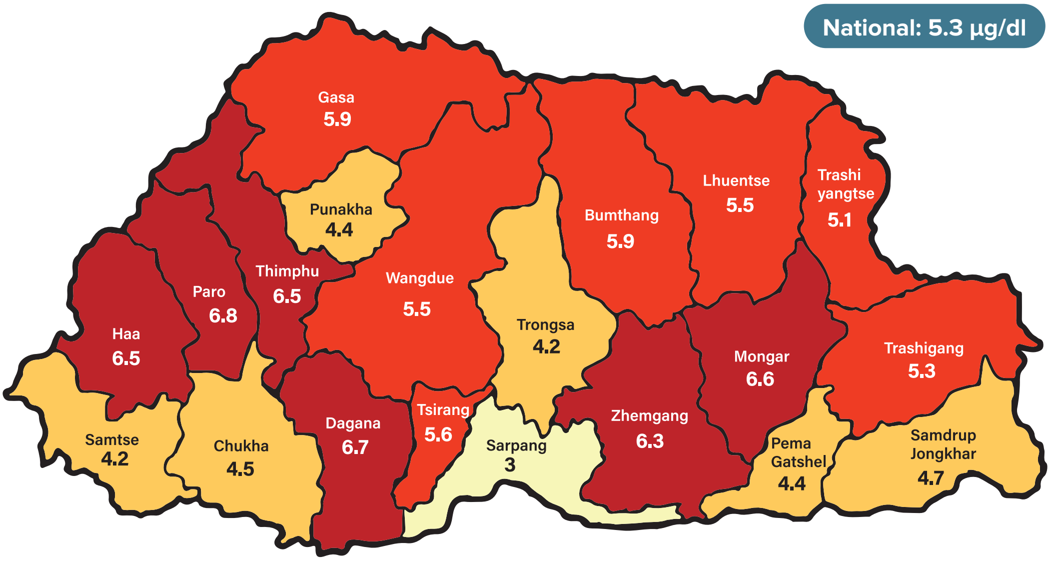

Figure 4.7: Mean blood lead level in children 1-6 years old by dzongkhag [National Blood Lead Level Survey 2024].

Overall, the mean blood lead level of children 1-6 years old was 5.3 µg/dL. Notably, higher mean BLL values were concentrated in western and central dzongkhags, with Paro (6.8 µg/dL), Dagana (6.7 µg/dL), and Mongar (6.6 µg/dL) showing elevated levels compared to the national mean. In contrast, southern dzongkhags such as Sarpang (3 µg/dL) and Samtse (4.2 µg/dL) reported lower mean BLLs. The central dzongkhag of Trongsa also displayed a lower level (4.2 µg/dL), potentially indicating regional variations in exposure sources.

CHAPTER 5

Anemia, Developmental Delays and Blood Lead Levels

Anemia

Key findings

- The overall prevalence of anemia among children 1-6 years old was 38.7%.
- The percentage of children with anemia rose as blood lead levels increased, indicating a strong link between lead exposure and anemia risk.
- The odds of anemia progressively increased with higher lead exposure, showing a clear trend that blood lead levels were associated with increased anemia risk in children.

Background

Exposure to lead can disrupt various biological systems, including the hematological system, leading to anemia. Factors contributing to anemia include nutritional deficiencies, chronic illnesses, and toxic exposures, including lead. Anemia is characterized by a decrease in red blood cell (RBC) count or hemoglobin levels below the reference range for a given population, which reduces the blood's oxygen-carrying capacity. The World Health Organization (WHO) defines anemia in children as a hemoglobin concentration of less than 11 g/dL. According to Bhutan's National Nutrition Survey 2015, the prevalence of anemia among children aged 6–59 months significantly declined from 80.6% in 2003 to 43.8% in 2015. The National Health Survey (NHS) 2023 found that 44.7% of the children aged 6-59 months were anemic. Anemia in this age group remains a public health concern of 'severe' significance, as defined by the World Health Organization's anemia prevalence classification.

Anemia poses a significant public health challenge, particularly in children, as it can hinder cognitive development, impede growth, and compromise overall health. Epidemiological studies demonstrate a clear correlation between elevated blood lead levels and increased rates of anemia in children. Even low levels of lead exposure are associated with a risk of anemia. Therefore, there is an urgent need for monitoring of blood lead levels in children and developing interventions to reduce lead exposure.

During the analysis of the anemia data, a standardized adjustment approach for hemoglobin concentrations, applicable across diverse population groups, was used to account for the effects of living at various elevations above sea level.

Table 5.1: Adjustments to hemoglobin concentration (g/L) in 500-meter increments in elevations [National Blood Lead Level Survey 2024].

Elevation range (meters above sea level)	Adjustments[a] in hemoglobin concentration (g/L)[b]
1-499	0
500-999	4
1000-1499	8
1500-1999	11
2000-2499	14
2500-2999	18
3000-3499	21
3500-3999	25
4000-4499	29
4500-5000	33

a. Adjustments are the amount subtracted from an individual's observed hemoglobin level or added to the hemoglobin cutoff defining anemia (in g/L).

b. Proposed adjustments for all population groups based on the equation: Hemoglobin adjustment (g/L) = $(0.0056384 \times \text{elevation}) + (0.0000003 \times \text{elevation}^2)$

Table 5.2: Hemoglobin cutoffs to define anemia in children aged 1-6 years old [National Blood Lead Level Survey 2024].

Population	Hemoglobin concentration (g/L)
Children, 6 - 23 months	<105
Children, 24 – 59 months	<110
Children, 5 – 11 years	<115

Further, the following cutoffs were used in defining anemia severity in individuals based on the updated WHO "Guideline on haemoglobin cutoffs to define anemia in individuals and populations."(24)

Table 5.3: Hemoglobin cutoffs to define anemia classification in children 1-6 years old [National Blood Lead Level Survey 2024].

Population	No Anemia (g/L)	Mild (g/L)	Moderate (g/L)	Severe (g/L)
Children, 6 - 23 months	≥105	95-104	70-94	<70
Children, 24 – 59 months	≥110	100-109	70-99	<70
Children, 5 – 11 years	≥115	110-114	80-109	<80

Results

The study analyzed the blood hemoglobin levels of 2,958 children and assessed the relationship between blood lead levels and the prevalence of anemia. The overall prevalence of anemia among children aged 1-6 years was 38.7%, with only 0.5% of the children having severe anemia. For comparison, the NHS 2023 found a prevalence of anemia of 44.7% in children 6-59 months old, which is a younger population than in the NBLLS.

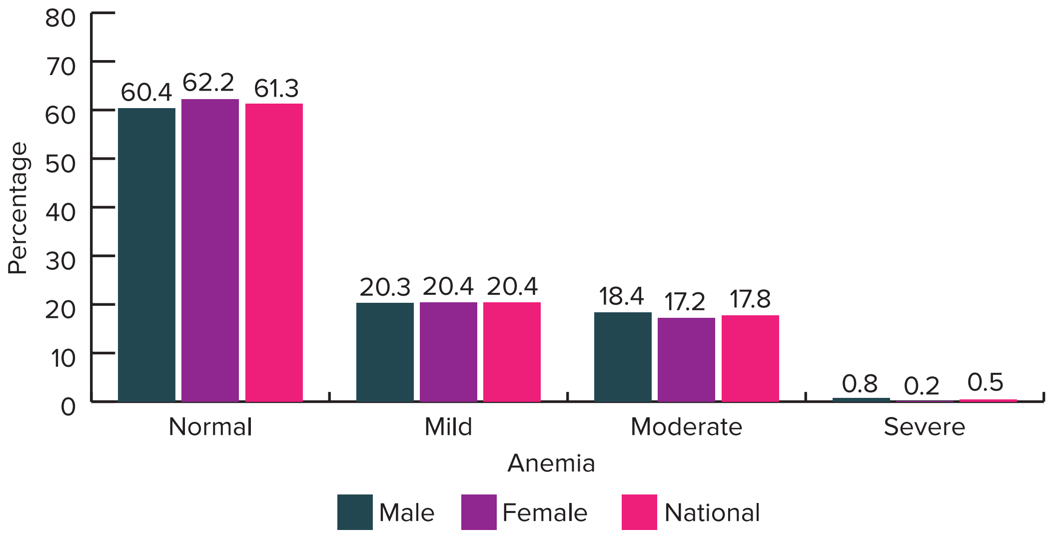

Figure 5.1: Percentage of anemia by sex among children 1-6 years old [National Blood Lead Level Survey 2024].

The prevalence of mild anemia was very similar between males and females; however males had a slightly higher prevalence of moderate (18.4%) and severe anemia (0.8%) compared to 17.2% and 0.2% in females.

Association Between Anemia and Blood Lead Levels

Over half of the children with blood lead levels of 10-19.9 µg/dL were anemic. The results indicate a clear trend in which the percentage of children with anemia increased as blood lead levels rose. Specifically, the prevalence of anemia was 32.0% among children with blood lead levels of less than 3.5 µg/dL and increased to 50.1% for those with BLLs between 10.0 to 19.9 µg/dL.

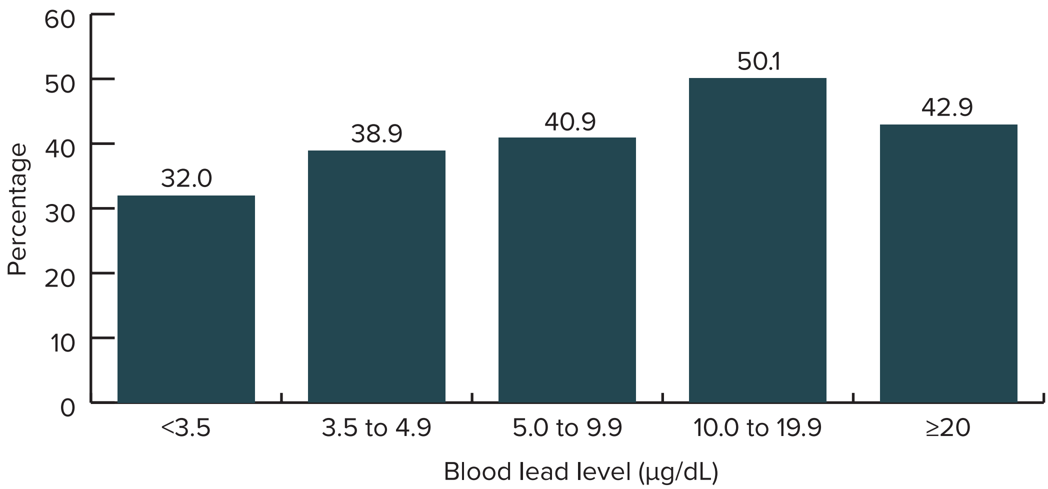

Figure 5.2: Percentage of anemia in children 1-6 years old by blood lead level [National Blood Lead Level Survey 2024].

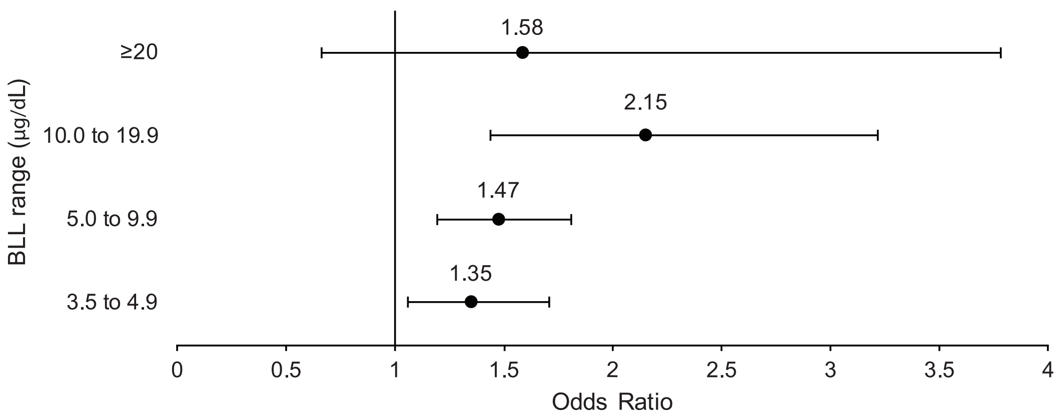

Figure 5.3: Blood lead level ranges and their corresponding odds ratios for anemia [National Blood Lead Level Survey 2024].

Figure 5.3 shows the progressive increase in the odds ratios (OR) in the risk of anemia with rising blood lead levels. The highest OR of 2.15 is observed in the 10.0 to 19.9 µg/dL category. Since only 21 children had a BLL ≥20 µg/dL, this likely caused this OR range's 95% confidence intervals to be much wider than the OR for the other BLL ranges.

Developmental Delay and Blood Lead Levels in Children 1-5 Years Old

Key findings

- The percentage of children aged 1- 5 years at risk for developmental delay was found to be 14.2%
- Male children (16.4%) were more likely to have developmental delay compared to female children (11.7%)
- As blood lead levels increased, a higher percentage of children had developmental delays.
- Blood lead levels were found to be associated with developmental delays in children, particularly in problem solving / cognition and personal-social domains for children with BLLs ≥20 µg/dL.

Background

Developmental delay occurs when a child fails to attain developmental milestones as compared to peers of the same population. Developmental delay can be identified in various domains of development such as motor, language and communication, cognition, social and emotional and self-help skills. Developmental delay is not a diagnosis by itself, but a categorical, illustrative term used in the clinic. Prematurity, medical problems, lead toxicity, and trauma can cause developmental delay. During this survey, the Bhutan Child Developmental Screening Tool (BCDST) was used to screen for developmental delays in children from 1 – 5 years. BCDST is the universal screening tool which is used in health centers by health workers. The tool screens motor, communication, cognition and personal-social development. A child was considered at risk of developmental delay if any one of the age specific milestones was not attained.

Results

Overall, 85.8% of the children 1-5 years old were developmentally on-track, while 7.4% and 6.7% needed to be monitored or required further assessment respectively. The highest percentage of developmental delay in a domain for both males and females was observed in the personal-social domain (6.4%) followed by cognition (6.3%). The lowest percentage of developmental delay was observed in physical development (2.9%).

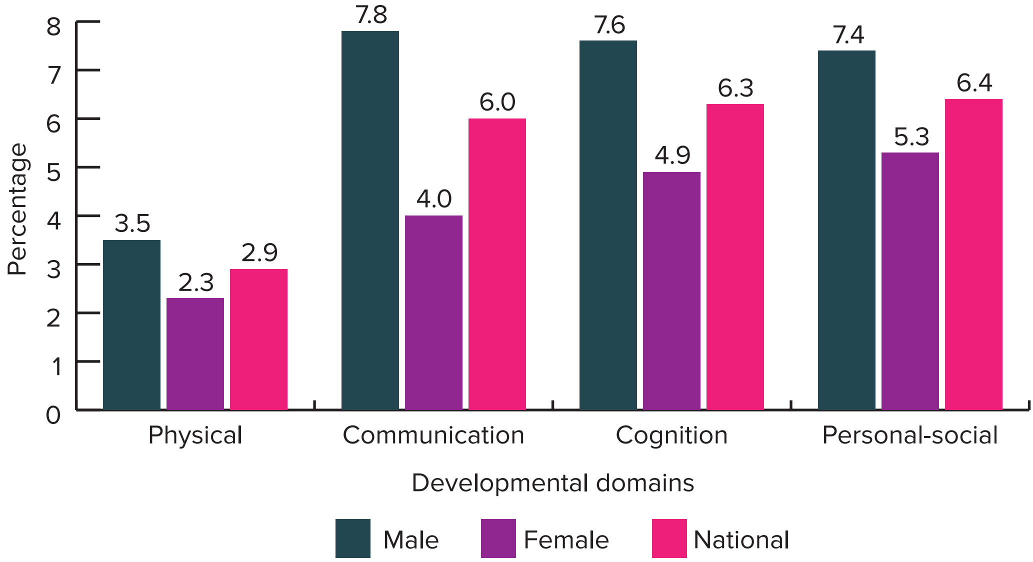

Figure 5.4: Percentage of children aged 1-5 years with developmental delay (needing further monitoring and assessment) by domain, and by sex [National Blood Lead Level Survey 2024].

Male children aged 1–5 years had higher percentages of developmental delay across all four domains compared to females.

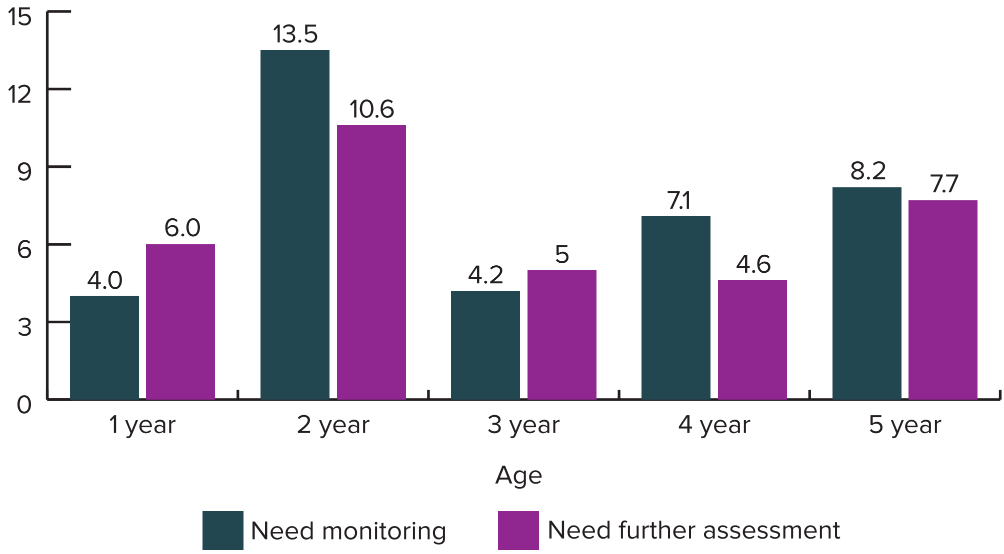

Figure 5.5 Percentage of children 1-5 years old by age needing further monitoring and assessment [National Blood Lead Level Survey 2024].

The data show that two-year-old children had the highest percentage of delay. The percentage of those needing monitoring was 13.5%, and 10.6% needed further assessment. Three and one-year-old children had the lowest combined need of monitoring and assessment at 9.2% and 10%, respectively. From three years of age onward to five years of age there was a progressive increase in the percentage of children needing monitoring.

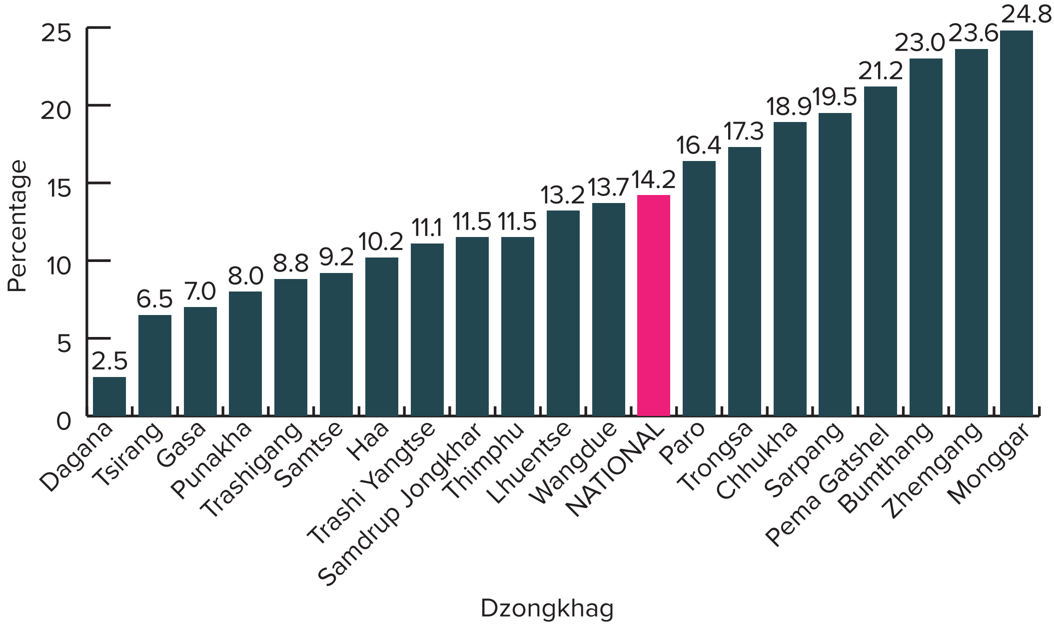

Figure 5.6: Percent of developmental delay (needing monitoring or further assessment) by dzongkhags [National Blood Lead Level Survey 2024].

The percentage of children needing monitoring or further assessment on a national level was 14.2%. The lowest percentage of developmental delay was in Dagana (2.5%) and Tsirang (6.5%) while the highest was in Zhemgang (23.6%) and Monggar (24.8%).

Association Between Developmental Delay and Blood Lead Levels

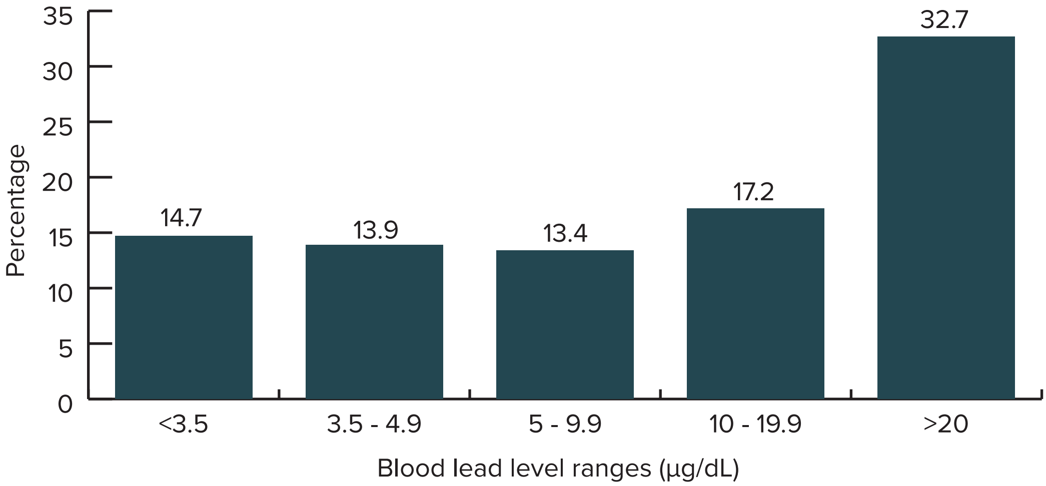

Figure 5.7: Percentage of developmental delay by BLLs among children 1-5 years old [National Blood Lead Level Survey 2024].

Among children 1-5 years old, 14.2% had developmental delay in at least one developmental domain. As BLLs increased, a higher percentage of children had delays. At a BLL of 10-19.9 µg/dL, the percentage of children with developmental delay increased to 17.2%, and increased dramatically to 32.7% in children with a BLL ≥20 µg/dL.

Table 5.4: Percentage of children 1-5 years old with delay in at least one developmental milestone and its association with blood lead levels (weighted analysis) n=2,378 [National Blood Lead Level Survey 2024].

Development Domain	Blood Lead Levels (µg/dL)	Percentage of children with delay in at least one developmental milestone	Unadjusted			Adjusted for age and sex			Number of children
			OR[1]	95% CI[2]	p-value[3]	aOR[1]	95% CI[2]	p-value[3]	
Physical Ability (Motor Development)	<3.3	4.9	Base			Base			529
	3.3 - 4.9	3.1	0.62	0.33, 1.19	0.1500	0.59	0.31, 1.12	0.1100	651
	5.0 - 9.9	1.8	0.35	0.18, 0.69	0.0030	0.33	0.17, 0.65	0.0010	1,053
	10.0 - 19.9	3.8	0.77	0.28, 2.13	0.6130	0.72	0.26, 1.96	0.5170	124
	≥20	4.9	1.01	0.13, 7.74	0.9950	0.92	0.12, 6.99	0.9390	21
Communication and Language	<3.3	5.8	Base			Base			529
	3.3 - 4.9	5.8	1.01	0.60, 1.70	0.9730	0.95	0.56, 1.59	0.8350	651
	5.0 - 9.9	5.7	0.99	0.61, 1.61	0.9700	0.91	0.56, 1.48	0.7090	1,053
	10.0 - 19.9	7.8	1.37	0.60, 3.11	0.4490	1.25	0.54, 2.89	0.6000	124
	≥20	17.1	3.37	0.92, 12.31	0.0660	3.02	0.82, 11.18	0.0970	21
Problem Solving / Cognition	<3.3	7.3	Base			Base			529
	3.3 - 4.9	6.0	0.82	0.48, 1.39	0.4550	0.78	0.46, 1.32	0.3600	651
	5.0 - 9.9	5.4	0.73	0.46, 1.17	0.1900	0.69	0.44, 1.09	0.1140	1,053
	10.0 - 19.9	9.2	1.29	0.60, 2.77	0.5080	1.21	0.56, 2.61	0.6220	124
	≥20	21.0	3.39	1.18, 9.75	0.0230	3.15	1.06, 9.33	0.0390	21

Development Domain	Blood Lead Levels (µg/dL)	Percentage of children with delay in at least one developmental milestone	Unadjusted			Adjusted for age and sex			Number of children
			OR[1]	95% CI[2]	p-value[3]	aOR[1]	95% CI[2]	p-value[3]	
Personal-Social	<3.3	6.1	Base			Base			529
	3.3 - 4.9	6.4	1.05	0.62, 1.78	0.8470	1.02	0.6, 1.72	0.9410	651
	5.0 - 9.9	6.0	0.98	0.60, 1.60	0.9290	0.94	0.57, 1.54	0.8010	1,053
	10.0 - 19.9	8.9	1.51	0.73, 3.13	0.2700	1.44	0.69, 2.99	0.3290	124
	≥20	21.7	4.25	1.35, 13.32	0.0130	4.01	1.27, 12.68	0.0180	21
Overall	<3.3	14.5	Base			Base			529
	3.3 - 4.9	14.1	0.97	0.67, 1.41	0.8720	0.94	0.65, 1.35	0.7210	651
	5.0 - 9.9	13.4	0.91	0.65, 1.29	0.6120	0.87	0.62, 1.23	0.4360	1,053
	10.0 - 19.9	17.2	1.23	0.70, 2.15	0.4770	1.16	0.66, 2.05	0.6020	124
	≥20	32.7	2.87	1.04, 7.94	0.0420	2.70	0.96, 7.58	0.0600	21

[1] Odds ratio
[2] Confidence interval
[3] Wald Test

Table 5.4 shows that lead was found to be associated with overall developmental delays in children. There was either strong or moderate evidence for this, particularly for blood lead levels (BLLs) ≥20 μg/dL in problem solving / cognition, personal-social, and overall developmental domains. Children with a BLL ≥20 μg/dL were 2.70 times more likely (aOR=2.70, 95% CI: 0.96,7.58, p=0.06) to have developmental delay compared to children with a BLL <3.3 μg/dL.

The odds of having developmental delay increased notably in the problem solving / cognition and personal-social domains. Compared to children with a BLL <3.3 μg/dL, children with a BLL ≥20 μg/dL were 3.15 times more likely to have a delay in problem solving / cognition, and 4.01 times more likely to have a delay in the personal-social domain (Table 5.4).

A general positive dose-response relationship was observed across developmental domains, except for motor development. Interestingly, children with BLLs of 5 to 9.9 μg/dL showed a significantly lower likelihood of motor development delays compared to those with BLLs <3.3 μg/dL (aOR=0.33, 95% CI: 0.17, 0.65, p=0.001), suggesting a possible anomaly or confounding factor.

The associations between BLLs and developmental milestones should be interpreted with caution for three reasons. First, the reference group with BLLs <3.3 μg/dL does not imply an absence of lead in their blood, as even low-level exposure can be harmful. Secondly, the small sample size for children with high BLLs, combined with the low prevalence of developmental delays in certain domains, may have limited the robustness of the statistical tests. Thirdly, studies on the neurological effects of lead have often been done on older, school age children, and have been based on laboratory BLLs from earlier in life. Laboratory BLL testing, which can report BLL well below 1 μg/dL, allows studies to compare children with BLL < 1 μg/dL with children having higher BLLs.

The NBLLS used the LeadCare II analyzer, which has a lower limit of detection (LOD) of lead in the blood of 3.3 μg/dL. Children in the survey with blood lead levels below the level of detection of the LeadCare II analyzer may still have been exposed to levels of lead capable of causing developmental delays. This should be taken into consideration in interpreting the percentages of children with developmental delay in the lowest blood lead level ranges.

Overall, these findings underscore the urgent need for lead exposure mitigation strategies and early developmental screening among high-risk populations to prevent long-term developmental impairment.

CHAPTER 6

Blood Lead Levels in Other Groups

Blood Lead Levels Among Pregnant or Breastfeeding Women

Key findings

- Nearly three out of five (58.9%) pregnant and breastfeeding women tested had a BLL ≥3.5 µg/dL.
- Lead exposure was observed across various age groups, places of residence, levels of education, and income quintiles.

Although the findings of the BLLs among pregnant or breastfeeding women were not nationally represented they are the first ever data on BLLs in this group in Bhutan (Sample size = 124 women).

Background

There is no level of lead in the blood that is considered safe. The first exposure to lead in life can occur during the first trimester of pregnancy as lead in the mother's blood passes to the baby via the placenta. The fetal BLL will be similar to that of the mother's BLL. Lead can be deposited in the developing fetal brain, bones, and soft tissue.

Lead also causes increased risks during the pregnancy. Miscarriages, preeclampsia, poor fetal growth, premature birth, and low birthweight are increased by lead. After birth, lead can continue to be passed to the baby through breastmilk, but only if the mother's BLL is very high.

The mother's BLL during pregnancy and breastfeeding depends on two sources: first, from ongoing exposure of lead to the woman, and secondly from lead which is remobilized from her bones. During pregnancy, bones are remodeled to release calcium and other essential micronutrients to the growing fetus. Unfortunately, lead is also released from bones posing a risk to the growing fetus. Because 94% of the total lead retained in adults is stored in bones, it is critical to minimize lead exposure to girls and women of reproductive age to prevent the accumulation of lead in bones which can later be transferred to the developing fetus and baby.

This survey selected all households from the NHS 2023 with a child aged 1-6. All pregnant women and those who were breastfeeding and had delivered within the past six months living in those selected households were invited to have their blood lead levels (BLLs) tested.

Results

A total of 124 pregnant or breastfeeding women were tested.

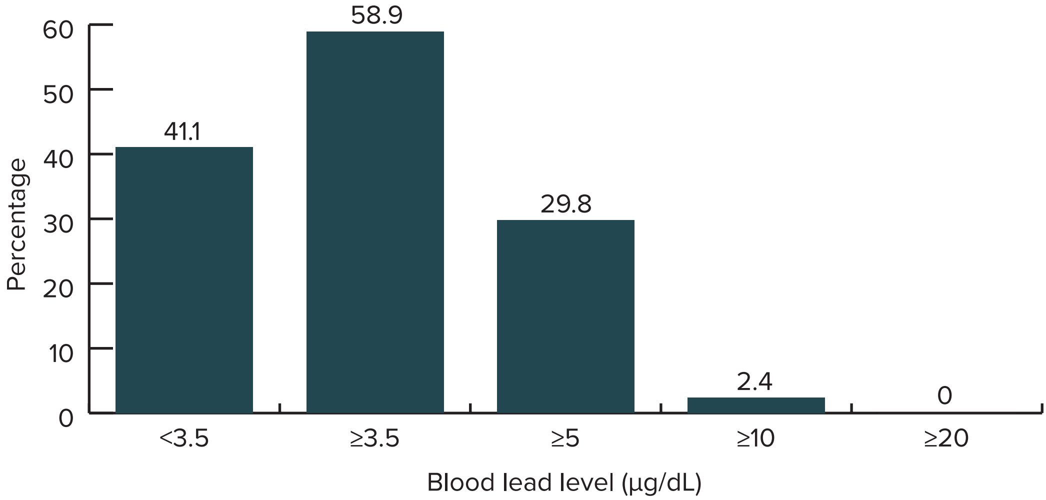

Figure 6.1: Percentage of pregnant or breastfeeding women with various blood lead levels [National Blood Lead Level Survey 2024].

Nearly three out of five (58.9%) pregnant and breastfeeding women tested had a BLL ≥3.5 µg/dL, and nearly one in three had a BLL ≥5 µg/dL. Slightly more women in rural areas (60.8%) had a BLL ≥3.5 µg/dL compared to women in urban areas (56.0%). Among women with less than a class 12 education, 61.3% had a BLL ≥3.5 µg/dL compared to 56.5% of women with a class 12 education or higher.

Although the sample was not nationally represented, the results are concerning.

Blood Lead Levels Among Monastic Children

Key findings

- Nearly 9 out of 10 (86.0%) children tested in monastic institutions had a BLL ≥3.5 µg/dL, compared to 75.9% of 1–6-year-old children.
- The mean BLL in children less than 13 years old in monastic institutions was 5.9 µg/dL, compared to 5.3 µg/dL in 1–6-year-old children.

Similar to the findings on pregnant and breastfeeding women, while the findings on the BLLs among monastic children were not nationally representative, they represent the first ever data on BLLs in children less than 13 years old in monastic institutions in Bhutan. Testing was done for 207 children from 17 monastic institutions, ranging in age from 4 - 12 years, with a mean age of 11 years.

Background

Blood lead levels (BLLs) are dependent on the amount of lead a person is exposed to and the rate at which their body absorbs the lead. Children absorb 4-5 times more lead than a non-pregnant adult does. Thus, one could assume that, if exposed to similar amounts of lead, an adolescent or adult should have a lower BLL compared to a young child.

Results

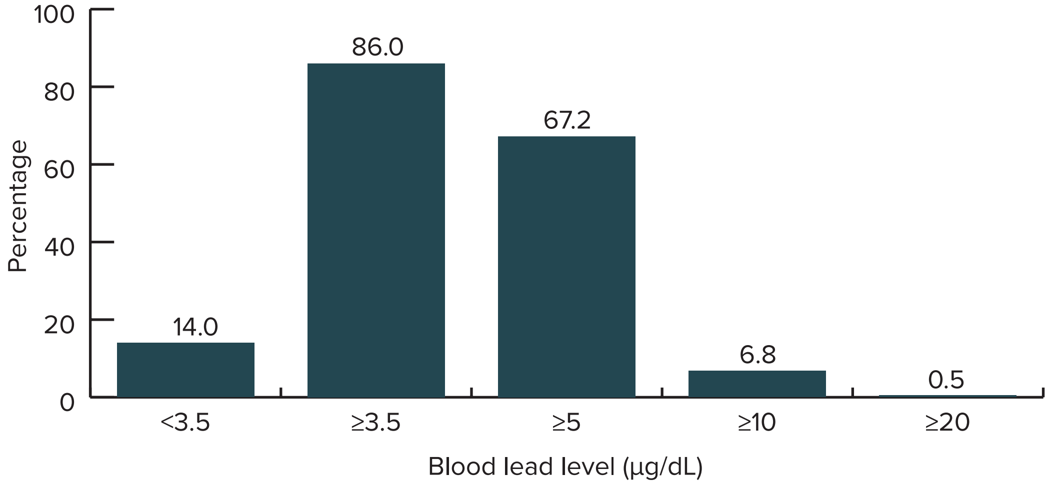

Figure 6.2: Percentage of children less than 13 years old from monastic institutions with various blood lead levels [National Blood Lead Level Survey 2024].

Alarmingly, 86.0% of the monastic children less than 13 years old tested had a BLL ≥3.5 µg/dL (Figure 6.2). This is 10 percent higher than the national prevalence in children aged 1-6 years old (75.9%). More alarming is that 67.2% of children in monastic institutions have a BLL ≥5 µg/dL which is 16% higher than in the 1-6 years old children (51.3%). The mean blood lead level in this group was 5.9 µg/dL, which is also higher than the mean blood lead level found among children aged 1 to 6 years old (5.3 µg/dL).

These findings show that children in monastic institutions are exposed to lead more often or at higher amounts of lead than children in general. Since the average age of the monastic children tested was 11 years, compared to 4 years old in the non-monastic 1–6-year-old children population, the BLLs in the monastic children would be expected to be lower if they were exposed to similar amounts of lead as children in general. This data show that children and likely adults in the monastic community are being exposed to higher amounts of lead. This increased lead exposure will lead to more health consequences in this population.

Blood Lead Levels Among Household Members from Phase -2

Key findings

- From Phase 2 household testing, 82% had a BLL ≥3.5 µg/dL.
- BLLs ≥3.5 µg/dL were found in household members from 7 months - 87 years of age.

Testing was done on 128 household members at 67 households during Phase 2. These households represent homes where a child tested in Phase 1 had a BLL ≥20 µg/dL, or a child had the highest BLL during the prior day's BLL testing. The BLLs among these selected household members were not nationally represented.

Background

Testing the BLLs of the household members in Phase 2 was intended to evaluate the extent of lead poisoning within the households of children with high blood lead levels. If common sources of lead exposure were present, other members of a household would be expected to have elevated blood lead levels.

Blood lead levels in a person are dependent on many factors. The person's age, rates of absorption and metabolism, nutritional status, eating habits, varying exposure to lead, and behaviors all influence a person's blood lead level. A young child who puts things in their mouth and whose body absorbs more lead will often have the highest BLL in a household.

Sources of lead exposure can vary from household to household and household member to household member. The occupation of household members may result in take-home lead that exposes children and other household members to lead.

Results

During Phase 2 household testing, a total of 128 people were tested, ranging in age from 7 months – 87 years old. The average age of household members was 31 years old. Overall, 82.0% of those tested had a BLL ≥3.5 µg/dL (Figure 6.3). While nationally represented BLL data for adults in Bhutan are not available, these percentages are higher than those of both the Phase 1 children 1-6 years old (75.9%) and the pregnant and breastfeeding women (58.9%). In addition, 56.1% of household members had BLL ≥5 µg/dL, compared to 51.3% of children 1-6 years old and 29.8% of pregnant and breastfeeding women. This seems to indicate that these households were exposed to higher amounts of lead. In contrast to the finding in 1–6-year-old children, a higher percentage of female household members (84.1%) had a BLL ≥3.5 µg/dL compared to males (79.7%).

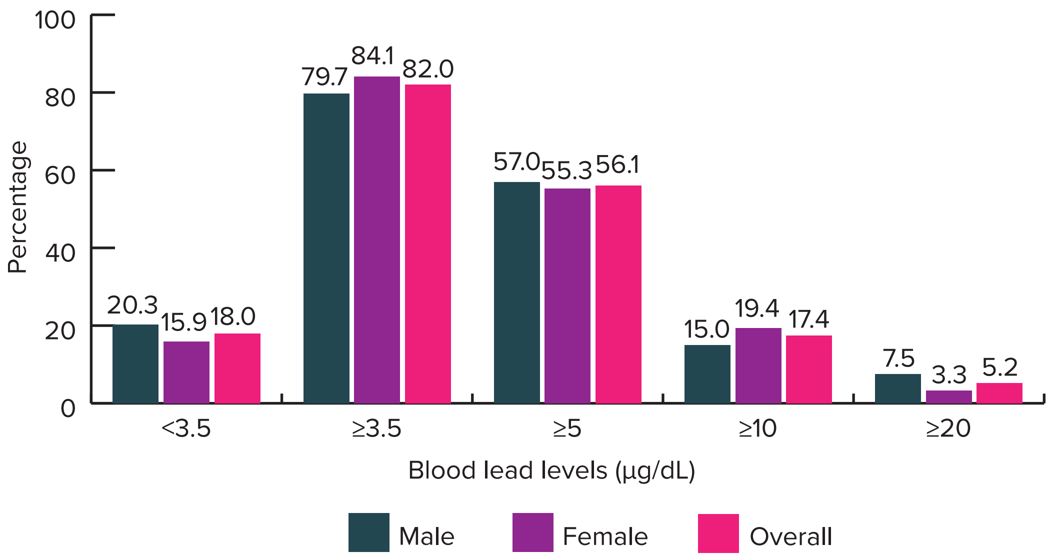

Figure 6.3: Percentage of household members with various blood lead levels by sex [National Blood Lead Level Survey 2024].

Figure 6.4 shows that household members above 40 years old had the highest percentage of BLL ≥3.5 µg/dL, followed closely by 21–40-year-olds.

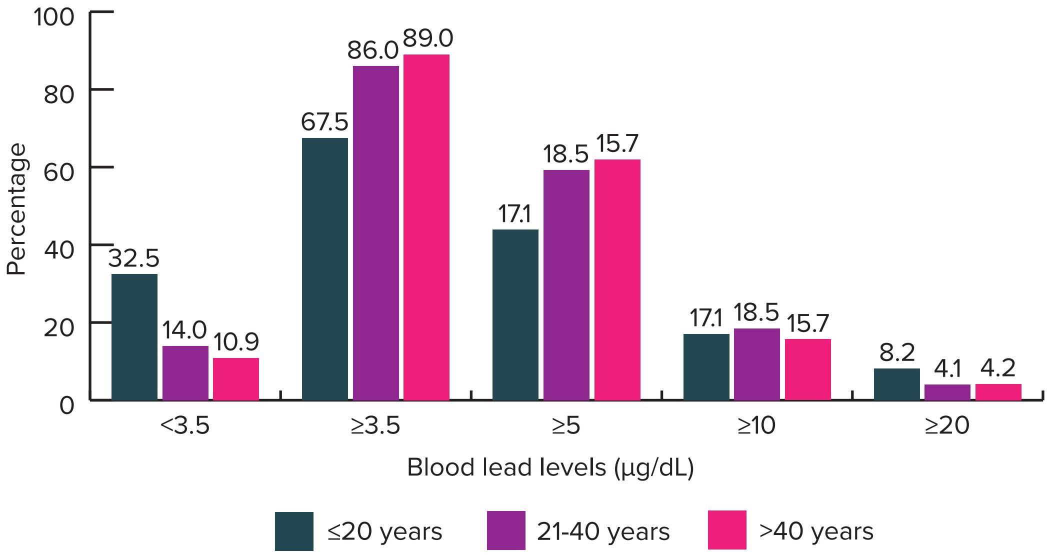

Figure 6.4: Percentage of household members with various blood lead levels by age [National Blood Lead Level Survey 2024].

These homes were selected because a child 1-6 years old from Phase 1 testing had a BLL ≥20 µg/dL or the highest BLL for the day of testing. The high percentages of other members of the household with a BLL ≥3.5 µg/dL suggest common exposures to lead in the household.

Further study will be necessary to understand the sources of lead in households, as it could be from occupational sources, consumption of different foods, religious practices, or other unidentified exposures.

CHAPTER 7

Sources of Lead

Key findings

- The sources of lead were widespread, with varying amounts of lead content in the items tested.
- Among the consumable samples tested, lead exceeded the reference threshold in 44.2% of *Jinlab*, and in 20.0% of spices and foods.
- Among non-consumable samples, lead exceeded the reference thresholds in 21.5% of kitchen items, 9.1% of toys, 3.3% of soil, and 0.8% of paints tested.
- Additionally, 75.2% of traditional Bhutanese and religious objects, and 47.2% of household items, including hardware, contained some amount of lead, however the risk of exposure is currently unknown.

Background

Lead contamination is a widespread environmental concern due to its persistence in the environment and toxic effects on human health. Significant sources of lead include industrial emissions from metal smelting and refining, lead-based paints, and leaded petrol, though the latter has been phased out from automobile use globally. In addition to these, lead-containing batteries, certain types of ceramics and glazes, and contaminated soil from previous industrial activities also contribute to environmental lead exposure. In some areas, however, unique sources persist, such as artisanal gold mining in which lead is used in ore processing, some spices, and certain traditional remedies and cosmetics that contain lead compounds. Many regions still face contamination from lead-based paints and petrol residues due to slower regulatory implementation and less strict environmental controls. For example, lead-based paints are still found in residences and schools in certain parts of Asia and Africa, while used lead-acid battery recycling often lacks proper safety protocols in regions of South Asia and Sub-Saharan Africa.

The routes of exposure to lead differ by environment, medium, and population behaviors. Ingesting contaminated water, soil, and dust may represent a significant pathway, particularly for children who may come into contact with lead-contaminated soil or deteriorating lead-based paint in older buildings. Occupational exposure in industries handling lead, such as battery recycling and manufacturing, is another primary pathway, particularly in regions with lax safety standards. Airborne lead from industrial emissions, especially in areas near smelting or recycling plants, can also expose surrounding communities through inhalation and, subsequently, soil deposition. Lead can inadvertently enter food in low levels from the soil, from pesticides used on crops, or from contamination during food processing.

Regulatory standards for acceptable lead levels in various media such as soil, air, and water—vary by country. These benchmarks are essential to guide interventions, especially in areas with vulnerable populations. The US Centers for Disease Control and Prevention currently recommends that blood lead levels in children should not exceed 3.5 µg/dL, as even low exposure can impact neurodevelopment. Similarly, the US Environmental Protection Agency's (EPA) threshold for lead in drinking water is 15 µg/L, while soil guidelines are set at 200 ppm for residential areas, though these can differ internationally.

Some regulatory bodies have created limits for the amount of allowable lead in certain consumable products including spices (1.5 ppm in the EU, 2.5 ppm in Bangladesh) and foods for infants and small children (0.01-0.02 ppm in the US). The US Food and Drug Administration (FDA) has calculated an interim reference level (IRL) which includes a 10x safety factor for the daily intake of lead. The IRL for children is 2.2 micrograms (µg) of lead per day and 8.8 µg of lead per day for women of reproductive age. This level is estimated to keep a child's BLL near 0.35 µg/dL, but there is currently no level of lead in one's body that is known to be safe. The US FDA estimated that if a child ingested 22 micrograms of lead per day, their BLL would increase to 3.5 µg/dL.

Bhutan does not yet have regulatory thresholds established for lead levels in consumer goods or consumable items. This survey researched the reference level guidelines of different regulatory bodies and chose reference levels based on USA regulatory bodies for soil, paint, toys and kitchenware and Bangladesh reference levels for spices.

For data analysis, reference thresholds were used for items for which a route of exposure was likely. The reference threshold for consumables, such as *jinlab* and spices was set at 2.5 parts per million (ppm). Reference thresholds for kitchen items, which come in contact with food, was set at 100 ppm. The reference threshold for toys and school items, which children handle and may put in their mouths, was likewise set at 100 ppm.

Results

A total of ten different broad categories of items including *Jinlab* were tested using portable X-ray fluorescence (pXRF) analyzers. The threshold for kitchen items was set at 100 parts per million (ppm) as recent studies have shown metal kitchen items with 100 or more ppm of lead have a high chance of leaching lead into food. While leaching studies were not conducted, these items are used in food preparation and serving. Bhutanese cuisine additionally is acidic due to ingredients like tomatoes, chilies, cottage cheese, and pickles, likely increasing the risk of lead leaching into food from kitchen items.

Table 7.1: Total number of samples tested by category and their reference threshold [National Blood Lead Level Survey 2024].

Samples tested	Reference threshold*	Total samples tested
Jinlab	2.5 ppm	767
Foods & Spices	2.5 ppm	75
Kitchen items	100 ppm	665
Cosmetics	10 ppm	14
Toys	100 ppm	209
School Items (Played with or touched by children)	100 ppm	41
Soil	200 ppm	60
Paint	1mg/cm^2	127
Religious & Traditional Bhutanese items	NA	214
Household Items	NA	246
Total Items tested		**2,418**

*Reference thresholds were based on the regulatory standards of the USA and Bangladesh. The threshold for kitchen items was set at 100 parts per million (ppm).

The above items were all tested during the home visits and visits to ECCDs, creche facilities, and schools. The only exception was that *Jinlab* samples were collected in lead-free bags at homes and all the samples were tested in Thimphu after the completion of the survey.

1. Jinlab

The term *Jinlab* (བྱིན་རླབས) represents the concept of spiritual blessings, envisioned as waves of sacred power radiating from a blessed source, like a person, object, or event, to bring benefit to others. Lamas confer these blessings through various means—touching with their hands, using sacred texts, offering consecrated food and drink, tying protective strings, or employing ritual items. Among the many forms of blessing, *Jinlab* pills hold special significance; these sacred medicinal substances are distributed by lamas as carriers of spiritual energy.

During preparations for the National Blood Lead Level Survey (BLLS) a variety of items, including samples of *Jinlab*, were tested for lead content using a portable X-ray fluorescence (pXRF) analyzer. The tests showed high lead content in numerous *Jinlab* samples, therefore, *Jinlab* samples were included in the survey among multiple items to be tested as possible sources of lead exposure.

A total of 767 *Jinlab* samples were collected, and each was tested three times. Of the *Jinlab* samples, 44.3% contained lead above the pXRF analyzer's level of detection (LOD), and 44.2% exceeded the reference threshold of 2.5 ppm. A maximum lead concentration of 5.7% (57,233 ppm) was found in one of the *Jinlab* samples. Of the total samples containing lead, the median concentration of lead was 85 ppm. Among the samples with lead, 10% of the samples had lead levels above 628 ppm.

Although a small amount of *Jinlab* is consumed compared to spices, the median amount of lead in *Jinlab* (85 ppm) is 34 times higher than the allowable level of lead in spices. Also, since spices are mixed in food, competitive absorption takes place when the food is ingested, so less lead will be absorbed when consumed with food compared to lead being consumed on an empty stomach, as *Jinlab* is sometimes taken.

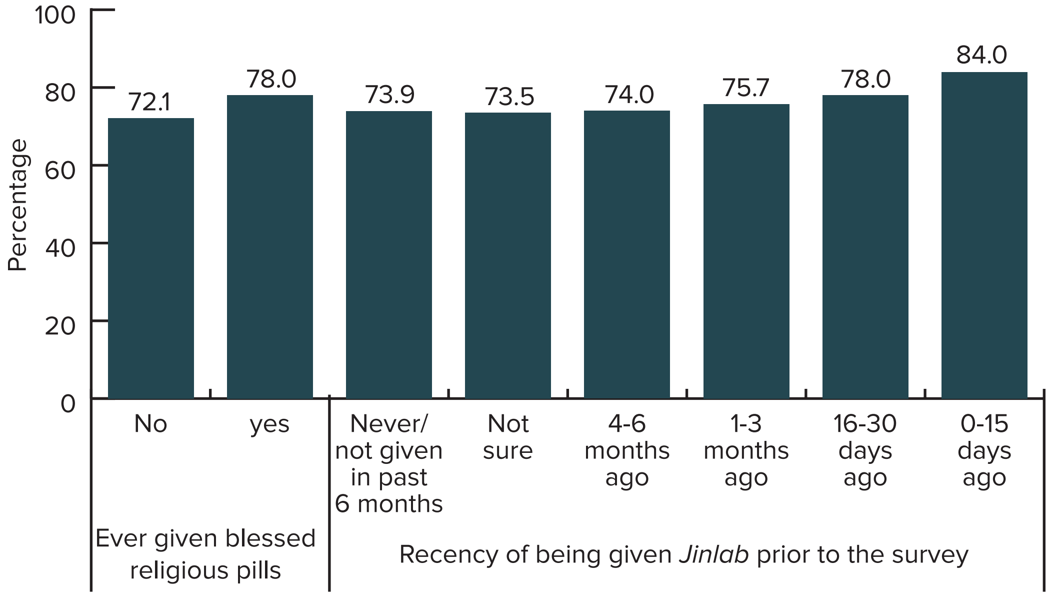

Figure 7.1: Percentage of children with blood lead levels ≥3.5 µg/dL categorized by ever given blessed religious pills *(Jinlab)* and recency of the giving of *Jinlab* [National Blood Lead Level Survey 2024].

During the survey, questions were asked about risk factors to which the child may be exposed. When asked if the child had ever been given *Jinlab*, two-thirds (65.1%) of children had been given *Jinlab* sometime in their life. Overall, 78.0% of the children who had ever been given *Jinlab* (religious pills) had a BLL ≥3.5 µg/dL as compared to 72.1% among those who had never been given *Jinlab*.

The survey also asked the parent/guardian when the last time *Jinlab* was given to the child. Figure 7.1 shows that 84.0% of the children given *Jinlab* in the last 15 days had a BLL ≥3.5 µg/dL. By comparison, 74.0% of children had a BLL ≥3.5 µg/dL if the last time the child was given *Jinlab* was 4-6 months ago. The children who had never been given *Jinlab* had the lowest percentage of children with a BLL ≥3.5 µg/dL (72.1%).

2. Spices

Among the 75 foods and spices tested, 26.7% had lead above the level of detection (LOD) of the pXRF analyzers. Twenty percent of the consumable items exceeded the reference threshold of 2.5 ppm, which is concerning. Specifically, 15 of 67 (22.4%) spices contained lead above the threshold. Approximately one third of turmeric samples and one fourth of chili powder exceeded the threshold. The maximum ppm of lead in the different spices had maximum lead ppm levels 4-80 times the threshold. This is concerning as Bhutanese cuisine is heavily spiced with chili, and Bangladesh in the past years identified adulterated turmeric as a key source of lead.

Table 7.2: XRF results for all foods / spices tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All foods / spices	20	15	26.7	20.0	--	75
Chili powder	4	3	36.4	27.3	123	11
Cumin (jeera)	3	0	75	0	9	4
Turmeric	12	9	46.2	34.6	93	26
Masala (any kind)	2	2	11.1	11.1	73	18
Spice, other	7	1	87.5	12.5	202	8
Food, other	8	0	100	0	--	8

**Reference threshold used: 2.5 ppm*
(>LOD) – any lead above the level of detection of the pXRF

3. Kitchen items

Among the 665 kitchen items tested, 45.1% had lead above the level of detection (LOD) of the pXRF analyzers, and 21.5% of the items exceeded the reference threshold of 100 ppm. Brass or metal eating plates / bowls and drinking cups / glasses had the highest percentage of items containing any lead and percentage of items above the threshold. The maximum ppm of lead in several categories is very concerning, raising the need for leach testing to determine how much lead will come off of these items during use.

Kitchen items pose a high risk since they are used directly with food. Bhutanese cuisine includes acidic ingredients (like tomatoes and chilies), which can increase lead leaching from these items into food, creating a direct pathway for lead ingestion and potential poisoning.

Table 7.3: XRF results for all kitchen items tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All kitchen items	300	143	45.1	21.5	--	665
Drinking cups / glasses	130	87	53.7	36.0	17,223	242
Plates / bowls	45	18	31.2	12.5	38,190	144
Eating utensils	19	6	32.8	10.3	9,425	58
Brass or metal eating plates / bowls	20	12	83.3	50.0	45,744	24
Pot / fry pan / wok (com-mercially made)	39	5	54.2	6.9	5,260	72
Traditional hand-made pots	7	4	58.3	25	8366	12
Traditional hand-made spoons / ladles	6	1	35.3	5.9	500	17
Kitchen, other	34	11	35.4	11.5	35,829	96

**Reference threshold used: 100 ppm*
(>LOD) – any lead above the level of detection of the pXRF

4. Cosmetics

Among the 14 cosmetic items tested, 14.3% had both lead content above the level of detection (LOD) of the pXRF analyzer and lead exceeding the reference threshold of 10 ppm for cosmetics. The single kohl sample tested did not contain lead, however, 2 of 13 other cosmetics tested did contain lead above the threshold.

Although the number of cosmetic samples tested in the survey was small, cosmetics pose a risk to both children and adults as they are applied to the face, skin, and lips and can be easily ingested.

Table 7.4: XRF results for all cosmetic items tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All cosmetics	2	2	14.3	14.3	--	14
Kohl	0	0	0	0	--	1
Cosmetics, other	2	2	15.4	15.4	25	13

**Reference threshold used: 10 ppm*
(>LOD) – any lead above the level of detection of the pXRF

5. Toys and school items

Among the 209 toys tested, 23% of the items contained lead above the LOD of the pXRF analyzer, and 9.1% of the items had lead levels that exceeded the threshold of 100 ppm. Many of the subcategories have very few items, however 9.0% of the commercially made toys for children over 1 year of age contained lead exceeding the threshold.

Among the 41 school items tested, 14.6% of the items contained an amount of lead above the LOD, and 9.8% of the items had lead levels that exceeded the threshold of 100 ppm. Most of the items were in the category of "school, other" which will require further investigation into the identity of these items.

Given that these items are often touched, played with, or used by children, any lead presence is concerning. Lead exposure from toys and school items can directly impact children, who are particularly vulnerable to lead's harmful effects on cognitive development. Children frequently put objects in their mouths, increasing the risk.

Table 7.5: XRF results for all toys and school items tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All toys	48	19	23.0	9.1	--	209
Pacifiers, nipples, teething toys	1	0	100	0	--	1
Toys for infants (< 1 yr.)	1	0	100	0	--	1
Toys for children (>1 yr) commercially made	44	17	23.4	9.0	56122	188
Toys for children (>1 yr) home-made	4	0	60.0	0.0	-	5
Toy jewelry, plastic	3	0	100	0	--	3
Playground equipment, plastic	1	0	100	0	--	1
Toys, other	2	1	20.0	10.0	28929	10
All School items	6	4	14.6	9.8	--	41
Writing implements	0	0	0	0	--	4
Non-writing implements	0	0	0	0	--	4
School furniture	1	1	0	100	200	1
School, other	5	3	15.6	9.4	3300	32

**Reference threshold used: 100 ppm*
(>LOD) – any lead above the level of detection of the pXRF

6. Soil

Lead is naturally found in the ground, so it is not surprising that 81.7% of the 60 total soil samples tested had some amount of lead above the LOD of the pXRF analyzer. Only 3.3% of the soil samples had a level of lead above the 200 ppm threshold.

The soil samples from yard / play areas and house drip lines show that some amount of lead is detectable in most soil. Driplines (areas where water drips off roofs) often collect pollutants from old paint and lead from the roof. Soil contamination is particularly dangerous for children who play outside and may come into contact with or ingest soil. Lead in soil can also be tracked indoors, increasing the exposure for residents.

Only one out of 20 soil samples from a play area at a house had lead exceeding 200 ppm. Likewise one out of 13 soil samples from an "other" location had lead exceeding the threshold.

From this current data it is not possible to determine if the lead present in the soil samples is from naturally-occurring lead in the soil or from contamination. Further testing will be needed to determine the impact lead in soil possibly is having on children.

Table 7.6: XRF results for all soil samples tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All soil	49	2	81.7	3.3	--	60
Soil, house dripline	15	0	78.9	0	--	19
Soil, house yard / play area	19	1	95.0	5.0	282	20
Soil, kitchen garden	0	0	0	0	--	4
Soil, ECCD / School	1	0	25	0	--	4
Soil, other	8	1	61.5	7.7	502	13

**Reference threshold used: 200 ppm*
(>LOD) – any lead above the level of detection of the pXRF

7. Paint

Among the 127 paint samples tested, only 1 (0.8%) of the samples exceeded the paint threshold of 1 mg/cm² (equivalent to 90 ppm). Additionally, 29.9% showed some amount of lead above the LOD of the analyzer, but less than the threshold. Although some of the samples contain lead, none of the indoor or outdoor wall paints exceeded the reference threshold.

Lead paint is a known hazard, particularly in older homes, as peeling paint or paint dust can result in lead exposure. While the lead presence in these samples is low, any lead paint poses a risk if it begins to degrade.

Table 7.7: XRF results for all paint samples tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All paint	38	1	29.9	0.8	--	127
Paint on walls, outside	9	0	24.3	0	--	37
Paint on walls, inside	16	0	28.6	0	--	56
Paint, other	13	1	38.2	2.9	1.0	34

**Reference threshold used: 1mg/cm²*
(>LOD) – any lead above the level of detection of the pXRF

8. Religious and traditional Bhutanese items

Many religious items such as incense burners and butter lamps are made of metal. Older ornate religious items made from different types of metals may have been fused together with lead, because of its low melting point and ease in use. Many of these metals are alloys that contain lead. A large proportion (75.2%) of the religious and traditional Bhutanese items tested contain detectable levels of lead above the LOD of the pXRF analyzer. Religious items were more likely to contain lead compared to other traditional Bhutanese items. This indicates a potential health risk, especially since religious items are often used in close contact with people during rituals, where lead could be inhaled or ingested after touching the item.

Table 7.8: XRF results for all religious and traditional Bhutanese items tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All religious / Traditional Bhutanese items	161	NA	75.2	NA	--	214
Incense burner, butter lamps	36	NA	94.7	NA	83,680	38
Religious pendant (worn on wrist or neck)	7	NA	43.8	NA	788,537	16
Prayer wheel handle	2	NA	66.7	NA	178	3
Religious item, other	104	NA	85.2	NA	121,481	122
Bhutanese items, (khuru dart, other)	17	NA	56.7	NA	55,080	35

**No reference threshold available for these items*
(>LOD) – any lead above the level of detection of the pXRF

Religious and traditional Bhutanese items are very unique to Bhutan. As no threshold for these types of items are available, only the presence of any lead in the items can be reported. However, as the maximum ppm of the item with the highest amount of lead has over 78.8% of lead (ppm=788,537) the risk of lead transferring to one's hand while using these items is high. The source testing found lead in a majority of these items. Additional testing is needed to determine how much of the lead can come off of these items while being used, and which items might be the greatest risk to humans.

9. Household items

Of the 246 household items tested, nearly half (47.2%) contain some level of lead above the pXRF LOD. Sixteen percent of indoor furniture tested had lead levels above the 1mg/cm^2 threshold for lead. This is worrisome as this could be a source of lead for toddlers and children as they will have contact with the furniture and possibly ingest peeling paint.

In testing fixtures or handles on cupboards, drawers, and doors, 69.2% had some amount of lead present. While no reference threshold has been set for these items due to lack of comparable studies, the presence of lead in these commonly touched items may pose a risk, especially in households with children who may frequently handle these objects. Household hardware is often made from brass which is a mixture of primarily copper and zinc. Other metals including lead can be added to the alloy, but lead is typically limited to less than 2% of lead (3.5% in the alloys with the highest amounts of lead).

Table 7.9: XRF results for all household items tested [National Blood Lead Level Survey 2024].

Items tested:	Number of samples		Percentage (%)		Maximum ppm of Pb above threshold*	Total number tested
	With any lead (>LOD)	Above reference threshold*	With any lead	Above reference threshold*		
All household items	116	NA	47.2	NA	--	246
Twist doorknobs / locks	7	NA	28.0	NA	47,672	25
Latch / bolt locks (doors & windows)	17	NA	60.7	NA	51,044	28
Fixtures or handles on cupboards, drawers, doors	18	NA	69.2	NA	48,582	26
Indoor furniture*	10	5	32.3	16.1	1130	31
Household, other	64	NA	47.1	NA	144,086	136

* Reference threshold used for furniture: 1 mg/cm^2
(>LOD) – any lead above the level of detection of the pXRF

These XRF finding show that the maximum amount of lead in the hardware ranged from 4.8 – 5.1%, higher than the amount of lead in brass. Also, the maximum amount of lead in a household "other" item was over 14% lead.

Additional testing will be needed to determine the amount of lead that can come off of these items and risk they pose to humans.

CHAPTER 8

Association of Blood Lead Levels and Risk Factors in Children

Association of Blood Lead Levels and Risk Factors in Children

Key Findings

- Male children were 1.58 and 1.39 time more likely to have a BLL ≥3.5 µg/dL and ≥5 µg/dL respectively, compared to females.
- Children in a household where a household member used or handled bullets were 1.80 times more likely to have a BLL ≥5 µg/dL.
- Having ever been given *Jinlab* and the recency of being given *Jinlab*, were both associated with higher BLLs.
- The religion the child's household practiced showed the strongest associations for BLLs ≥3.5 µg/dL and ≥5 µg/dL.
- There was no statistical difference in blood lead levels in children by age, location of residence, or income quintiles.

Background

As the potential sources of lead vary by country, culture, and both household and individual practices, more than two dozen questions related to risk factors were asked during Phase 1 of the NBLLS. Some questions were related to the household, while others were specific to the child. The data were analyzed for statistical associations. These associations or lack thereof will help guide necessary policies and interventions and direct future research into lead poisoning in Bhutan.

Results

The percentages of children with a BLL ≥3.5 µg/dL and ≥5 µg/dL were high across all ages of children. There was no statistically significant difference or association between BLLs by age, urban vs. rural living location, or income quintiles. There was, however, an association between BLLs and sex. A higher percentage of males had BLLs ≥3.5 µg/dL and ≥5 µg/dL compared to females. Male children were 1.58 and 1.39 more likely to have BLLs ≥3.5 µg/dL and ≥5 µg/dL, respectively, compared to female children.

Table 8.1: Prevalence of blood lead levels ≥3.5 µg/dL and ≥5 µg/dL and the associated demographic characteristics among children 1-6 years old in Bhutan: crude Odds Ratio and adjusted Odds Ratio, adjusted for age and sex (weighted analysis) n=2959 [National Blood Lead Level Survey 2024].

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Numer of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Age (in completed years)											
1 year	78.8	Base	Base		0.3497	55.2	Base	Base		0.0963	411
2 year	78.5	0.98	0.99	0.71, 1.38		55.2	1.00	1.01	0.75, 1.35		464
3 year	74.0	0.76	0.76	0.54, 1.06		50.4	0.83	0.82	0.62, 1.08		522
4 year	73.9	0.76	0.76	0.55, 1.05		52.1	0.88	0.89	0.67, 1.18		465
5 year	75.2	0.82	0.81	0.58, 1.13		49.2	0.79	0.78	0.59, 1.03		516
6 year	75.9	0.85	0.85	0.62, 1.16		47.5	0.74	0.74	0.57, 0.96		581
Sex											
Female	71.7	Base	Base		<0.0001	47.1	Base	Base		<0.0001	1415
Male	79.9	1.57	1.58	1.31, 1.89		55.2	1.39	1.39	1.20, 1.62		1544
Area											
Urban	77.0	Base	Base		0.4262	52.7	Base	Base		0.4736	1,153
Rural	75.2	0.91	0.92	0.75,1.13		50.4	0.91	0.93	0.77, 1.13		1,806

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Numer of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Income quintile											
Lowest	76.5	Base	Base			49.0	Base	Base			605
Second	77.6	1.06	1.06	0.77,1.46		52.5	1.15	1.16	0.89, 1.50		577
Middle	74.2	0.88	0.88	0.66,1.18	0.8284	50.4	1.06	1.05	0.82, 1.36	0.7428	593
Fourth	76.0	0.97	0.97	0.72,1.32		52.9	1.17	1.17	0.90, 1.52		631
Highest	75.6	0.95	0.96	0.68,1.35		51.6	1.11	1.11	0.83, 1.49		553

[1] Crude Odds Ratio
[2] Adjusted Odds Ratio
[3] Confidence Intervals
[4] Adjusted Wald test

For housing factors, living in a home with mud-based/rammed exterior and interior walls showed a statistically significant difference in child BLLs levels compared to other types of home construction. Children living in a home with exterior mud-based/rammed walls were 1.62 times more likely to have a BLL ≥3.5 µg/dL compared to children living in a home with cement exterior walls. Similarly, children living in a home with interior mud-based/rammed walls were 1.42 times more likely to have a BLL ≥3.5 µg/dL compared to children living in a home with cement interior walls.

Children living in a home with wood/bamboo flooring were 2.42 more likely to have a BLL ≥3.5 µg/dL compared to children living in a home with cement/tile/marble floors. A similar finding was seen at a BLL ≥5 µg/dL.

Neither the age of the house nor having access to a car battery or a solar system battery made a statistical difference in the percentages of children with BLLs ≥3.5 µg/dL and ≥5 µg/dL (Table 8.2).

Additional pXRF testing will be needed on the mud-based/rammed walls to determine if the mud itself has lead in the walls, if there is another source of lead present in the rammed wall construction, or if there is another common risk factor in these homes. A possible reason for children who live in a home with wood/bamboo flooring having high BLLs could be from the challenge of cleaning wooden floors compared to other types of flooring if dust is contaminated with lead. Additional testing of the flooring and dust is needed to confirm this finding.

Table 8.2: Prevalence of blood lead levels ≥3.5 µg/dL and ≥5 µg/dL and the associated housing factors among children 1-6 years old in Bhutan: crude Odds Ratio and adjusted Odds Ratio, adjusted for age and sex (weighted analysis) n=2959 [National Blood Lead Level Survey 2024].

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Material (External Wall)											
Cemented	73.8	Base	Base		0.0002	50.1	Base	Base		0.4844	1,680
Mud-based/ rammed earth	81.9	1.60	1.62	1.28, 2.04		53.8	1.16	1.17	0.96, 1.44		925
Wood/ bamboo/ plywood	71.1	0.87	0.87	0.63, 1.20		51.3	1.05	1.06	0.80, 1.42		312
Others	75.9	1.11	1.10	0.48, 2.52		51.7	1.07	1.09	0.50, 2.34		42
Material (Interior Wall)											
Cemented	74.6	Base	Base		0.0271	50.4	Base	Base		0.5554	2,062
Mud-based/ rammed earth	80.4	1.40	1.42	1.11, 1.82		53.7	1.14	1.16	0.94, 1.43		709
Wood/ bamboo/ plywood	73.7	0.96	0.95	0.58, 1.55		53	1.11	1.11	0.75, 1.65		152
Others	83.5	1.73	1.67	0.68, 4.13		51.2	1.03	1.02	0.50, 2.08		36

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Floor Material											
Concrete/tiles/marbles	70.3	Base	Base		<0.0001	46.5	Base	Base		<0.0001	1,540
Wood/bamboo	84.8	2.37	2.42	1.92, 3.06		59.8	1.71	1.74	1.44, 2.10		1,185
Mud/Clay	82	1.93	1.91	1.06, 3.47		39.9	0.76	0.76	0.48, 1.22		90
Others	62.9	0.72	0.72	0.49, 1.08		44.1	0.91	0.91	0.62, 1.33		144
Roof Material											
CGI/Tin	76.8	Base	Base		0.0354	51.3	Base	Base		0.6744	2,650
Wood/bamboo/thatch	75	0.91	0.89	0.56, 1.41		55.8	1.20	1.18	0.80, 1.74		143
Concrete/slates	67.1	0.62	0.59	0.36, 0.95		47.7	0.87	0.84	0.52, 1.35		141
Others	57.2	0.40	0.37	0.16, 0.88		47	0.84	0.81	0.34, 1.92		25
Age of the house (building)											
Less than 10 years	74.3	Base	Base		0.1897	49.6	Base	Base		0.1818	1,107
10 or more years	77	1.16	1.16	0.93, 1.44		52.4	1.12	1.13	0.95, 1.34		1,852

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Accessible car batteries or a solar system batteries in the house[5]											
No	76	Base	Base		0.4225	51.1	Base	Base		0.4957	2,782
Yes, Car Batteries	72.8	0.85	0.88	0.55,1.39		52.1	1.04	1.07	0.72,1.59		134
Yes, Solar System Batteries	84	1.66	1.69	0.69,4.12		63.6	1.67	1.66	0.86,3.22		39
A place to recycle or throw away old car batteries near house											
No	76	Base	Base		0.9987	51.4	Base	Base		0.6357	2,890
Yes	75.2	0.96	1.00	0.48, 2.09		47.9	0.87	0.88	0.52, 1.49		69

[1] Crude Odds Ratio
[2] Adjusted Odds Ratio
[3] Confidence Intervals
[4] Adjusted Wald test
[5] Four households had both types of batteries and all four had elevated BLLs.

Table 8.3: Prevalence of blood lead levels ≥3.5 µg/dL and ≥5 µg/dL and the associated risk factors among children 1-6 years old in Bhutan: crude Odds Ratio and adjusted Odds Ratio, adjusted for age and sex (weighted analysis) n=2959 [National Blood Lead Level Survey 2024].

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Household member practice metal artisan work											
No	75.7	Base	Base		0.1801	51	Base	Base		0.1500	2,858
Yes	82.9	1.56	1.60	0.81, 3.17		59.1	1.39	1.41	0.88, 2.26		101
Household member use or handle bullets											
No	75.4	Base	Base		0.0836	50	Base	Base		0.0019	2,736
Yes	82	1.49	1.46	0.95, 2.24		64.5	1.81	1.80	1.24, 2.62		223
Aluminium cooking pots used for the preparation of food[5]											
No	73.7	Base	Base		0.3064	50	Base	Base		0.6229	403
Yes	76.3	1.15	1.15	0.88, 1.52		51.6	1.07	1.07	0.83, 1.38		2,556
Aluminium ladles/spoons used for cooking or serving food[5]											
No	68.6	Base	Base		0.0095	46.5	Base	Base		0.1238	267
Yes	76.7	1.51	1.53	1.11, 2.10		51.8	1.24	1.25	0.94, 1.67		2,692
Stainless Steels plates used for eating[5]											
No	78.6	Base	Base		0.0008	54.6	Base	Base		0.0006	1,742
Yes	72	0.70	0.71	0.59, 0.87		46.5	0.72	0.73	0.61, 0.87		1,217
Given any local or traditional medicines											
No	76.1	Base	Base		0.5677	51.5	Base	Base		0.2359	2,904
Yes	69.8	0.73	0.79	0.35, 1.79		41.3	0.66	0.70	0.38, 1.27		55

Characteristic	Children with BLL ≥3.5 µg/dL					Children with BLL ≥5 µg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Kohl, Kajal, Surma, eyeliner, eye shadow, or other home-made cosmetics used on child											
No	76.8	Base	Base		0.1167	51.9	Base	Base		0.6423	2,664
Yes	68.3	0.65	0.76	0.55, 1.07		46.6	0.81	0.93	0.68, 1.27		295
Child eat with his/her fingers or hands											
Seldom or Rarely	76.7	Base	Base		0.7647	53.6	Base	Base		0.5257	619
Some of the time	75.3	0.93	0.93	0.72, 1.21		50.6	0.88	0.88	0.72, 1.15		1,273
Most of the time	76.3	0.98	1.00	0.77, 1.30		50.9	0.90	0.91	0.70, 1.10		1,067
Hand Washing before eating											
Most of the time	76.6	Base	Base		0.2682	50.7	Base	Base		0.7123	2,204
Some of the time	73.4	0.84	0.84	0.68, 1.05		52.9	1.09	1.08	0.88, 1.33		689
Seldom or Rarely	79.8	1.21	1.14	0.63, 2.08		54.5	1.16	1.11	0.66, 1.88		66

[1] Crude Odds Ratio
[2] Adjusted Odds Ratio
[3] Confidence Intervals
[4] Adjusted Wald test
[5] Caveat: The child may or may not have used these utensils. The information was asked about household use of these utensils.

Table 8.3 shows one potential occupational risk to children's BLL. If a household member used or handled bullets, the child was 1.80 times more likely to have a BLL ≥5 µg/dL. This could be from the household member bringing lead home on their hands or clothing, or the child may have access to lead bullets after they have been fired. Either way, the potential connection must be further investigated to prevent lead poisoning in children.

None of the following showed a statistically significant association to BLLs: the use of kohl, eye makeup or home made cosmetics, living near a place where batteries were discarded or recycled, and handwashing before eating. In addition, eating with fingers/hands did not show an association in this study, whereas it was associated with higher BLLs in the 2018 study in Thimphu and Phuentsholing.

The use of stainless-steel plates for eating showed a statistically significant protective effect at both ≥3.5 µg/dL and ≥5 µg/dL BLLs.

Table 8.4: Prevalence of blood lead levels ≥3.5 μg/dL and ≥5 μg/dL and the associated religious factors among children 1-6 years old in Bhutan: crude Odds Ratio and adjusted Odds Ratio, adjusted for age and sex (weighted analysis) n=2959 [National Blood Lead Level Survey 2024].

Characteristic	Children with BLL ≥3.5 μg/dL					Children with BLL ≥5 μg/dL					Number of children
	Percent with BLL	Crude OR[1]	Adjusted for age and sex			Percent with BLL	Crude OR[1]	Adjusted for age and sex			
			aOR[2]	95% CI[3]	p-value[4]			aOR[2]	95% CI[3]	p-value[4]	
Religion											
Christianity	57.4	Base	Base		<0.0001	30	Base	Base		<0.0001	60
Buddhism	78.5	2.71	2.85	1.69, 4.8		54.2	2.76	2.81	1.58, 5.02		2,530
Hinduism	62.1	1.22	1.26	0.72, 2.2		36	1.31	1.32	0.71, 2.43		369
Ever been given any blessed religious pills											
No	72.1	Base	Base		0.0014	46.5	Base	Base		0.0007	994
Yes	78	1.38	1.40	1.14, 1.72		53.9	1.35	1.37	1.14, 1.65		1,965
Recency of being given religious pills (*Jinlab*)											
Never	72.1	Base	Base		0.0093	46.5	Base	Base		0.0003	994
Not sure	78.3	1.40	1.43	1.05, 1.94		51	1.20	1.23	0.93, 1.61		444
4-6months ago	74.3	1.12	1.12	0.78, 1.61		51	1.20	1.18	0.87, 1.61		237
1-3months ago	75.7	1.21	1.23	0.91, 1.66		49.4	1.12	1.15	0.89, 1.48		524
16-30 days ago	78	1.38	1.41	1.00, 2.00		55.5	1.43	1.48	1.10, 1.99		375
0-15 days ago	83.1	1.90	1.94	1.34, 2.80		63.3	1.99	2.03	1.51, 2.72		385

[1] Crude Odds Ratio
[2] Adjusted Odds Ratio
[3] Confidence Intervals
[4] Adjusted Wald test

Among religious factors having an association with BLLs ≥3.5 µg/dL and ≥5 µg/dL, the type of religion practiced in the household showed the strongest association, and it was highly statistically significant. Children living in a household that practiced Hinduism were 1.26 times more likely to have a BLL ≥3.5 µg/dL and 1.32 times more likely to have a BLL ≥5 µg/dL, compared to children whose household practiced Christianity. The association was stronger if the household practiced Buddhism. Children living in a household that practiced Buddhism were 2.85 times more likely to have a BLL ≥3.5 µg/dL and 2.81 times more likely to have a BLL ≥5 µg/dL, compared to a child whose household practiced Christianity.

Having ever taken *Jinlab* (blessed religious pills) was associated with BLLs ≥3.5 µg/dL and ≥5 µg/dL compared to children who had never taken *Jinlab*. Analyzing the data on how recently the child had taken *Jinlab*, Table 8.4 shows that those children who had taken *Jinlab* within 15 days of the survey were 1.94 and 2.03 times more likely to have a BLL ≥3.5 µg/dL and ≥5 µg/dL, respectively, compared to children who had never taken *Jinlab*. Children who had taken *Jinlab* 16-30 days before the survey were also more likely to have a BLL ≥3.5 µg/dL and ≥5 µg/dL compared to children who had never taken *Jinlab*.

Among all children in the survey, 65.1% of children had been given *Jinlab* at least once in their life and 50.4% had been given *Jinlab* in the past six months. However, these percentages vary by the household religion reported. Among 2,530 children whose household reported practicing Buddhism, 71.6% of the children had been given *Jinlab* at least once in their life and 56.1% of children had been given *Jinlab* in the past 6 months. Among 369 children whose households practiced Hinduism, 32% of the children had been given *Jinlab* at least once in their life and 19.9% of children in these households had been given *Jinlab* in the past 6 months. Among households reporting practicing Christianity, 6.9% of the children had been given *Jinlab* at least once in their life and 6% had been given *Jinlab* in the past six months.

As reported in Chapter 7, numerous sources of lead were identified during the survey. Some items, including items unique to Bhutan, need to have further testing to understand if an exposure pathway exists, such as the leaching of lead into food from kitchenware or if handling/touching items made with lead results in contamination of hands. It is clear that items that are directly consumed pose a much higher risk for lead poisoning. Of the

767 samples of *Jinlab* tested with the pXRF during source testing, 44.2% of them were found to have lead exceeding the 2.5 ppm threshold. This is concerning, as *Jinlab* is being taken by a majority of children. The analysis also shows an association between ever having taken *Jinlab* and the recency of having taken *Jinlab* and lead poisoning. It is critical that steps are taken to address this source of lead.

Jinlab is clearly one source of lead exposure in Bhutan, however, it is not the only source. The data show that children whose households practice Hinduism and Christianity in Bhutan also have a large percentage of children with lead poisoning. The problem of lead poisoning is complex with numerous potential sources.

Additional research is required to further identify the sources and risk of lead poisoning in Bhutan and develop strategies to prevent it. Now we must work together to end this problem for the future of the next generation.

CHAPTER 9

Recommendations from the NBLLS

Recommendations from Bhutan's NBLLS

Bhutan's National Blood Lead Level Survey (NBLLS) 2024 has positioned the country at the forefront among low- and middle-income countries by achieving nationally represented data on pediatric blood lead levels. This accomplishment also positions Bhutan to be at the forefront in addressing the problem of lead poisoning.

The following is an overview of recommendations to achieve an environment that is free of lead and safe for Bhutan's children and future generations. Ending lead poisoning will take decades of work and extensive coordination of multi-sectoral efforts with strong cooperation between ministries, NGOs, donors, and all of society. The extent of lead poisoning in Bhutan may appear daunting, and the cost to address it high. However, widespread lead poisoning is already undermining the country's academic and economic potential and harming health. Preventing lead poisoning is possible, and it is also cost effective.

Advocacy and regulatory policy development: Policies and regulations must be developed and implemented to monitor the import, use and disposal of the raw metal lead (Pb), lead compounds and alloys, and all lead-containing products that pose a risk to humans and to all living things.

Address identified lead sources: Urgent work must be done to remove lead from *Jinlab* and identify the source of lead in spices. As both items are ingested, any spice or *Jinlab* that contains lead causes detrimental effects.

Expand blood lead level and environmental lead source research: Further research is needed to better understand lead poisoning and the sources of lead. Currently all blood lead level data are from healthy children and adults. Are patients being hospitalized or dying from lead poisoning? Knowing this would help determine the urgency of adding blood lead testing and medical treatment options at referral hospitals. Other studies among pregnant women, monastic communities, and other at-risk groups would assist in developing prevention strategies to limit lead poisoning.

Build human and testing capacity: As lead poisoning is a newly identified issue, building both human and testing capacity is an essential early step. Currently lead source testing is limited, and portable blood lead level testing is restricted to research purposes. Expanding laboratory capacity is urgently needed, as well as training pre-service and in-service health workers.

Public awareness: It is critical to raise awareness of lead and its health consequences. However, messages to the public must be evidence-based, clear, and coordinated with policies and regulations to be effective.

Overarching recommendation: A task force, guided by technical experts, should be created to oversee the coordination of all aspects of a multi-sectoral strategy/action plan to reduce lead poisoning.

Following are recommendations categorized into two time-frames: urgent recommendations and medium to long-term recommendations:

Priority Recommendations for Urgent Action

1. **Advocacy and regulatory policy development:**
    a. Disseminate findings to policymakers, stakeholders, and donors.
    b. Establish a taskforce to study, develop, and coordinate a muti-sectoral strategy/action plan.
    c. Evaluate international partnerships to help confront lead poisoning.

2. **Address known sources of lead in consumables:**
    a. *Jinlab*: 44% of samples tested in the NBLLS contained lead. Since *Jinlab* is directly consumed, any lead present in *Jinlab* increases blood lead levels.
        i. Collaborate with relevant stakeholders to discuss how Jinlab can be made without lead, create a plan for the *Jinlab* in people's possession that contains lead (Pb), and develop a system for spot-checking *Jinlab* for lead.
    b. Spices: 22% of spices tested in the NBLLS contained lead.
        i. Expand testing of spices to identify those with lead (Pb), determine where the spices are sold/produced and how lead is contaminating the spices. Develop regulations to remove contaminated spices from the market and create a system for monitoring spices for lead.

3. **Capacity building:**
    a. Human capacity
        i. Increase capacity to conduct BLL & XRF lead source research
        ii. Strengthen healthcare workers' knowledge on lead poisoning.
    b. Testing capacity
        i. Assess expanding capillary and venous blood lead level testing for clinical and/or research purposes.
        ii. Assess expanding portable and laboratory lead source testing for public health and research purposes.
        iii. Formalize protocols for environmental XRF testing for regulatory purposes and training.

4. **Conduct further research:**
    a. Currently, all lead poisoning data have been collected from healthy children and adults. It is unknown if children or adults are being hospitalized and/or dying from severe lead poisoning. A study is urgently needed among hospitalized patients with symptoms suggestive of severe lead poisoning. This study would help identify if blood lead level testing and medical chelation therapy at referral hospitals is needed to save lives.

Further Recommendations for Medium to Long-Term Action

1. **Advocacy and regulatory policy development:**
    a. Develop import and regulatory policies for lead (Pb) for: foods, spices, toys, paints, household items, pesticides and herbicides, and other products.
    b. Develop industrial, professional, and environmental policies to reduce lead use.
    c. Develop a system to monitor lead (Pb) and enforce regulatory compliance.

2. **Raise awareness:**
   a. Raise awareness of lead poisoning for everyone. Report on new research findings and policies created to regulate and limit lead (Pb) in the country. Raise awareness in healthcare facilities, schools, ECCDs, and other venues.
   b. Promote Bhutan's research and progress in addressing lead poisoning at local and international conferences. Consider hosting an international lead conference to network with top researchers, academicians, clinicians, development partners, and donors.

3. **Capacity building:**
   a. Human capacity:
      i. Incorporate current lead poisoning data, recommendations, and intervention/treatment protocols into all pre-service healthcare curriculum.
      ii. Use continuing professional development to strengthen in-service healthcare workers' knowledge on lead poisoning and current intervention/treatment protocols.
   b. Testing capacity:
      i. Expand blood lead level testing capacity of both capillary screening and venous lab-based testing.
      ii. Expand laboratory-based source testing to be able to conduct leach testing for lead on kitchen items, develop lead thresholds for items unique to Bhutan, and to test foods to the level of parts per billion.
   c. Intervention/treatment capacity:
      i. Develop public health and clinical intervention protocols to provide the best preventive and medical care.

4. **Blood lead level monitoring and research:**
    a. Plan for blood lead level testing in future national surveys.
    b. Evaluate how blood lead level screening could be expanded into maternal and child health programs, infertility testing, and clinical practice.
    c. Conduct research among the monastic community, pregnant women, and at-risk populations to design interventions best suited for that population.
    d. Expand research to evaluate the effectiveness of interventions and treatment protocols to reduce blood lead levels.
    e. Collaborate with top universities and world experts on lead (Pb) research.

REFERENCES

1. Rees N, Fuller R. The Toxic Truth : Children ' s Exposure to Lead Pollution Undermines a Generation of Future Potential. 2020;1–90. Available from: https://www.unicef.org/media/73246/file/The-toxic-truth-children's-exposure-to-lead-pollution-2020.pdf
2. Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, et al. Low-level environmental lead exposure and children's intellectual function: An international pooled analysis. Environ Health Perspect. 2005;113(7):894–9.
3. Reuben A, Caspi A, Belsky DW, Broadbent J, Harrington H, Sugden K, et al. Association of Childhood Blood Lead Levels With Cognitive Function and Socioeconomic Status at Age 38 Years and With IQ Change and Socioeconomic Mobility Between Childhood and Adulthood. Jama [Internet]. 2017;317(12):1244. Available from: http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.2017.1712
4. Health Canada. Toxicological Review and Recommended Toxicological Reference Values for Environmental Lead Exposure in Canada. 2010;622.
5. Center for Disease Control and Prevention. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention. Report of the Advisory Committee on Childhood Lead Poisoning Prevention (ACCLP) of the Centers for Disease Control and Prevention [Internet]. 2012. Available from: http://www.cdc.gov/nceh/lead/acclpp/final_document_030712.pdf
6. Navas-Acien A, Guallar E, Silbergeld EK, Rothenberg SJ. Lead exposure and cardiovascular disease - A systematic review. Environ Health Perspect [Internet]. 2007;115(3):472–82. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1849948/
7. Liu Z, Yu Y, Li X, Wu A, Mu M, Li N, et al. Maternal lead exposure and risk of congenital heart defects occurrence in offspring. Reprod Toxicol [Internet]. 2015;51:1–6. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0890623814002913?via%3Dihub
8. Lanphear BP, Rauch S, Auinger P, Allen RW, Hornung RW. Low-level lead exposure and mortality in US adults: a population-based cohort study. Lancet Public Heal [Internet]. 2018;3(4):e177–84. Available from: http://dx.doi.org/10.1016/S2468-2667(18)30025-2

9. 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 Heal. 2023;7(10):e831–40.

10. Erbele P, Pem D, Tobgay P, Pelden S, Gurung MS, Ugen S, et al. Blood Lead Levels in children 2 through 59 months old in Bhutan. Bhutan Heal J [Internet]. 2019 Nov;5(216):7–14. Available from: https://doi.org/10.47811/bhj.83

11. Pem D, Wangdi U, Gyeltshen N, Wangdi K, Wangdi C, Erbele P. Potential sources of lead in children's environments, Thimphu, Bhutan. Bhutan Heal J. 2022;8(2):13–7.

12. Lanphear, Bruce; Navas-Acien, Ana; Bellinger D. Lead Poisoning. N Engl J Med. 2024;1621–31.

13. World Health Organization. Exposure to lead: a major public health concern, third edition. Preventing disease through healthy environments. 2023;1–7. Available from: https://www.semanticscholar.org/paper/A-Comprehensive-Study-of-Cd(II)-Removal-from-via-Athapaththu/cbf2349bab5b8f621038554bddeb0102628e30ad%0Ahttps://ir.lib.uwo.ca/etd/1783%0Ahttps://ir.lib.uwo.ca/etdhttps://ir.lib.uwo.ca/etd/1783

14. WHO. WHO guideline for clinical management of exposure to lead [Internet]. 2021. 1–92 p. Available from: http://apps.who.int/iris.

15. Barry PSI. A comparison of concentrations of lead in human tissues. Br J Ind Med. 1975;32(2):119–39.

16. Canfield, Richard L.; Henderson, Charles R.; Cory-Slechta, Deborah A.; Cox, Christipher; Jusko, Todd A.; Lampherar BP. Intellectual Impairment in Children with Blood Lead Concentrations below 10 µg per Deciliter. N Engl J Med. 2003;348:1517–26.

17. Crawfurd L, Todd R, Hares S, Sandefur J, Bonnifield RS. How Much Would Reducing Lead Exposure Improve Children ' s Learning in the Developing World ? 2023;(July 2023):1–59. Available from: https://www.cgdev.org/publication/how-much-would-reducing-lead-exposure-improve-childrens-learning-developing-world

18. Gajewska K, Laskowska M, Almeida A, Pinto E, Skórzyńska-Dziduszko K, Błażewicz A. Lead levels in non-occupationally exposed women with preeclampsia. Molecules. 2021;26(10):1–10.

19. Fisher M, Marro L, Arbuckle TE, Potter BK, Little J, Weiler H, et al.

Association between toxic metals, vitamin D and preterm birth in the Maternal–Infant research on environmental chemicals study. Paediatr Perinat Epidemiol. 2023;37(5):447–57.

20. Dhakal GP, Sharma KP, Bajgai GP, Sharma TR, Bajgai TM, Tenzin J, et al. Vitamin D Status among the Population Visiting Jigme Dorji Wangchuck National Referral Hospital, Bhutan. Indian J Endocrinol Metab. 2023;27(5):436–9.
21. Park E, Kim S, Cho S, Kim H, Jung I, Moon JD, et al. The Association Between Blood Lead Levels and Coronary Artery Calcium Score Determined by Using Coronary Computed Tomography Angiography. J Korean Med Sci. 2023;38(26):1–11.
22. Harari F, Sallsten G, Christensson A, Petkovic M, Hedblad B, Forsgard N, et al. Blood Lead Levels and Decreased Kidney Function in a Population-Based Cohort. Am J Kidney Dis. 2018;72(3):381–9.
23. Weaver V, Navas-Acien A, Tellez-Plaza M, Guallar E, Muntner P, Silbergeld E, et al. Blood cadmium and lead and chronic kidney disease in US adults: A joint analysis. Am J Epidemiol. 2009;170(9):1156–64.
24. WHO. Guideline on haemoglobin cutoffs to define anemia in individuals. Geneva: World Health Organization. 2024;1-57. Available from: https://iris.who.int/bitstream/handle/10665/376196/9789240088542-eng.pdf

APPENDICES

Appendix 1: Phase 1 - Data collection protocol

Overview

For each household with a child 1-6 years of age selected for the NBLLS Phase 1 testing, enumerators collected data on the child and household, conducted a developmental screen, and collected blood samples for BLL and Hgb on the selected child. They also collected BLL and Hgb for any woman in the household who was pregnant or had delivered in the past 6 months and was breastfeeding. Hgb were tested at the home, and appropriate follow up was given. Blood samples for BLL were transported to the central testing location. The household was provided a handout educating about lead.

Protocol for household identification and location

For each child selected from the NHS 2023 data set, the following information was provided to the NBLLS enumerator, along with contact phone numbers. Enumerators attempted to call every household before the visit to explain the survey and arrange a time to visit the household. If contact by phone was unsuccessful, the enumerator visited the household and explained the survey in person.

Question	Information provided to enumerators
Name of the Dzongkhag	
Name of the Gewog	
ID of Primary Sampling Unit (PSU)	
Unique ID number	
Name of the child's mother	
Name of the selected child	

At each household visit, the following data were collected.

Question	Answer options
Date and time of visit.	• Automatically recorded (by tablet CAPI)
Result of the household (HH) visit.	• HH located, contacted, and interview completed • HH located, contacted, and partially interviewed • HH located, no HH member or competent person to respond • HH located, asked to come later • HH located, entire HH absent for extended period of time • HH located, contacted, refused to participate • Dwelling vacant • Dwelling destroyed • Dwelling not found • Other
If other, specify.	
Record of household's location.	-GPS coordinates automatically recorded

After the enumerator introduced themselves to the household, the enumerator explained Phase 1 of the survey to a parent, guardian, or an adult decision maker and answered any questions they had. A colored handout in English and Dzongkhag was given to each parent to help explain what lead was and ways to reduce lead exposure. The English version is provided below.

Lead Handout

WHAT IS LEAD?

How can you avoid lead poisoning?

Lead is a poison!
It causes:

- Brain injury and makes learning harder
- Growth and development problems
- Low blood levels
- High blood pressure, strokes, kidney problems and other medical problems in adults

Lead poisoning happens when lead dust is swallowed or breathed in.

Where is lead found?

- Car batteries and in areas surrounding battery recycling sites
- Some paints and in old chipped and peeling paint
- Dirt and fluids around auto repair and petrol stations
- Kohl and some other cosmetics
- Some spices and other sources we are still looking for...

Children who do not regularly eat nutritious foods will absorb more lead!

How can I protect my child?

1. Keep hands clean
- Wash hands often with soap and water
- Always wash hands before eating and before sleeping

2. Keep things clean
- Regularly clean toys, especially those which infants and children put in their mouth
- Use a wet mop or cloth to regularly clean the floors and around windows to remove dust

3. Give your child healthy foods:
- Foods high in iron, calcium, and vitamin C help block lead from entering the body
  - » Iron is in red meat, pulses or beans, green leafy vegetables, and cereals
  - » Calcium is in milk, yogurt, cheese, and green leafy vegetables
  - » Vitamin C is in oranges, broccoli, tomatoes, and chilis

If agreeing to have the selected child in the survey, written informed consent was requested and taken using the tablet containing CAPI software. A thumb print for informed consent was also an option. The data and time of the consent were recorded. If the person refused to give consent, a reason for refusal was recorded.

If consent was given, the following questions related to the selected household were asked.

Questionnaire

Question	Information provided to enumerators	
What is the exterior wall material of the house?	• Brick/Cement blocks • Stone with mud • Wood planks • Bamboo with mud • Stone with cement • Rammed earth	• Cane bamboo • Trunk of banana leaves • Plywood • Mud blocks • Prefabricated wall • Other specify
What is the roof material of the house?	• Metal sheets CGI • Thatch Banana leaf • Bamboo • Planks shingles • Tarpaulin	• Tiles • Slates • Concrete cement • Tin sheets • Other specify
What is the interior wall material of the house?	• Bricks / Cement blocks • Stone with mud • Wood planks • Bamboo with mud • Stone with cement • Rammed earth • Cane bamboo	• Trunks of banana leaves • Plywood • Mud blocks • Prefabricated wall • Planned wall • Other specify
What is the floor material?	• Planks on timber • Planks on concrete • Terrazzo • Earthen clay • Wood block on concrete	• Tiles on concrete • Marble on concrete • Bamboo • Wood logs • Other specify
About how old is the house?	• Less than 10 years old • 10 years or older	

Question	Information provided to enumerators
What religion does the household belong to?	• Buddhist • Hinduism • Christianity • Islam • Other
If other, please specify	

Next, questions related to household lead risk factors were asked.

Question	Answer options
Does anyone in the house practice metal artisan work? (picture shown)	• Yes • No
Does anyone in the house use fishing weights to catch fish? (picture shown)	• Yes • No
Does anyone in the house use or handle bullets? (police, military, security guard, other)	• Yes • No
Do you have accessible car batteries or a solar system battery in the house? (picture shown)	• Yes • No
Is there a place to recycle or throw away old car batteries near your house?	• Yes • No
If so, how far away is that place (distance in meters)?	
Are hand-made or traditional metal cooking pots used for the preparation of food? (picture shown)	• Yes • No
Are brass/bronze/copper cooking pots used for the preparation of foods? (picture shown)	• Yes • No
Are hand-made aluminum ladles / spoons used for cooking or serving food? (picture shown)	• Yes • No
Are brass/bronze/copper ladles/spoons used for cooking or serving foods? (picture shown)	• Yes • No
Are brass/bronze/copper plates used for eating? (picture shown)	• Yes • No
Are stainless steel plates used for eating? (picture shown)	• Yes • No
Are decorative metal spoons used for eating? (picture shown)	• Yes • No
Is metal jub or cup or Lota used for drinking? (picture shown)	• Yes • No

For each 1–6-year-old child selected in the household, the following questions were asked.

Question	Answer options
What is the name of the child?	
What is the sex of the child?	• Male • Female
When is the child's birthday?	
Was the child born preterm?	• Yes • No
If so, when was the child's estimated date of delivery?	
If so, at which week of pregnancy was the child born?	
Where has the child lived in the past month?	• Most of the time at this house • More time at another house
Is "kohl", "kajal", "surma", eye liner, eye shadow, or other home-made cosmetics used on the child? (picture shown)	• Yes • No
Does the child eat from a metal plate?	• Yes • No
How often does the child eat with his / her fingers or hands?	• Most of the time • Some of the time • Seldom
How often does the child wash their hands with soap and water before eating?	• Most of the time • Some of the time • Seldom
Has the child been given any traditional medicines in the past 30 days? (picture shown)	• Yes • No
Has the child ever been given any *Jinlab*, *rilbu*, blessed religious pills or substances? (picture shown)	• Yes • No
In the past 6 months, how many time has the child been given *Jinlab*, *damze*, blessed pills, or religious pills?	• Enter quantity:
When was the last time the child was given *Jinlab / rilbu*, blessed pills, or religious pills?	• 0 - 15 days ago • 16 - 30 days ago • 1 - 3 months ago • 4 - 6 months ago • Not sure

Question	Answer options
From where was the *Jinlab / rilbu*, blessed pills, or religious pills obtained?	• Purchased • Free • Not sure/unknow
If purchased, from where?	
What is your name so I can call you with the child's BLL result?	
What is your relationship to the child?	• Relationship options provided
What is your phone number?	

Once the above listed questions were asked about the household, household risk factors, and risk factors for the child, an inquiry was made if there was any pregnant or breastfeeding woman in the household who had delivered in the past six months. If so, they were invited to take part in the survey, the survey was explained, and questions answered before written or a thumb print informed consent was requested of each woman.

For each consenting women in the household, the following set of questions was asked.

Question	Answer options
Is there any woman aged 15-49 years old in the household who is currently pregnant or delivered in the past 6 months?	• Yes • No
If so, how many women are there?	• Yes • No
For each woman the following questions were asked.	
What is your name?	
What is your date of birth?	
Are you currently pregnant?	• Yes • No
If so, how many weeks pregnant are you?	
Have you delivered a baby in the past 6 months?	• Yes • No
If so, when did you deliver?	
Where have you lived in the past months?	

Question	Answer options
Have you taken any local or traditional medicine in the past 30 days?	• Yes • No
Have you ever eaten *Jinlab, damze, rilbu,* blessed religious pills or substances? (picture shown)	• Yes • No
In the past 6 months, how many times have you taken *Jinlab / rilbu,* blessed pills, or religious pills?	
When was the last time you took *Jinlab / rilbu,* blessed pills, or religious pills?	• 0 - 15 days ago • 16 - 30 days ago • 1 - 3 months ago • 4 - 6 months ago
From where was the *Jinlab / rilbu,* blessed pills or religious pills obtained?	• Purchased • Free • Not sure/unknow
If purchased, from where?	
Do you have *Jinlab / rilbu,* blessed pills, or religious pills? If you have some, may I have a sample of it?	• Yes, sample provided • Yes, sample not provided • No
Do you have any local or traditional medicine? If you have some, may I have a sample of it?	• Yes, sample provided • Yes, sample not provided • No
Can I have your phone number so I can call you with your BLL result.	

Bhutan Child Developmental Screening Tool

BCDST: Next, for each child 1-5 years old, the appropriate Bhutan Child Development Screening Tool was used to evaluate the child's development. The results were entered into the CAPI.

CHILD DEVELOPMENTAL SCREENING TOOL (BCDST 12m) Screening Schedule: 12 months-17 months 29 days Note for the screener: If the child is 'Preterm' ensure that age is corrected before screening			
DEVELOPMENTAL DOMAIN	**MILESTONES**		
PHYSICAL DEVELOPMENT	Walks sideways holding onto a stable support (chair, low table, sofa etc.)	Yes	No
	Walks forward when held by both hands	Yes	No
	While holding onto a stable support (chair, pillar, etc.), child is able to squat down, pick up a toy and return to standing	Yes	No
	Picks up small objects using pincer grasp (thumb and index finger)	Yes	No
COMMUNICATION/ LANGUAGE	Follows simple instructions (using gestures) such as "give" "go " "come " etc.	Yes	No
	Uses fingers to point at people or objects he/she wants to show	Yes	No
	Specifically says "apa", "ama", "mama" or "dada", "baba" or "papa"	Yes	No
PROBLEM SOLVING / COGNITION	Put objects/toys in and takes out of a container	Yes	No
	Able to imitate gestures	Yes	No
	Looks at objects/animals/pictures when named	Yes	No
PERSONAL - SOCIAL	Waves "tata", "bye bye" appropriately	Yes	No
	Drinks water, milk or juice from a cup with assistance	Yes	No
	Plays with toys/objects appropriately (hugging stuffed animals, making sound of animal toys, car race, etc.)	Yes	No

RESULT:
☐ Development on track
☐ Needs monitoring
☐ Needs further assessment

ACTION:
☐ C4CD interventions
☐ Rescreen in:........ Weeks ☐ Next well child clinic visit
☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:______________________________
DATE OF SCREENING : (DD)/ (MM)/ (YYYY)
NAME OF HEALTH FACILITY:______________________________

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

BHUTAN CHILD DEVELOPMENTAL SCREENING TOOL (BCDST 18m)

Screening Schedule: 18 months

Note for the screener: If the child is 'Preterm' ensure that age is corrected before screening

DEVELOPMENTAL DOMAIN	MILESTONES		
PHYSICAL DEVELOPMENT	Walks independently	Yes	No
	Bends over or squats to pick up an object from the floor and then stands up again without support	Yes	No
	Climbs up a few stairs holding rail or other support, placing both feet on same step	Yes	No
COMMUNICATION/ LANGUAGE	Says several (4-6 words) meaningful single words	Yes	No
	Shakes and nods her/his head while agreeing or disagreeing	Yes	No
	Follows simple one step instructions without using gestures such as "pick up the toy", "bring that cloth" etc	Yes	No
PROBLEM SOLVING / COGNITION	Identifies at least one body part by pointing	Yes	No
	Recognizes several people in addition to immediate family	Yes	No
	Able to turn pages of a book	Yes	No
PERSONAL - SOCIAL	Feeds self, even though may spill some food	Yes	No
	Helps to undress by taking off socks, hats or shoes	Yes	No
	Gets your attention or tries to show you something or seeks help by pulling on your hand or clothes	Yes	No
	Engages in pretend play (telephone, cooking, feeding, etc.)	Yes	No

RESULT:	ACTION:
☐ Development on track	☐ C4CD interventions
☐ Needs monitoring	☐ Rescreen in:........ Weeks ☐ Next well child clinic visit
☐ Needs further assessment	☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:____

DATE OF SCREENING : (DD)/ (MM)/ (YYYY)

NAME OF HEALTH FACILITY:____

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

BHUTAN CHILD DEVELOPMENTAL SCREENING TOOL (BCDST 24m) Screening Schedule: 24 months			
DEVELOPMENTAL DOMAIN	**MILESTONES**		
PHYSICAL DEVELOPMENT	Walks up and down stairs with both feet on each step holding onto railing or wall or adult's hand using one hand	Yes	No
	Runs and stops without falling	Yes	No
	Kicks a ball forward	Yes	No
	Turns pages of a book singly (one at a time)	Yes	No
COMMUNICATION/ LANGUAGE	Correctly names at least one familiar object or picture	Yes	No
	Speaks some two-word sentences like, "Mama eat," "Go home," "Daddy Play,"	Yes	No
	Has a vocabulary of 50 words	Yes	No
PROBLEM SOLVING / COGNITION	Identifies self in photograph/mirror/cellphone	Yes	No
	Identifies 6 body parts	Yes	No
	Finds chair or other items to help reach objects that he/she wants	Yes	No
PERSONAL - SOCIAL	Interacts with peers	Yes	No
	Shows wide variety of emotions, e.g., fear, anger, sympathy, joy	Yes	No
	Understands difference between things that can be eaten and not eaten	Yes	No
	Anticipates need to relieve(toilet) by using same word for urination and defecation	Yes	No

RESULT:
☐ Development on track
☐ Needs monitoring
☐ Needs further assessment

ACTION:
☐ C4CD interventions
☐ Rescreen in:........ Weeks ☐ Next well child clinic visit
☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:____________________________________
DATE OF SCREENING : (DD)/ (MM)/ (YYYY)
NAME OF HEALTH FACILITY:____

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

CHILD DEVELOPMENTAL SCREENING TOOL (CDST 36m) Screening Schedule: 36 months			
DEVELOPMENTAL DOMAIN	**MILESTONES**		
PHYSICAL DEVELOPMENT	Climbs stairs with alternate foot (one foot on each step) holding onto railing or wall or adult's hand using one hand	Yes	No
	Kicks a ball by swinging his/her foot forward	Yes	No
	Throws ball/object with one hand	Yes	No
COMMUNICATION/ LANGUAGE	Converses using three to four word sentences	Yes	No
	Able to say his/her name/nickname when asked	Yes	No
	Uses pronouns such as "I", "you", "me"	Yes	No
	Follows 2 step related instructions like 'get your cup and bring it to me'	Yes	No
PROBLEM SOLVING / COGNITION	Identifies common objects (cars, cups, mugs, phones, pots, shoes etc) with their uses	Yes	No
	Understand what "two" means	Yes	No
	Understands "big and small" or "short and long"	Yes	No
PERSONAL - SOCIAL	Shows affection for friends without prompting	Yes	No
	Understands the idea of "mine", "his" or "hers"	Yes	No
	Understands and stays away from common dangers like fire, stairs, unfamiliar animals	Yes	No
	Washes hands independently	Yes	No

RESULT: ☐ Development on track ☐ Needs monitoring ☐ Needs further assessment	**ACTION:** ☐ C4CD interventions ☐ Rescreen in:........ Weeks ☐ Next well child clinic visit ☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:______________________________

DATE OF SCREENING : (DD)/ (MM)/ (YYYY)

NAME OF HEALTH FACILITY:______________________________

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

CHILD DEVELOPMENTAL SCREENING TOOL (CDST 48m) Screening Schedule: 48 months			
DEVELOPMENTAL DOMAIN	**MILESTONES**		
PHYSICAL DEVELOPMENT	Hops and stands on one foot up to 2 seconds	Yes	No
	Jump forward at least 6 inches with both feet leaving the ground at same time	Yes	No
	Catch a large ball/object with both hands	Yes	No
	Holds a pencil in a tripod grip	Yes	No
COMMUNICATION/ LANGUAGE	Child's speech is understood by unfamiliar people, although some errors persist	Yes	No
	Sings simple song	Yes	No
	Asks questions beginning with "why" or "how"	Yes	No
PROBLEM SOLVING / COGNITION	Understands opposites, e.g., day and night, hot and cold, etc.	Yes	No
	Understands positional terms like 'IN', 'UNDER', 'UP', etc.	Yes	No
	Names some colours	Yes	No
	Counts to 4	Yes	No
PERSONAL - SOCIAL	Shows interest in interactive games or make-believe	Yes	No
	Responds to other children and people outside the family	Yes	No
	Feeds self in tidy manner	Yes	No

RESULT:	**ACTION:**
☐ Development on track ☐ Needs monitoring ☐ Needs further assessment	☐ C4CD interventions ☐ Rescreen in:........ Weeks ☐ Next well child clinic visit ☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:______________________________

DATE OF SCREENING : (DD)/ (MM)/ (YYYY)

NAME OF HEALTH FACILITY:______________________________

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

CHILD DEVELOPMENTAL SCREENING TOOL (CDST 60 m) Screening Schedule: 60 months			
DEVELOPMENTAL DOMAIN	**MILESTONES**		
PHYSICAL DEVELOPMENT	Hops on one foot on the same spot for two times	Yes	No
	Stands on one foot for at least 5 seconds	Yes	No
	Able to walk on tiptoes	Yes	No
COMMUNICATION/ LANGUAGE	Tells longer stories from TV, book or stories that he/she has heard or from past events (birthday celebration, Tsechu, picnic, shopping, etc.)	Yes	No
	Uses words like “tomorrow” and “yesterday”	Yes	No
	Uses future tense (e.g., Ama will come today, I will go out later, etc.)	Yes	No
PROBLEM SOLVING / COGNITION	Counts to 10 or more things (in any language)	Yes	No
	Recognizes at least 5 different colors.	Yes	No
	Aware of gender	Yes	No
PERSONAL - SOCIAL	Goes to toilet independently	Yes	No
	Dresses and undresses independently	Yes	No
	Brushes teeth independently	Yes	No
	Able to concentrate on any single activity without getting distracted easily for at least 5 minutes	Yes	No

RESULT:	**ACTION:**
☐ Development on track ☐ Needs monitoring ☐ Needs further assessment	☐ C4CD interventions ☐ Rescreen in:........ Weeks ☐ Next well child clinic visit ☐ Referral for further assessment

COMMENTS:

NAME AND INITIAL OF SCREENER:______________________________
DATE OF SCREENING : (DD)/ (MM)/ (YYYY)
NAME OF HEALTH FACILITY:______________________________

IMPORTANT NOTE: The developmental status of the child can only be confirmed by qualified healthcare provider trained in child development assessment.

Capillary Blood Collection / Testing Protocol

Capillary Blood Collection: After the developmental screening was completed, the selected children and eligible women in the household had their blood collected following this capillary blood collection protocol.

Daily check of blood testing supplies:

Item:	Quantity			Item:	Quantity		
	Phase 1	Phase 2	Phase 3		Phase 1	Phase 2	Phase 3
LeadCare II analyzer	-	1	-	Plastic work area	1	1	1 - 3
HemoCue analyzer	1	1	1 -3	Reagent holder (plastic)	1	1	1 - 3
D-Wipes	8	20	40	HemoCue cuvettes (in bottle)	8	20	40
Alcohol wipes	8	20	40	Bandaids	10	20	40
Gloves (correct size)	5	10	30	Permanent marker	1	1	1 - 3
Lancets (of each color needed)	6	12	25	Replacement batteries (AA)	4	4	8
Gauze	8	20	40	HemoCue cleaner	1	1	1 - 3
LeadCare capillary tubes/ plungers (in bottle)	8	30	40	Ziplock bag for reagent tubes with blood samples	1	2	1 - 3
LeadCare reagent tubes	8	30	40	Sharps container	1	1	1 - 3
				Biohazard trash bag	1	1	1 - 3

*For testing in urban areas where more households will be visited daily, double the supplies!

Preparation:

1. Confirm questions were answered and consent was given.
2. Place the plastic work area on a flat surface. Place the HemoCue box or supplies box, and sharps container beside it. Set out a biohazard trash bag next to work area. Now open the boxes.
3. Use 1 D-Wipe to first clean the plastic work area. Use the same wipe to clean your hands.

    --Fold the wipe and place it on the upper corner of the plastic work area.
4. Allow the work area and your hands to dry.
5. Do not touch non-survey items to avoid lead contamination.
6. Next remove the HemoCue analyzer, plastic reagent holder, and marker. Use the folded D-Wipe to wipe them off and place them on the plastic work area.
7. Remove the rest of the items needed for testing (except the capillary tube). Place on the clean, dry work area.
8. Write the participant's NHS ID number or unique ID on the plastic reagent container. Loosen the top of the container—so it is easier to use later. Place it in the plastic reagent holder to prevent it from spilling.
9. Finally, remove a capillary tub and place it on the plastic reagent tube holder, preventing the tip from touching anything.
10. Open the gauze and one alcohol wipe and place it on the clean plastic work area.
11. Request a parent to hold small children on their lap. Older children can sit by themselves.

Item & quantity needed on the clean work area:	
D- Wipe	1
Alcohol wipes	2
Gloves (pair)	1
Lancet	
(Use table below to select lancet size)	1
Gauze	1
Reagent tube	1
HemoCue cuvette	1
Bandaid	1
Permanent marker	1
Plunger	1
Capillary tube (place on plastic reagent holder)	1

<table>
<tr><th>Age</th><th>Lancet color</th><th>Site</th></tr>
<tr><td>2 – 4 mths</td><td>Green</td><td rowspan="2">Heel</td></tr>
<tr><td>5 – 11 mths</td><td>Blue</td></tr>
<tr><td>1 – 3 yrs</td><td>Pink</td><td rowspan="3">Finger</td></tr>
<tr><td>4 – 8 yrs</td><td>Green</td></tr>
<tr><td>9 yrs and older</td><td>Blue</td></tr>
</table>

Blood collection for lead testing:

12. Decide which hand to test. Massage the participant’s hand and middle and ring finger to get good blood flow.
13. Put on your gloves.
14. Use 1 new D-Wipe to thoroughly clean the participant’s hand, focusing on the middle and ring fingers. Allow it to dry.
15. Once clean, do not let the clean hand and fingers touch anything!
16. Turn on the HemoCue analyzer. It will automatically turn off in 5 minutes if not used.
17. Use the opened alcohol wipe to wipe the finger to be pricked. Allow the finger to dry.
18. With the palm up, prick the lateral side of the finger using the appropriate colored lancet.

19. Remove the first drop of blood with a clean gauze. Keep the finger in a downward position to maintain blood flow.
20. Hold the capillary tube almost horizontal by the GREEN end while collecting blood to the BLACK line. Ensure there are NO air bubbles. If there are air bubbles discard the capillary tube and start again.
21. When filled to the BLACK line, use clean gauze to wipe any excess blood from the outside of the capillary tube.

    --Use caution not to drain the blood from the end of the capillary tube.

22. Open the reagent container and dispense the entire volume of blood into the reagent container using a plunger.
23. Dispose of the empty capillary tube in the sharps container.
24. Close the reagent container securely and invert 8 – 10 times.

Blood collection for HemoCue Hgb testing:

25. Use a gauze to wipe blood from the finger. If necessary, massage the finger to get a LARGE drop of blood.

    -If blood flow has stopped, explain that it is not essential to check the Hgb. If they would like it checked, open the second alcohol wipe to clean another finger to prick and collect testing sample.

26. Fill a HemoCue microcuvette completely in one step.
27. Carefully use the gauze to wipe off the outside of the HemoCue microcuvette without drawing blood out of the microcuvette. Visually inspect it.

    --If the microcuvette is not completely filled with blood or has any central air bubbles, discard and fill a new microcuvette. Small bubbles around the edge can be ignored.

28. Immediately place the microcuvette in the analyzer and gently slide it to the measuring position. Record the Hgb on the tablet.
29. Hold pressure on the pricked site with gauze. Place a Band-Aid on the site if necessary.
30. Provide advice or recommendations as directed by the CAPI.
31. Discard sharps into sharps container and other used items into a biohazard trash bag.

32. Ensure the labeled lead reagent container is fully closed and place it in a zip-lock bag.
33. If more people are being tested, start from item #7.
34. Transport the blood samples to the designated central testing location.
35. Transport biohazard trash and sharps to the designated central testing location for disposal.

Inform the participant or parent that they will receive a call if there is lead in the blood. If a high amount of lead is found in the blood, a team may return to test more household members and test for lead in the house.

The Hgb test was done in the house using a HemoCue Hb 301 analyzer and results were recorded in the tablet. During the survey, everyone's Hgb was adjusted for elevation and evaluated with the 2024 WHO anemia guidelines.

Based on the Hgb level, reassurance, nutritional advice, or a referral to a healthcare facility was made. The referral letter is provided on the next page.

The blood sample for BLL testing was carried by the enumerator to the central testing location in each dzongkhag for testing. The following blood results, as displayed on the LeadCare II analyzer, were recorded into the tablet for each child or woman.

Question	Answer options
Report the Hbg level of the person.	
Report the BLL for the person.	• Low • BLL Value: __________ • High
Repeat BLL value if 1st result was ≥30 µg/dL.	• Low • BLL Value: __________ • High

Each enumerator who collected the blood sample called the parent or guardian with the BLL results. If the household was selected for Phase 2 household testing based on the child's BLL, the enumerator would inform the adult during the phones call.

Referral letter

Date: ______ / ______ / __2024__

To: Health Care Professional,

____ was recently included in the Lead Prevalence Study, part of the National Health Survey. In screening this person's blood, the results required further evaluation at:

☐ the nearest healthcare facility
☐ the nearest referral hospital

The following results were found:

☐ Hemoglobin (Hgb) level: _______________ gm/dL
(Tested on a HemoCue Hb 301 analyzer)

- Please test this person's hemoglobin level. If anemic, treat per standard protocols.

Kind regards,
Lead Prevalence Technical Working Group,
National Health Survey

Appendix 2: LeadCare II BLL testing protocol

As the enumerators traveled from dzongkhag to dzongkhag, central testing locations were designated by the supervisor. All central testing locations were below 8,000 feet elevation, to stay within LeadCare II analyzer testing parameters. Enumerators collected blood samples for BLL testing at homes and transported them to the central testing location for daily testing. The following protocol outlines the procedure used to minimize environmental contamination during testing of blood samples.

A clean room with minimal to no drafts was used for BLL testing. Prior to setting up the LeadCare II analyzers, the paint on the walls and the table where testing was conducted were first tested with a pXRF to ensure no lead was present. A D-Lead surface wipe (ESCA Tech), which binds lead and other metals, was used to wipe the table and nearby floor and walls. A lead-free sheet of plastic was placed on the table and all equipment and supplies were placed on it. The trained person/s conducting the testing used a D-Wipe (ESCA Tech) to clean their hands and wore PPE during testing.

During testing of the blood samples, the LeadCare II protocol in the Quick Reference Guide was followed. Calibration and quality controls were conducted with each new batch of reagents and whenever necessary.

The LeadCare II Quick Reference Guide is available at:
https://www.magellandx.com/uploads/2020/10/70-6552-LeadCare-II-QRG-Rev_05.pdf

Appendix 3: Rationale for the design of the BLL testing in the National Blood Lead Level Survey

The rationale for the design of this National Blood Lead Level Survey (NBLLS) was based on UNICEF's technical document, *Approaches to blood lead level testing*, (February 2022) which states, "Decisions on which options the government will take on blood sampling, testing and analysis will depend on the context, objectives, capacities and available resources."

The most accurate or "gold standard" for blood lead testing comes from a venous blood sample that is tested in an International Laboratory Accreditation Cooperation (ILAC) laboratory approved for blood lead level testing. In Bhutan, however, that option is not possible.

Bhutan carefully investigated several options for blood lead level testing for the National Blood Lead Level Survey (NBLLS). The survey had two main purposes: first, to collect nationally represented data on BLLs in children, as well as data on other populations and secondly, to immediately collect data on the potential sources of lead in children's environments.

Conducting environmental XRF testing immediately after blood lead level testing allowed for the best opportunity to identify potential sources of lead in children's environments.

Leading up to the survey, multiple blood lead testing options were discussed extensively with senior stakeholders. Bhutan's context, objective, capacities and available resources were all considered. After all options were considered, the LeadCare II point-of-care analyzer was determined to be the best option for the NBLLS.

Rationale

I. **Venous blood sample collection for laboratory blood lead testing was not possible at the time for the following reasons:**

    a. **Lack of phlebotomists skilled in drawing blood from infants & children:** While Bhutan has many trained healthcare professionals, at the time of the data collection there was a nation-wide shortage. There were not enough phlebotomists skilled in drawing blood on infants & children who could travel across the country to safely collect venous blood samples for the survey.

b. **Travel and transport challenges:** Although Bhutan is a small country with a population of fewer than 800,000 people, they are scattered in rural towns and villages across this mountainous country. Some homes can be reached only by hiking several days from a main road. Enumerators would have faced difficulties in traveling and transporting samples. Using a testing method in which samples would need to be processed in an accredited lead testing laboratory would have delayed the follow up of high BLLs and environmental testing by months and dramatically increased the cost of the survey.

c. **Laboratory capacity challenges:** While there was a graphite furnace and a mass spectrometer in the country, there were challenges with accessing the equipment, availability of reagents, and adequate trained technicians. It would have also been difficult to process thousands of samples being collected for the NBLLS in addition to the lab's regular activities and responsibilities. Bhutan's current laboratory facilities are not ILAC accredited for lead testing, as is recommended by UNICEF.

d. **Challenges with sending blood to a laboratory outside of the country:** This was not an acceptable option politically or logistically. Even if it were acceptable, it would have delayed the follow up of high BLLs and conducting XRF testing to find potential sources of lead in children's environments. This would have again dramatically increased the cost of the survey.

II. Other blood lead testing methods were considered and rejected:

a. **Dried Blood Spot Sampling:** This method collects peripheral blood from a finger or heel stick onto a paper for processing at a central lab. Collecting blood on paper would expose samples to environmental contamination while drying. The drying time needed before samples could be transported would have created challenges for the field enumerators. Testing at a laboratory would have delayed the follow up of high BLLs and conducting XRF testing to find potential sources of lead in children's environments.

b. **Mitra microsampling using VAMS technology:** This new technology by Neoteryx used a proprietary device to collect a microsample from peripheral blood to test for lead. The Centre de Toxicologie du Québec developed a method for testing the sample for lead and published their paper in January 2023 (see citation below). This method showed promise for use in epidemiological studies, however at the time of developing this survey this method had yet to be field tested. The lack of a track record on this technology created hesitation in senior decision makers in the Ministry of Health.

An article on Neoteryx's website stated that the method has been introduced in the country of Georgia for use in their lead surveillance program with the support of UNICEF. It required an inductively coupled plasma-mass-spectrometer (ICP-MS), thus this would not easily work in Bhutan due to gaps in Bhutan's laboratory capacity. It does not appear that this method has been used much in clinical or research settings. By comparison, LeadCare II has been used in multiple clinical settings and epidemiological studies for decades.

Breton A, Cirtiu CM, Fleury N, Lajeunesse A, Rudge J. *Method development for the quantification of lead levels in whole blood sampled on Mitra® with VAMS® tips by inductively coupled plasma-MS/MS. Bioanalysis.* 2023 Jan;15(2):71-81

III. Ethical concerns

a. **Pain, discomfort, and risk of injury:** Given the lack of skilled pediatric phlebotomists, the risk of injury from a venous blood draw exceeded the benefits.

b. **Delays in providing care for critically high BLLs:** Given the delays of weeks to months for laboratory BLL results, the potential harm of delaying treatment outweighed the advantage of a result processed in a laboratory.

c. **Delays in collecting national data:** Considering the high prevalence of children with lead found in the first study, in 2018, further delaying a national survey until local lab capacity was adequately developed would only delay Bhutan's ability to intervene for the benefit of children's health.

IV. Benefits of using LeadCare II

a. **No phlebotomists or laboratory technicians are needed:** The LeadCare II analyzer is a small, portable, CLIA-waived device that uses two drops of blood from a finger prick or heel prick for analysis. Enumerators were trained to collect peripheral blood samples and test the blood.

b. **Immediate blood lead level results to conduct environmental testing:** Testing samples on the LeadCare II takes 3 minutes, and samples were tested each evening. The BLLs of household members and environments of children with the highest blood lead levels were tested within 1-2 days. Immediate XRF testing allowed for the best opportunity to find potential sources of lead. In addition, if anyone had a dangerously high blood lead level, immediate care could be provided.

c. **LeadCare II analyzer has been used extensively in research, surveillance, and clinical screening.** LeadCare II has a long history, and comparison to other countries and studies is possible.

d. **Accuracy:** In a 2021 study (see citation below) the BLL results of LeadCare II were compared to ICP-MS results. LeadCare II overestimated blood lead levels. However, for values under 10 µg/dL, the positive bias was less than 0.3 µg/dL. The positive bias was more significant for higher values. For values over 45 µg/dL, LeadCare II overestimated the values by 20-30 µg/dL.

   --In Bhutan's first pediatric blood lead study, one child out of 531 had a BLL of 30.9 µg/dL while 80% had BLLs between 3.3 – 20 µg/dL. Given the known data from Bhutan, LeadCare II was anticipated to provide accurate results in the BLL range previously identified in Bhutan.

Nakata H, Nakayama SMM, Yabe J, Muzandu K, Toyomaki H, Yohannes YB, Kataba A, Zyambo G, Ikenaka Y, Choongo K, Ishizuka M. *Assessment of LeadCare® II analysis for testing of a wide range of blood lead levels in comparison with ICP-MS analysis.* Chemosphere. 2021 May;271:129832.

e. Portability: As LeadCare II is a portable analyzer weighing 1 kg and can be run on batteries, it was ideal for remote areas of Bhutan where electricity was not always certain.

f. LeadCare II is the only point-of-care blood lead testing device option.

V. Challenges with LeadCare II

a. **Limits of lead detection:** LeadCare II has a range of detection of 3.3 to 65 µg/dL.

b. **Accuracy:** A 2021 study (see citation above) compared blood lead level results of the LeadCare II analyzer and an ICP-MS analyzer. LeadCare II overestimated blood lead levels. However, for values under 10 µg/dL, the positive bias was less than 0.3 µg/dL. The positive bias was more significant for higher values. For values over 45 µg/dL, LeadCare II overestimated the values by 20 - 30 µg/dL.

c. **Environmental contamination:** Lead on skin can contaminate the blood sample and falsely elevate it. A protocol was developed to minimize environmental contamination during collection of the blood sample. Additionally, the finger or heel was cleaned with a D-wipe (ESCA Tech) prior to the prick to minimize lead contamination. The site used for processing the blood sample with the LeadCare II was tested for lead with an XRF and cleaned using D-lead surface wipes (ESCA Tech). Both of these wipes bind lead, minimizing any lead contamination during collecting and processing the samples.

Appendix 4: Phase 2 - Household data collection protocol

Overview

For households selected for Phase 2 testing, a Phase 2 team returned to the house to retest any BLLs ≥30 µg/dL, test all other consenting household members present for BLL and Hgb, and conduct environmental testing with the pXRF looking for sources of lead in the child's home and, if applicable, conduct pXRF source testing at the child's ECCD/School or daycare.

Protocol

Prior to visiting the household, a call was made to explain the child's BLL results and to obtain permission to return for Phase 2 testing. After the Phase 2 enumerators arrived, they discussed the child's BLL with the head of the household or adult decision maker and explained Phase 2 of the survey. A colored handout in English and Dzongkhag was given to each household to help explain what lead was and ways to reduce lead exposure (shown in appendix 1).

After answering any questions, the enumerators requested written or thumb print informed consent and/or assent from all willing to be tested. Next, the following questions were asked. The questions pertaining to "child" refers to the 1–6-year-old child who was tested in Phase 1.

Question	Answer options
Does the child attend a creche, ECCD, or school?	• Yes • No
If so, what is the name of the creche, ECCD, or school?	
Can you provide the contact number for the creche, ECCD or school?	

Next, line listing of all household members from oldest to the youngest (≥ 2 months of age) was done.

Question	Answer options
What is the name of the household member?	
What is the person's date of birth?	
What is the person's sex?	• Male • Female

Question	Answer options
If female, is the person pregnant?	• Yes • No
If so, how many weeks pregnant?	
If female, has the woman delivered in the past 6 months?	• Yes • No

Once line listing was completed, blood was collected following the capillary blood collection protocol listed in Phase 1 with two minor deviations. A heel stick was used for infants less than one year of age, and BLLs tests were done in the home with a LeadCare II analyzer, taking care to minimize environmental contamination. If the household was over 8,000 feet elevation, a second blood sample was collected and tested at a location below 8,000 feet elevation to confirm the results. The following results were reported for each person.

Question	Answer options
Report the Hbg level for the person.	
Report the BLL for the person.	• Low • BLL Value: __________ • High
Repeat BLL value if 1st result was ≥30 µg/dL.	• Low • BLL Value: __________ • High

The Hgb test was done in the house using a HemoCue Hb 301 analyzer and recorded in the tablet. During the survey, everyone's Hgb was adjusted for elevation and evaluated with the 2024 WHO anemia guidelines.

Based on the Hgb level, reassurance, nutritional advice, or a referral to a healthcare facility was made. Also, for those with a BLL ≥30 µg/dL, a repeat capillary blood collection was done on a different finger after thorough cleaning. The lower of the two BLLs was taken as the correct result. If the person was anemic or had a BLL ≥30 µg/dL, a referral to a healthcare facility was made. The referral letter is provided on the next page.

Referral Letter

Date: _____ / ______ / __2024__

To: Health Care Professional,

____ was recently included in the Lead Prevalence Study, part of the National Health Survey. In screening this person's blood, the results required further evaluation at:

☐ the nearest healthcare facility
☐ the nearest referral hospital

The following results were found:

☐ Hemoglobin (Hgb) level: ________________ gm/dL
(Tested on a HemoCue Hb 301 analyzer)

- Please test this person's hemoglobin level. If anemic, treat per standard protocols.

☐ Blood lead level (BLL): ______________________ micrograms/dL
(Tested on a LeadCare II analyzer)

If the BLL was 30 - 44.9 micrograms/dL:

- Test the person's Complete Blood Count (CBC), peripheral blood smear looking for basophilic stippling, and iron studies if available.
- Prescribe iron and calcium for 30 days.
- Follow up in 30 – 60 days with a CBC.

If the BLL was 45 micrograms/dL or higher:

- Evaluate for signs & symptoms of lead poisoning.
- Consider admission to the hospital
- Test the person's Complete Blood Count (CBC), peripheral blood smear looking for basophilic stippling, and iron studies.
- Contact RCDC to request that a venous blood sample be tested for lead.
- Prescribe iron and calcium for 60 days.

- Call the person below to discuss if other treatment is needed.
- Follow up in 30 – 60 days with a CBC.

Kind regards,
Lead Prevalence Technical Working Group,
National Health Survey

Portable XRF Source Testing

Next, the pXRF source testing for lead was explained to the head of the household or adult decision maker, and the source testing was conducted.

The following data were collected on a tablet for each XRF test.

Question	Answer options
Which pXRF was used for the testing?	• Blue • Orange
What item is being tested?	• New item being tested • Additional test of the last item • Error in testing
What is the category of the item being tested?	• Kitchen items • Food • Toys • Cosmetics • Household • School/Office • Bhutanese items • Paint • Soil
Following the selection of the category of the item being tested, a sub-categorization menu was offered to give a more specific classification of the item.	

The item questions were repeated for each additional pXRF test conducted. At the completion of the survey, the data from the tablet were merged with the data stored in the pXRF analyzers for analysis.

Portable XRF testing was conducted only by those who completed pXRF safety and testing training.

XRF methods: The Restriction of Hazardous Substances (RoHS) method was used for most of the testing. The soil method was used to test soil as well as spices and other consumables. The paint method was used for testing paint on walls and surfaces of furniture and painted items.

For the testing of soil, spices, and other consumable items, a lead-free piece of plastic wrap was placed over the end of the pXRF analyzer to prevent lead contamination of the analyzer. Spices were first tested directly in their container. If lead was detected ≥ 5 ppm, the spice was placed in a small lead-free zip-lock bag for repeat testing.

The XRF focal person for the NBLLS was available by phone to assist with any technical issues with the pXRF testing throughout the survey.

The protocols below were used by trained enumerators for daily calibration of pXRF and testing procedures.

Portable XRF protocol at homes:

1. Before leaving, do a CalCheck on the charging station
2. Discuss the BLL finding with family
3. Obtain appropriate consents for blood testing
4. List all household members from oldest to youngest,
   --exclude those already tested (if Phase 1 BLL was less than 30 µg/dL
   --if anyone had a BLL ≥30 µg/dL, recheck their BLL
5. Test hemoglobin and lead of all family members
6. Once all blood testing is done, discuss all results
7. Explain what XRF testing is—testing for the possible sources of lead
8. Obtain consent for XRF testing
9. Start with Lead Paint method
   a. Test outside walls
   b. Test inside walls, especially high-touch areas and child furniture
   c. Test furniture, especially high-touch areas and child furniture
10. Change to RoHS method
    a. Test high-touch items used by child
       i. Bottle, pacifier, teething toys
       ii. Child toys
       iii. Child paints, pens, pencils

   b. Test other high-touch items
      i. Prayer wheels or other religious items
      ii. Door latches
   c. Go to kitchen
      i. Test pots, pans, cups, plates, serving and eating utensils
      ii. Make sure to test child's plates and utensils

11. Change to Soil method
    a. Put on plastic wrap
    b. Set up portable field station
    c. Test spices
       i. If spices are over 5 ppm, put into plastic bag and test with portable field station
          1. Fill bag with 1 cm of spice for accurate test
          2. Test spices 3 times
    d. Test any kohl or cosmetics
    e. Move outside and test a few soil samples, especially along the roof dripline and child play area
12. Give final feedback to household members about the results found
13. Reinforce handwashing with soap and water, keeping dust cleaned up, and good nutrition
14. Thank them for their participation

XRF Protocol for CAPI entry:

1. Perform Cal Check on the charging base at the beginning of each day

At the testing site:

2. Confirm consent has been given
3. Check pXRF for damage
4. Use the safety wrist strap at all times
5. Turn on and log in using YOUR user code
6. Observe ALL safety practices

7. Follow ALARA principle
   "As Low As Reasonably Achievable"
8. Confirm correct testing method before testing an item
9. Use plastic wrap if testing soil or spices
10. Take a picture of the test item


Swipe to the left, tap to change to the camera


Tap to take a picture.


Tap to delete if necessary.

11. Conduct the test
12. The required data should be entered into the CAPI
13. Repeat from step 8 (to test the next item)

When finished at the site:

14. Turn pXRF off
15. Properly pack the pXRF in its case
16. Store pXRF in a secure location at all times

The Olympus Vanta C pXRF analyzer has a 2 parts per million (ppm) lower limit of detection (LOD) depending on the substance being tested and the method used. The paint and RoHS methods have cut-off values shown below.

Method used:	Pass	Inconclusive	Fail
Paint	<1 mg/cm2	--	≥ 1 mg/cm2
RoHS Alloy Mixed Polymer	• < 700 ppm • < 500 ppm • < 700 ppm	• 700 - < 1,300 ppm • 500 - < 1,500 ppm • 700 - < 1,300 ppm	• ≥ 1,300 ppm • ≥ 1,500 ppm • ≥ 1,300 ppm
Soil	No pre-set limits		

On the following pages are cards designed for enumerators to interpret the results of each item tested and give guidance to household members as to if the item should continue to be used or not. These cut-offs for recommendations are not as stringent as international reference level guidelines. In the absence of local testing and regulation, practical consideration needed to be considered in developing recommendations for household members. Many recommendations to household members centered on limiting the use of items by children or pregnant women. As there is no regulation of items in the marketplace it was not possible to give any recommendations for safe lead-free alternatives.

Common items which will be tested. These will be in pull down menus in the CAPI tablets:

Category & item to focus on testing	3 digit code	Method to use	Where to test	
			HH	ECCD
Kitchen items (100):				
Drinking cup/glass (hot or cold)	101	RoHS	X	X
Plate / bowl	102	RoHS	X	X
Eating utensil (note if used by baby / child)	103	RoHS	X	X
Brass or metal eating plate / bowl	104	RoHS	X	
Pot / fry pan/ wok (commercially made)	121	RoHS	X	
Traditional hand-made pots	151	RoHS	X	
Traditional hand-made spoons	152	RoHS	X	
Kitchen, other (describe in CAPI notes)	199	RoHS	X	
Food (200):				
Spices (test spices 3 times if the ppm is 5 or more)				
Chili powder	201	Soil	X	
Cumin, jeera	204	Soil	X	
Turmeric	205	Soil	X	
Curry	206	Soil	X	
Masala (any kind)	207	Soil	X	
Ginger	211	Soil	X	
Garlic	212	Soil	X	
Tinge / Szechuan pepper	213	Soil	X	
Spice, other (describe in CAPI notes)	239	Soil	X	
Food, other (describe in CAPI notes)	299	Soil	X	

Category & item to focus on testing	3 digit code	Method to use	Where to test	
			HH	ECCD
Toys:				
Pacifiers, nipples, teething toys	301	RoHS	X	X
Toys for infants (less than 1 y.o.)	302	RoHS	X	X
Commercially made toys for children (1+ y.o.)	311	RoHS	X	X
Homemade toys for children (1+ y.o.)	312	RoHS	X	X
Toy jewelry, metal (note if made from a bullet)	331	RoHS	X	X
Toy jewelry, plastic	332	RoHS	X	X
Playground equipment:				
Commercial playground equipment PLASTIC	371	RoHS	X	X
Commercial playground equipment METAL	372	RoHS	X	X
HOMEMADE playground equipment	373	RoHS	X	X
Toys, other (describe in CAPI notes)	399	RoHS	X	X
Cosmetics (400):				
Kohl, eye makeup used on children	401	Soil	X	
Cosmetics, other (describe in CAPI notes)	499	Soil	X	
Household (500):				
Twist doorknobs / locks	502	RoHS	X	X
Latch / bolt lock (doors or window)	503	RoHS	X	X
Fixtures or handle on cupboards, drawers, doors	504	RoHS	X	
Indoor furniture (at homes)	550	Paint	X	
Outdoor furniture (at homes)	570	Paint	X	
Household, other (describe in CAPI notes)	599	RoHS	X	
School / Office (600):				
Writing implements (pens, pencils, markers, crayons, chalk, etc.)	600	RoHS		X
Non-writing implements (eraser, scissor, ruler, stapler, etc.)	610	RoHS		X
School furniture (not in homes)	650	Paint		X
School, other (describe in CAPI notes)	699	RoHS		X

Category & item to focus on testing	3 digit code	Method to use	Where to test	
			HH	ECCD
Bhutanese items (700):				
Khuru darts	701	RoHS		
Traditional medicine, oral	721	Soil	X	
Traditional medicine, topical	722	Soil	X	
Traditional medicine, other	729	Soil	X	
Incense stick or powder, incense burner, butter lamp	751	Soil	X	
Prayer wheel handle	752	RoHS	X	
Religious pendant (worn on wrist or neck)	753	RoHS	X	
Religious item, other (describe in CAPI notes)	759	RoHS	X	
Bhutanese item, other (describe in CAPI notes)	799	RoHS	X	
Paint (800):				
Paint on walls OUTSIDE (if FAIL, describe)	800	Paint	X	X
Paint on walls INSIDE (if FAIL, describe)	820	Paint	X	X
Paint, other (describe in CAPI notes)	899	Paint	X	X
Soil (900):				
Soil, HOUSE dripline	901	Soil	X	
Soil, HOUSE kitchen garden	902	Soil	X	
Soil, HOUSE yard / play area	903	Soil	X	
Soil, ECCD ETC. dripline	911	Soil		X
Soil, ECCD ETC. kitchen garden	912	Soil		X
Soil, ECCD ETC. play area	913	Soil		X
Soil, other (describe in CAPI notes)	999	Soil	X	X

Appendix 5: Data collection protocol for monastic children <13-years-old

Overview

For each monastic institution selected, after obtaining necessary permissions and consents, enumerators collected limited data on the child and collected blood samples for BLL and Hgb. Hgb were tested at the institution, and appropriate follow up was given. Blood samples for BLL were transported to the central testing location.

Protocol

As time permitted, teams of enumerators visited monastic institutions, selected by purposive sampling. The survey was explained to an adult decision maker and questions were addressed. Once all questions were addressed, the decision maker was requested to provide written informed consent for the children to participate. A colored handout in English and Dzongkhag discussing lead poisoning and ways to reduce lead exposure was given to the adult decision maker at each institution (a copy is shown in appendix 1).

Answers to the following questions were entered into the tablet.

Question	Answer options
What is the name of the monastic institution?	
GPS coordinates	Entered automatically
What Dzongkhag was the institution in?	All 20 Dzongkhag options listed
What is the name of contact person at institution?	
What is the title of contact person?	
What is the phone number of contact person?	
Total number of individuals at the institution?	
Total number of individuals less than 12 years of age?	
What is the date of the visit?	

After verbal assent was provided by each child <12 years old, the following questions were asked.

Question	Answer options
What is the name of the child?	
What is the unique ID of the monk or nun?	
What is the child's date of birth?	

Next, the enumerators collected capillary blood for BLL and Hbg testing following the same capillary blood collection protocol as used in Phase 1 (shown in appendix 1). The Hgb analysis was done immediately using a HemoCue Hb 301 analyzer, and results were recorded in the tablet. The child's Hgb was adjusted for elevation and evaluated according to the 2024 WHO anemia guidelines. Based on the Hgb level, reassurance, nutritional advice, or a referral to a healthcare facility was made, as in Phase 1.

Question	Answer options
Report the Hbg level for the child.	
Report the BLL for the child.	• Low • BLL Value: ______ • High
Repeat BLL value if 1st result was ≥30 µg/dL.	• Low • BLL Value: ______ • High

The blood sample for BLL testing was carried by the enumerator to the central testing location in each dzongkhag for analysis. After testing, the BLL results were recorded in the tablet for each child from the monastic institution. The enumerator who collected the blood samples then called the institution to inform the adult decision maker of the results. A repeat BLL test was done for anyone with a BLL ≥30 µg/dL. The referral to a healthcare facility is shown in Phase 2 (shown in appendix 4).

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Table 3.1: Number of eligible children, number of interviews, and response rates, according to residence (unweighted); [National Blood Lead Level Survey 2024]

Respondent Number and Response Rate	Residence		
	Urban	Rural	Total
Eligible Children (1-7 years)			
Number of eligible children	1,479	2,148	3,627
Number of eligible children interviewed	1,164	1,821	2,985
Response rate	78.7	84.8	82.3
Haemoglobin and blood lead test			
Number of eligible Children	1,479	2,148	3,627
Number of eligible children tested	1153	1806	2959
Response Rate	78.0	84.1	81.6

Table 4.1: Percentage of children with various blood lead levels by background characteristics; [National Blood Lead Level Survey 2024]

Background characteristics	Percentage of children with BLLs (µg/dL)					Number of children
	<3.5	≥3.5	≥5	≥10	≥20	
Age (in completed year)						
1 year	21.2	78.8	55.2	8.4	1.0	411
2 year	21.5	78.5	55.2	7.8	0.9	464
3 year	26.0	74.0	50.4	4.7	0.6	522
4 year	26.1	73.9	52.1	6.8	1.1	465
5 year	24.8	75.2	49.2	4.2	0.7	516
6 year	24.1	75.9	47.5	3.5	0.0	581
Sex						
Male	20.1	79.9	55.2	6.4	0.8	1,544
Female	28.3	71.7	47.1	5.0	0.6	1,415
Area						
Urban	23.0	77.0	52.7	5.2	0.8	1,153
Rural	24.8	75.2	50.4	6.1	0.6	1,806
Income quintile						
Lowest	23.5	76.5	49.0	8.2	0.5	605
Second	22.4	77.6	52.5	5.8	1.1	577

Background characteristics	Percentage of children with BLLs (µg/dL)					Number of children
	<3.5	≥3.5	≥5	≥10	≥20	
Middle	25.8	74.2	50.4	4.8	0.5	593
Fourth	24.0	76.0	52.9	5.6	0.7	631
Highest	24.4	75.6	51.6	4.2	0.6	553
National (Total)	**24.1**	**75.9**	**51.3**	**5.7**	**0.7**	**2,959**

Table 4.2: Percentage of children with various blood lead levels by dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Blood lead levels (µg/dL)						Number of children
	<3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Bumthang	7.8	92.2	89.7	62.1	4.7	0.9	132
Chhukha	45.5	54.5	51.6	41.2	2.6	0.0	243
Chhukha (Other than P/ling Thromde)	16.7	83.3	78.4	65.7	4.4	0.0	155
Phuentsholing Thromde	86.7	13.3	13.3	6.2	0.0	0.0	88
Dagana	1.6	98.4	98.4	80.7	6.4	1.0	67
Gasa	2.6	97.4	96.5	59.1	8.3	0.0	49
Haa	3.1	96.9	96.9	74.3	8.7	0.0	64
Lhuentse	8.7	91.3	90.2	51.3	8.2	0.0	90
Monggar	11.5	88.5	85.5	64.9	11.8	2.3	162
Paro	1.3	98.7	98.7	88.3	3.9	0.0	151
Pema Gatshel	34.8	65.2	58.3	29.3	7.9	0.0	96
Punakha	50.1	49.9	48.6	19.8	5.8	1.2	103
Samdrup Jongkhar	28.8	71.2	68.4	40.5	6.2	0.0	186
Samdrup Jongkhar (Other than SJ Thromde)	30.2	69.8	67.0	41.6	8.0	0.0	104
Samdrup Jongkhar Thromde	24.7	75.3	72.1	37.3	1.1	0.0	82
Samtse	37.0	63.0	59.6	28.2	3.3	0.0	185

Dzongkhag	Blood lead levels (µg/dL)						Number of children
	<3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Sarpang	56.9	43.1	38.4	14.7	0.2	0.0	212
Sarpang (Other than Gelephu Thromde)	51.7	48.3	42.5	16.3	0.0	0.0	133
Gelephu Thromde	79.8	20.2	20.2	7.2	1.1	0.0	79
Thimphu	6.3	93.7	92.1	66.8	7.9	1.6	457
Thimphu (Other than T/phu Thromde)	4.2	95.8	93.1	79.2	7.3	1.7	112
Thimphu Thromde	6.9	93.1	91.8	63.7	8.1	1.5	345
Trashigang	16.3	83.7	78.6	45.3	6.8	0.4	214
Trashi Yangtse	10.8	89.2	87.5	40.9	1.4	0.8	123
Trongsa	46.3	53.7	51.4	36.3	3.8	0.0	104
Tsirang	8.6	91.4	90.1	51.0	6.3	0.0	92
Wangdue	16.7	83.3	80.6	55.5	5.2	0.0	133
Zhemgang	18.5	81.5	78.1	60.6	8.4	3.6	96
National (Total)	**21.5**	**78.5**	**75.9**	**51.3**	**5.7**	**0.7**	**2,959**

Table 4.3: Percentage of children with various blood lead levels by background characteristics; [National Blood Lead Level Survey 2024]

Background characteristics	Blood lead levels (µg/dL)					Number of children
	Mean	SD	Median	Min	Max	
Age (in completed year)						
1 year	5.8	3.7	5.2	0.0	29.8	411
2 year	5.6	3.6	5.1	0.2	35.3	464
3 year	5.1	3.0	4.8	0.0	27.7	522
4 year	5.5	3.8	5.0	0.2	36.7	465
5 year	5.2	3.0	4.8	0.0	33.1	516
6 year	4.9	2.4	4.7	0.0	17.5	581
Sex						
Male	5.6	3.259	5.2	0.0	35.3	1,544

Background characteristics	Blood lead levels (µg/dL)					Number of children
	Mean	SD	Median	Min	Max	
Female	5.1	3.203	4.6	0.0	36.7	1,415
Area						
Urban	5.2	3.3	4.8	0.0	35.3	1,153
Rural	5.4	3.2	5.0	0.0	36.7	1,806
Income quintile						
Lowest	5.5	3.5	4.8	0.0	35.3	605
Second	5.5	3.4	5.1	0.1	33.1	577
Middle	5.2	2.9	5.0	0.0	21.9	593
Fourth	5.3	3.4	5.0	0.0	36.7	631
Highest	5.1	2.9	4.8	0.0	29.8	553
National (Total)	**5.3**	**3.2**	**4.9**	**0.0**	**36.7**	**2,959**
Note: Multiple Imputation with a Truncated Normal Distribution were carried out for values below LOD						

Table 4.4: Mean blood lead levels (µg/dL) of children aged 1-6 by dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Mean	SD	Median	25th Percentile	75th Percentile	Min	Maxs
Bumthang	5.9	2.6	5.6	4.3	6.8	1.5	21.4
Chhukha	4.5	2.8	4.1	2.1	6.7	0.2	12.8
Dagana	6.7	3.8	6.0	5.3	7.2	2.1	28.3
Gasa	5.9	2.4	5.1	4.5	6.9	1.0	13.8
Haa	6.5	2.7	6.0	5.0	7.5	0.8	17.5
Lhuentse	5.5	2.5	5.0	4.0	6.7	0.4	13.2
Monggar	6.6	4.3	6.0	4.1	7.5	0.6	29.8
Paro	6.8	1.9	6.5	5.6	7.7	1.1	15.0
Pema Gatshel	4.4	2.9	3.8	2.7	5.2	0.4	17.3
Punakha	4.4	5.3	3.3	2.3	4.7	0.0	21.1
Samdrup Jongkhar	4.7	2.6	4.5	3.1	6.0	0.1	17.5
Samtse	4.2	2.7	3.8	2.7	5.3	0.1	19.1
Sarpang	3.0	1.9	2.8	1.8	3.9	0.0	11.9
Thimphu	6.5	4.2	5.6	4.4	7.1	0.5	35.3

Dzongkhag	Mean	SD	Median	25th Percentile	75th Percentile	Min	Maxs
Trashigang	5.3	3.1	4.7	3.7	6.3	0.1	21.9
Trashi Yangtse	5.1	2.3	4.5	3.9	5.8	0.3	20.7
Trongsa	4.2	3.0	3.8	1.9	6.0	0.1	15.4
Tsirang	5.6	2.5	5.0	4.2	6.9	0.5	16.4
Wangdue Phodrang	5.5	2.4	5.2	4.1	6.5	0.2	15.1
Zhemgang	6.3	5.3	5.3	3.6	6.9	0.8	36.7
Total	**5.3**	**3.4**	**4.9**	**3.5**	**6.6**	**0.0**	**36.7**

Note: The BLL values below the LOD were imputed using a truncated normal distribution approach.

Table 4.5: Percentage of children with various blood lead levels by background characteristics; [National Blood Lead Level Survey 2024]

Background characteristics	Blood lead levels (µg/dL)					Total	Number of children
	<3.5	3.5-4.9	5.0-9.9	10.0-19.9	20.0		
Age (in completed year)							
1 year	21.2	23.7	46.7	7.4	1.0	100	411
2 year	21.5	23.3	47.4	6.9	0.9	100	464
3 year	26.0	23.6	45.7	4.1	0.6	100	522
4 year	26.1	21.8	45.4	5.7	1.1	100	465
5 year	24.8	26.1	45.0	3.5	0.7	100	516
6 year	24.1	28.4	44.0	3.5	0.0	100	581
Sex							
Male	20.1	24.6	48.8	5.6	0.8	100	1,544
Female	28.3	24.6	42.1	4.4	0.6	100	1,415
Area							
Urban	23.0	24.3	47.5	4.4	0.8	100	1,153
Rural	24.8	24.8	44.4	5.5	0.6	100	1,806
Income quintile							
Lowest	23.5	27.5	40.8	7.7	0.5	100	605
Second	22.4	25.0	46.8	4.6	1.1	100	577
Middle	25.8	23.7	45.7	4.3	0.5	100	593

Background characteristics	Blood lead levels (µg/dL)					Total	Number of children
	<3.5	3.5-4.9	5.0-9.9	10.0-19.9	20.0		
Fourth	24.0	23.1	47.3	4.9	0.7	100	631
Highest	24.4	24.0	47.4	3.6	0.6	100	553
National (Total)	**24.1**	**24.6**	**45.6**	**5.0**	**0.7**	**100**	**2,959**

Table 4.6: Percentage of children with various blood lead levels by dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Blood lead levels (µg/dL)					Total	Number of children
	<3.5	3.5-4.9	5.0-9.9	10.0-19.9	20.0		
Bumthang	10.3	27.6	57.4	3.8	0.9	100	132
Chhukha	48.4	10.4	38.7	2.6	0	100	243
Chhukha (Other than P/ling Thromde)	21.6	12.7	61.4	4.4	0.0	100	155
Phuentsholing Thromde	86.7	7.1	6.2	0.0	0.0	100	88
Dagana	1.6	17.7	74.3	5.4	1.0	100	67
Gasa	3.5	37.4	50.8	8.3	0.0	100	49
Haa	3.1	22.6	65.6	8.7	0.0	100	64
Lhuentse	9.8	38.9	43.1	8.2	0.0	100	90
Monggar	14.5	20.6	53.0	9.5	2.3	100	162
Paro	1.3	10.5	84.4	3.9	0.0	100	151
Pema Gatshel	41.7	29.0	21.3	7.9	0.0	100	96
Punakha	51.4	28.7	14.0	4.6	1.2	100	103
Samdrup Jongkhar	31.6	27.9	34.3	6.2	0	100	186
Samdrup Jongkhar (Other than SJ Thromde)	33.0	25.4	33.6	8.0	0.0	100	104
Samdrup Jongkhar Thromde	27.9	34.7	36.3	1.1	0.0	100	82
Samtse	40.4	31.3	25.0	3.3	0.0	100	185
Sarpang	61.6	23.7	14.4	0.2	0	100	212
Sarpang (Other than Gelephu Thromde)	57.5	26.1	16.3	0.0	0.0	100	133
Gelephu Thromde	79.8	13.0	6.1	1.1	0.0	100	79

Dzongkhag	Blood lead levels (µg/dL)					Total	Number of children
	<3.5	3.5-4.9	5.0-9.9	10.0-19.9	20.0		
Thimphu	7.9	25.3	58.9	6.3	1.6	100	457
Thimphu (Other than T/phu Thromde)	6.9	13.9	71.9	5.6	1.7	100	112
Thimphu Thromde	8.2	28.1	55.7	6.5	1.5	100	345
Trashigang	21.4	33.4	38.4	6.4	0.4	100	214
Trashi Yangtse	12.5	46.6	39.5	0.7	0.8	100	123
Trongsa	48.6	15.1	32.5	3.8	0.0	100	104
Tsirang	9.9	39.1	44.7	6.3	0.0	100	92
Wangdue	19.4	25.1	50.3	5.2	0.0	100	133
Zhemgang	21.9	17.5	52.2	4.8	3.6	100	96
National (Total)	**24.1**	**24.6**	**45.6**	**5.0**	**0.7**	**100**	**2,959**

Table 5.5 : Percentage of children 1-6 years old with anemia levels by background characteristics; [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Anemia category									Number of children
	Normal		Mild		Moderate		Severe		Total	
	%	CI	%	CI	%	CI	%	CI	%	
Age (in completed year)										
1 year	59.7	[54.1,65.0]	21.7	[17.8,26.3]	18.1	[14.0,23.1]	0.5	[0.1,2.2]	100	411
2 year	60.8	[55.9,65.6]	23.5	[19.6,27.8]	15.1	[11.9,18.9]	0.6	[0.2,1.6]	100	464
3 year	60.7	[56.0,65.3]	24.1	[20.1,28.6]	14.1	[11.2,17.7]	1.0	[0.4,2.9]	100	522
4 year	67.1	[62.1,71.8]	22.0	[17.9,26.6]	10.9	[8.3,14.3]	0.0		100	464
5 year	54.6	[49.8,59.4]	15.6	[12.6,19.2]	29.0	[24.9,33.5]	0.8	[0.3,1.9]	100	516
6 year	64.4	[60.0,68.7]	16.5	[13.3,20.2]	18.9	[15.6,22.6]	0.2	[0.0,1.1]	100	581
Sex										
Male	60.4	[57.8,63.0]	20.3	[18.2,22.6]	18.4	[16.4,20.6]	0.8	[0.5,1.5]	100	1,543
Female	62.2	[59.1,65.1]	20.4	[18.2,22.9]	17.2	[15.1,19.5]	0.2	[0.1,0.6]	100	1,415
Area										
Urban	61.0	[57.7,64.2]	21.7	[19.1,24.6]	16.8	[14.6,19.2]	0.5	[0.2,1.3]	100	1,153
Rural	61.4	[58.8,64.0]	19.5	[17.6,21.5]	18.5	[16.6,20.7]	0.5	[0.3,1.0]	100	1,805
Income quintile										
Lowest	59.0	[54.6,63.3]	21.2	[18.0,24.7]	19.6	[16.3,23.3]	0.2	[0.0,1.6]	100	604
Second	56.6	[51.6,61.6]	20.6	[17.0,24.7]	22.0	[18.5,26.1]	0.7	[0.3,1.9]	100	577
Middle	60.4	[56.1,64.7]	21.6	[18.3,25.4]	17.8	[14.6,21.6]	0.1	[0.0,0.8]	100	593

Socio-demographic characteristics	Anemia category									Number of children
	Normal		Mild		Moderate		Severe		Total	
	%	CI	%	CI	%	CI	%	CI	%	
Fourth	61.4	[57.1,65.5]	20.4	[17.2,24.1]	17.2	[14.1,20.9]	0.9	[0.3,2.4]	100	631
Highest	69.1	[64.5,73.4]	17.8	[14.6,21.4]	12.5	[9.9,15.5]	0.6	[0.3,1.5]	100	553
Total	**61.3**	**[59.2,63.3]**	**20.4**	**[18.8,22.0]**	**17.8**	**[16.4,19.4]**	**0.5**	**[0.3,0.9]**	**100**	**2,958**

Table 5.6: Percentage of children 1-6 years old with anemic levels by dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Normal		Mild		Moderate		Severe		Total	Number of Children
	%	CI	%	CI	%	CI	%	CI	%	
Bumthang	58.2	[48.4,67.3]	17.8	[11.6,26.2]	23.4	[16.0,32.8]	0.7	[0.1,4.9]	100	132
Chhukha	69.1	[62.0,75.5]	17.7	[12.9,23.8]	13.2	[9.2,18.4]	0		100	243
Chhukha (Other than P/ ling Thromde)	65	[55.0,73.9]	18.5	[12.0,27.3]	16.5	[11.0,24.1]	0		100	155
Phuentsholing Thromde	75	[64.8,82.9]	16.6	[10.3,25.7]	8.4	[4.0,16.7]	0		100	88
Dagana	68.5	[54.8,79.6]	23.2	[12.7,38.5]	8.3	[3.5,18.5]	0		100	67
Gasa	63.2	[45.2,78.2]	14.6	[7.0,28.0]	17	[8.2,32.1]	5.2	[1.3,18.8]	100	49
Haa	46.6	[34.4,59.3]	27.7	[18.4,39.4]	23.6	[15.2,34.8]	2.1	[0.3,11.4]	100	64
Lhuentse	35.5	[25.9,46.3]	34.6	[25.7,44.7]	27.6	[19.8,37.2]	2.3	[0.6,8.6]	100	90
Monggar	50.2	[40.8,59.5]	27.7	[20.2,36.7]	21.3	[14.9,29.5]	0.8	[0.1,5.5]	100	161
Paro	62.5	[54.2,70.1]	23.1	[16.9,30.8]	14.4	[9.2,21.8]	0		100	151
Pema Gatshel	52.4	[42.1,62.5]	24.6	[17.4,33.6]	23	[14.4,34.7]	0		100	96
Punakha	62.9	[53.0,71.8]	13.9	[8.2,22.4]	21.3	[14.7,29.9]	1.9	[0.5,7.1]	100	103

Dzongkhag	Normal		Mild		Moderate		Severe		Total	Number of Children
	%	CI	%	CI	%	CI	%	CI	%	
Samdrup Jongkhar	64.5	[55.4,72.6]	16.8	[12.2,22.6]	18.8	[12.4,27.3]	0		100	186
Samdrup Jongkhar (Other than SJ Thromde)	63.8	[51.9,74.2]	15.9	[10.6,23.3]	20.3	[12.2,31.7]	0		100	104
Samdrup Jongkhar Thromde	66.3	[55.6,75.6]	19	[11.9,29.1]	14.6	[8.2,24.7]	0		100	82
Samtse	75.8	[67.5,82.4]	14.2	[9.9,20.0]	10.1	[6.2,15.9]	0		100	185
Sarpang	77.8	[70.5,83.8]	12.6	[8.5,18.3]	9.5	[6.2,14.3]	0		100	212
Sarpang (Other than Gelephu Thromde)	79.7	[70.7,86.5]	11.9	[7.4,18.7]	8.4	[4.8,14.3]	0		100	133
Gelephu Thromde	69.6	[59.0,78.4]	15.9	[8.6,27.5]	14.5	[8.5,23.6]	0		100	79
Thimphu	58.8	[54.0,63.4]	21.2	[17.5,25.4]	19.1	[15.7,23.1]	0.9	[0.3,2.5]	100	457
Thimphu (Other than T/phu Thromde)	63.3	[53.0,72.6]	21.4	[14.6,30.3]	13.7	[8.2,22.1]	1.5	[0.4,5.8]	100	112
Thimphu Thromde	57.6	[52.2,62.8]	21.2	[17.0,26.0]	20.5	[16.6,25.0]	0.8	[0.2,3.0]	100	345
Trashigang	48.2	[40.2,56.4]	22.1	[16.6,28.8]	28.8	[22.3,36.3]	0.8	[0.2,3.6]	100	214
Trashi Yangtse	45.9	[36.6,55.6]	30.2	[22.4,39.4]	22.1	[15.8,30.1]	1.7	[0.4,6.5]	100	123
Trongsa	52.2	[42.6,61.6]	26.3	[18.4,36.0]	21.6	[14.8,30.3]	0		100	104
Tsirang	74.3	[63.1,82.9]	14.6	[8.2,24.7]	11.1	[5.5,21.1]	0		100	92
Wangdue	68.8	[58.6,77.5]	18.4	[12.0,27.3]	12.8	[8.3,19.2]	0		100	133
Zhemgang	50.9	[39.6,62.2]	24.9	[17.9,33.6]	24.1	[15.3,35.8]	0		100	96
National (Total)	**61.3**	**[59.2,63.3]**	**20.4**	**[18.8,22.0]**	**17.8**	**[16.4,19.4]**	**0.5**	**[0.3,0.9]**	**100**	**2,958**

Table 5.7: Percentage of children 1-5 years old with developmental delay by background characteristics; [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Developmental delays				Overall developmental delays			Number of children (1-5 years)
	Physical	Communication	Cognition	Personal-social	On Track	Need Monitoring	Need further assessment	
Age								
1 year	3.0	5.1	5.3	1.7	90.0	4.0	6.0	411
2 year	5.6	12.4	6.2	14.7	76.0	13.5	10.6	464
3 year	2.1	4.0	4.8	4.5	90.8	4.2	5.0	522
4 year	2.3	3.4	8.4	2.3	88.3	7.1	4.6	465
5 year	1.9	5.1	6.9	8.3	84.1	8.2	7.7	516
Sex								
Male	3.5	7.8	7.6	7.4	83.6	8.0	8.4	1242
Female	2.3	4.0	4.9	5.3	88.3	6.8	4.9	1136
Area								
Urban	3.0	7.0	6.1	7.0	85.5	7.7	6.8	946
Rural	2.9	5.3	6.5	6.0	86.0	7.3	6.7	1432
Income quintile								
Lowest	2.7	5.9	7.0	5.9	85.0	7.3	7.7	475
Second	3.7	7.0	7.8	8.2	81.8	10.7	7.5	452
Middle	3.3	7.1	8.3	6.3	84.2	8.5	7.2	494
Fourth	2.9	4.4	4.2	5.3	88.7	6.4	4.9	500
Highest	2.1	5.6	4.5	6.8	88.9	4.5	6.6	457
National (Total)	**2.9**	**6.0**	**6.3**	**6.4**	**85.8**	**7.4**	**6.7**	**2378**

Table 5.8: Percentage of children 1-5 years old with developmental delay by Dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Developmental delays			Overall developmental delays				Respondent Number
	Physical	Communication	Cognition	Personal-social	On Track	Need Monitoring	Need further assessment	
Bumthang	4.0	1.9	10.1	11.9	77.0	17.0	6.0	98
Chhukha	3.4	8.5	11.1	8.2	81.1	9.1	9.8	182
Chhukha (Other than P/ling Thromde)	0.0	2.4	6.1	4.7	90.9	5.7	3.3	113
Phuentsholing Thromde	8.1	16.8	17.9	13.0	67.7	13.6	18.7	69
Dagana	0.0	2.5	0.0	0.0	97.5	0.0	2.5	49
Gasa	2.2	2.3	0.0	2.6	93.0	3.7	3.3	42
Haa	0.0	6.6	5.4	0.0	89.8	2.5	7.8	54
Lhuentse	3.1	4.6	7.2	6.0	86.8	5.7	7.5	67
Monggar	4.2	3.7	10.0	13.5	75.2	16.0	8.8	128
Paro	3.7	11.5	3.6	9.5	83.6	6.3	10.1	125
Pema Gatshel	5.5	16.4	10.2	9.5	78.8	8.6	12.6	74
Punakha	1.5	3.4	1.5	7.1	92.0	4.0	4.0	81
Samdrup Jongkhar	2.7	6.0	4.2	5.5	88.5	3.3	8.2	156
Samdrup Jongkhar (Other than SJ Thromde)	0.9	6.2	5.2	7.1	87.5	3.5	9.0	85
Samdrup Jongkhar Thromde	7.3	5.5	1.4	1.4	91.0	2.8	6.2	71
Samtse	3.3	2.9	3.7	2.3	90.8	4.1	5.2	149

Dzongkhag	Developmental delays			Overall developmental delays				Respondent Number
	Physical	Communication	Cognition	Personal-social	On Track	Need Monitoring	Need further assessment	
Sarpang	4.2	5.9	8.5	9.7	80.5	13.0	6.6	181
Sarpang (Other than Gelephu Thromde)	3.4	4.4	7.0	9.1	80.9	14.5	4.6	109
Gelephu Thromde	7.8	12.0	14.8	12.0	78.7	6.9	14.4	72
Thimphu	2.4	6.0	4.5	4.7	88.5	6.8	4.7	387
Thimphu (Other than T/phu Thromde)	2.7	4.2	6.5	4.1	89.0	8.3	2.7	101
Thimphu Thromde	2.3	6.4	4.0	4.9	88.4	6.5	5.2	286
Trashigang	2.4	2.1	5.2	2.4	91.2	5.3	3.5	173
Trashi Yangtse	4.3	9.1	6.3	6.3	88.9	2.1	9.1	93
Trongsa	4.2	10.7	9.9	11.0	82.7	6.4	10.9	86
Tsirang	0.0	2.7	5.3	3.9	93.5	1.2	5.3	77
Wangdue	3.0	8.4	5.3	3.9	86.3	6.5	7.2	101
Zhemgang	2.1	2.9	16.1	9.9	76.4	15.1	8.4	75
National (Total)	**2.9**	**6.0**	**6.3**	**6.4**	**85.8**	**7.4**	**6.7**	**2378**

Table 5.9: Percentage of children 1-5 years old with developmental delay by Blood lead levels; [National Blood Lead Level Survey 2024]

Blood lead level (µg/dL)	Physical	Communication	Cognition/problem solving	Personal/ social	Development delay	
					On track	Delayed
					%	%
<3.5	4.9	6.1	7.8	6.1	85.3	14.7
3.5-4.9	3.0	5.5	5.3	6.5	86.1	13.9
5-9.9	1.8	5.7	5.4	6.0	86.6	13.4
10-19.9	3.8	7.8	9.2	8.9	82.8	17.2
≥20	4.9	17.1	21.0	21.7	67.3	32.7
Total	2.9	6.0	6.3	6.4	85.8	14.2

Table 5.10: Prevalence of anemia among children aged 1-6 years old and its association with blood lead level (weighted analysis) n=2958; [National Blood Lead Level Survey 2024]

Blood Lead Level (µg/dL)	Percentage of children with anemia	OR[1]	95% CI	p-value[2]	Number of children
<3.5	32.0	Base		0.0006	730
3.5 to 4.9	38.9	1.35	1.06, 1.71		763
5.0 to 9.9	40.9	1.47	1.19, 1.81		1,301
10.0 to 19.9	50.1	2.15	1.44, 3.22		143
≥20	42.9	1.58	0.66, 3.78		21

[1] Odds Ratio adjusted for age and sex
[2] Adjusted Wald test of the null hypothesis

Table 6.1: Percentage of pregnant or breastfeeding women with various blood lead levels by background characteristics; [National Blood Lead Level Survey 2024]

Background characteristics	Blood lead levels (µg/dL)				Total	Number of children
	<3.3	3.3-4.9	5-9.9	10-19.9		
Age						
15-29	38.6	33.3	24.6	3.5	100.0	57
30-49	38.8	29.9	29.9	1.5	100.0	67
Residence						
Urban	40.0	28.0	32.0	0.0	100.0	50
Rural	37.8	33.8	24.3	4.1	100.0	74
Education						
<Class 12 (include NFE)	37.1	37.1	24.2	1.6	100.0	62
≥Class 12	40.3	25.8	30.6	3.2	100.0	62
Income quintile						
Lowest	64.3	35.7	0.0	0.0	100.0	14
Second	33.3	29.6	33.3	3.7	100.0	27
Middle	42.9	40.5	14.3	2.4	100.0	42
Fourth	40.9	18.2	36.4	4.5	100.0	22
Highest	15.8	26.3	57.9	0.0	100.0	19
National (Total)	**38.7**	**31.5**	**27.4**	**2.4**	**100.0**	124

Table 6.2: Percentage of pregnant or breastfeeding women with various blood lead levels by background characteristics; [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Blood lead level (µg/dL)					Respondent Number
	<3.3	≥3.3	≥3.5	≥5	≥10	
	%	%	%	%	%	
Age						
15-29	38.6	61.4	56.1	28.1	3.5	57
30-49	38.8	61.2	61.2	31.3	1.5	67
Residence						
Urban	40.0	60.0	56.0	32.0	0.0	50
Rural	37.8	62.2	60.8	28.4	4.1	74
Education						
<Class 12 (include NFE)	37.1	62.9	61.3	25.8	1.6	62
≥Class 12	40.3	59.7	56.5	33.9	3.2	62
Income quintile						
Lowest	64.3	35.7	35.7	0.0	0.0	14
Second	33.3	66.7	63.0	37.0	3.7	27
Middle	42.9	57.1	54.8	16.7	2.4	42
Fourth	40.9	59.1	59.1	40.9	4.5	22
Highest	15.8	84.2	78.9	57.9	0.0	19
Total	**38.7**	**61.3**	**58.9**	**29.8**	**2.4**	**124**

* Unweighted analysis

Table 6.3: Percentage of pregnant or breastfeeding women with blood lead levels by exposure to lead (Behaviour); [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Given any local or traditional medicines	Ever been given any blessed religious pills	Times given blessed religious pills					Number of women
			Not given	<16 days	16-30 days	31-60 days	61-180 days	
Age								
15-29	1.8	50.9	59.6	31.6	7.0	1.8	0.0	57
30-49	1.5	59.7	53.7	34.3	9.0	0.0	3.0	67
Residence								
Urban	2.0	58.0	52.0	34.0	10.0	2.0	2.0	50
Rural	1.4	54.1	59.5	32.4	6.8	0.0	1.4	74

Socio-demographic characteristics	Given any local or traditional medicines	Ever been given any blessed religious pills	Times given blessed religious pills					Number of women
			Not given	<16 days	16-30 days	31-60 days	61-180 days	
Education								
<Class 12 (include NFE)	1.6	54.8	61.3	30.6	8.1	0.0	0.0	62
≥Class 12	1.6	56.5	51.6	35.5	8.1	1.6	3.2	62
Income quintile								
Lowest	0.0	50.0	57.1	35.7	7.1	0.0	0.0	14
Second	0.0	55.6	59.3	33.3	3.7	0.0	3.7	27
Middle	2.4	54.8	64.3	23.8	11.9	0.0	0.0	42
Fourth	0.0	63.6	40.9	40.9	9.1	4.5	4.5	22
Highest	5.3	52.6	52.6	42.1	5.3	0.0	0.0	19
Total	**1.6**	**55.6**	**56.5**	**33.1**	**8.1**	**0.8**	**1.6**	**124**

Table 6.4: Prevalence of lead levels in pregnant and breastfeeding women who were given traditional medicine or blessed religious pills *(jinlab)*; [National Blood Lead Level Survey 2024]

Characteristics	Blood lead level (µg/dL)					Number of children
	<3.3	≥3.3	≥3.5	≥5	≥10	
Given any local or traditional medicines						
Yes	0.0	100.0	100.0	50.0	0.0	2
No	39.3	60.7	58.2	29.5	2.5	122
Ever been given any blessed religious pills						
Yes	39.1	60.9	60.9	36.2	4.3	69
No	38.2	61.8	56.4	21.8	0.0	55
Times given *Jinlab* prior to the survey						
Not given	38.6	61.4	57.1	24.3	0.0	70
<16 days	43.9	56.1	56.1	34.1	7.3	41
16-30 days	30.0	70.0	70.0	40.0	0.0	10
31-60 days	0.0	100.0	100.0	100.0	0.0	1
61-180 days	0.0	100.0	100.0	50.0	0.0	2
Total	**38.7**	**61.3**	**58.9**	**29.8**	**2.4**	**124**

Table 6.5: Blood lead levels in monastic children [National Blood Lead Level Survey 2024]

	n	%
Mean		5.9
SD		2.8
Median		5.7
25th Percentile		4.5
75th Percentile		7.0
Lower than 3.3	26	12.6
3.3-4.9	42	20.3
5-9.9	125	60.4
10-19.9	13	6.3
>20	1	0.5

Note: The respondents were from the selected monastic institutions and does not represent the national figure

Table 6.6: Percentage of household members by BLL category; [National Blood Lead Level Survey 2024]

BLL category	Sex			Respondent Number
	Male (%)	Female (%)	Overall (%)	
<3.5	20.3	15.9	18.0	23
3.5-4.9	22.7	28.8	26.0	32
5-9.9	42.0	35.9	38.7	49
10-19.9	7.6	16.1	12.2	17
≥20	7.5	3.3	5.2	7
Total	100	100	100	128

Table 6.7: Percentage of household members by BLL category; [National Blood Lead Level Survey 2024]

BLL	Male	Female	Overall	Total respondent
<3.3	13	14.2	13.6	18
≥3.3	87	85.8	86.4	110
≥3.5	79.7	84.1	82.0	105
≥5	57	55.3	56.1	73
≥10	15	19.4	17.4	24
≥20	7.5	3.3	5.2	7

Table 6.8: BLL category of the household members by sex and age category; [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Blood Lead Level (µg/dL)						Number of HH members
	<3.5	3.5-4.9	5-9.9	10-19.9	≥20	Total	
	%	%	%	%	%	%	
Sex							
Male	20.3	22.7	42	7.6	7.5	100	59
Female	15.9	28.8	35.9	16.1	3.3	100	69
Age							
≤20	32.5	23.5	26.9	8.9	8.2	100	32
21-40	14	26.7	40.8	14.4	4.1	100	62
>40	10.9	27	46.3	11.5	4.2	100	34
Total	**18**	**26**	**38.7**	**12.2**	**5.2**	**100**	**128**

Table 8.5: Percentage of children 1-6 years old with blood lead levels by exposure to lead (household); [National Blood Lead Level Survey 2024]

Characteristics	Blood lead level (µg/dL)						Number of Children
	>3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Metal artisan work							
Yes	11.9	88.1	82.9	59.1	3.9	0.0	101
No	21.8	78.2	75.7	51.0	5.8	0.7	2,858
Fishing weight							
Yes	27.3	72.7	70.3	46.6	3.8	2.5	71
No	21.3	78.7	76.1	51.4	5.8	0.6	2,888
Bullet/arms							
Yes	16.0	84.0	82.0	64.5	8.3	0.6	223
No	22.0	78.0	75.4	50.0	5.5	0.7	2,736
	21.5	78.5	75.9	51.3	5.7	0.7	2,959
Battery (car/solar)							
Yes	21.7	78.3	75.7	54.4	6.0	0.5	177
No	21.5	78.5	76.0	51.1	5.7	0.7	2,782
Battery recycling (distance from house)							
No	21.5	78.5	76.0	51.1	5.7	0.7	2,782
≤100 mts	11.4	88.6	77.5	53.7	3.1	0.0	25
>100mts	27.0	73.0	59.6	49.7	7.2	0.0	11

Characteristics	Blood lead level (µg/dL)						Number of Children
	>3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Material (External Wall)							
Cemented	23.7	76.3	73.8	50.1	4.5	0.8	1,680
Mud-based/rammed earth	15.4	84.6	81.9	54.3	7.6	0.6	815
Wood/bamboo/ plywood	23.2	76.8	73.7	51.2	7.4	0.6	422
Others	24.1	75.9	75.9	51.7	5.3	0.0	42
Roofing Material							
Metal CGI	20.9	79.1	76.7	51.3	5.8	0.7	2,539
Shingles/planks	21.0	79.0	75.3	56.1	4.8	0.0	142
Concrete/cement based	29.7	70.3	68.4	49.1	5.1	0.9	143
Tin-sheets	15.4	84.6	78.7	52.8	7.3	1.7	111
Others	52.9	47.1	47.1	38.0	0.0	0.0	24
Material (Interior Wall)							
Cemented	23.5	76.5	73.7	49.7	5.0	0.9	1,706
Mud-based/rammed earth	17.1	82.9	80.4	53.7	6.9	0.3	709
Wood/bamboo/ plywood	20.7	79.3	77.2	54.0	6.8	0.5	508
Others	16.5	83.5	83.5	51.2	0.0	0.0	36
Floor Material							
Concrete/tiles/ marbles	31.9	68.1	65.6	44.8	2.8	0.7	501
Wood/bamboo	18.8	81.2	78.7	53.6	6.5	0.7	2,224
Mud/Clay	16.7	83.3	82.0	39.9	0.6	0.0	90
Others	31.7	68.3	62.9	44.1	6.1	0.7	144
Age of House							
Less than 10 years	23.3	76.7	74.3	49.6	5.1	0.6	1,107
10 or more years	20.3	79.7	77.0	52.4	6.1	0.8	1,852
Total	**21.5**	**78.5**	**75.9**	**51.3**	**5.7**	**0.7**	**2,959**

Table 8.6: Number and percent of children EVER being given *jinlab* in their life and frequency of being given *Jinlab* by background characteristics [National Blood Lead Level Survey 2024]

Socio-demographic characteristics	Given any local or traditional medicines	Ever been given any blessed religious pills	Times given blessed religious pills in last 6 months					Number of respondents
			Not given	<16 days	16-30 days	31-60 days	61-180 days	
Age								
1 year	1.2	59.6	50.2	39.2	7.9	1.3	1.4	411
2 year	1.0	60.4	54.2	34.3	9.0	1.2	1.3	464
3 year	2.6	65.0	51.1	38.4	9.0	1.2	0.3	522
4 year	2.6	67.3	47.9	37.9	10.0	2.4	1.7	465
5 year	2.0	68.9	46.2	42.9	8.2	1.6	1.2	516
6 year	1.8	67.7	48.7	40.0	8.2	1.5	1.6	581
Sex								
Male	1.5	65.4	49.6	38.2	8.8	2.0	1.5	1,544
Female	2.3	64.7	49.7	39.6	8.7	1.0	1.0	1,415
Area								
Urban	1.5	68.2	46.4	38.6	11.5	1.7	1.8	1,153
Rural	2.1	63.0	51.8	39.1	6.8	1.4	0.8	1,806
Income quintile								
Lowest	1.7	59.9	53.5	36.5	6.5	2.5	1.0	605
Second	1.4	61.2	53.3	36.9	7.6	1.2	1.0	577
Middle	2.1	65.2	49.4	38.6	8.7	1.8	1.5	593
Fourth	1.2	70.9	46.7	39.6	11.3	1.1	1.3	631
Highest	3.2	67.6	45.6	43.0	9.1	1.0	1.4	553
Religion								
Buddhism	1.8	71.6	43.9	43.0	9.9	1.8	1.5	2,530
Hinduism	2.7	32.0	80.1	18.0	2.0	0.0	0.0	369
Christianity	0.5	6.9	94.0	4.4	1.6	0.0	0.0	60
Total	**1.9**	**65.1**	**49.6**	**38.9**	**8.7**	**1.5**	**1.2**	**2,959**

Table 8.7: Number and percent of children EVER being given *jinlab* in their life and frequency of being given *Jinlab* by Dzongkhag; [National Blood Lead Level Survey 2024]

Dzongkhag	Given any local or traditional medicines	Ever been given any blessed religious pills	Times given blessed religious pills (in last 6 months)					Number of children
			Not given	<16 days	16-30 days	31-60 days	61-180 days	
Bumthang	3.4	89.2	20.4	61	13.8	3.4	1.5	132
Chhukha	0.6	45.6	65	32	2.2	0	0.8	243
Chhukha (Other than P/ling Thromde)	1	47.2	64.8	30.1	3.7	0	1.3	155
Phuentsholing Thromde	0	43.3	65.3	34.7	0	0	0	88
Dagana	0	57.3	53.5	41.3	5.2	0	0	67
Gasa	1.5	84.7	34.8	57	8.1	0	0	49
Haa	0	63.2	59	23.4	16.3	1.3	0	64
Lhuentse	1.1	75.4	27.8	49.3	18.4	3.3	1.2	90
Monggar	1.6	82.7	29.2	46.9	15.6	7.1	1.2	162
Paro	0	62.6	52.1	32.1	13.9	1.6	0.4	151
Pema Gatshel	0.4	72.1	43.2	42.1	8.8	0.4	5.5	96
Punakha	0.8	66.1	48.7	39.5	10.6	1.3	0	103
Samdrup Jongkhar	1	68.1	50	42.6	5.7	0.4	1.4	186
Samdrup Jongkhar (Other than SJ Thromde)	0.8	65.4	51.9	39.8	5.9	0.5	1.9	104
Samdrup Jongkhar Thromde	1.3	75.6	45.1	50	4.9	0	0	82
Samtse	2.6	36.4	71.4	22.4	6.2	0	0	185
Sarpang	3.8	60.5	56.8	39	3.6	0.5	0.1	212
Sarpang (Other than Gelephu Thromde)	3.9	59.3	57.9	38.5	3.6	0	0	133
Gelephu Thromde	3.3	65.9	51.8	41.1	3.5	2.9	0.7	79

Dzongkhag	Given any local or traditional medicines	Ever been given any blessed religious pills	Times given blessed religious pills (in last 6 months)					Number of children
			Not given	<16 days	16-30 days	31-60 days	61-180 days	
Thimphu	2.2	63.5	53.1	33.2	10	1.5	2.2	457
Thimphu (Other than T/phu Thromde)	2.5	67	53.4	36.7	7.1	0.8	1.8	112
Thimphu Thromde	2.2	62.6	53	32.4	10.7	1.6	2.3	345
Trashigang	1.8	72.2	42.2	46.3	7.8	1.4	2.3	214
Trashi Yangtse	0.8	74.1	42.8	45	8.1	1.6	2.6	123
Trongsa	1	84.5	33.5	49.4	8.9	3.4	4.7	104
Tsirang	1	48.1	64.9	35.1	0	0	0	92
Wangdue	2.6	79.7	39	48.6	12.4	0	0	133
Zhemgang	8	90.7	36.1	53.3	4.8	5.8	0	96
National (Total)	**1.9**	**65.1**	**49.6**	**38.9**	**8.7**	**1.5**	**1.2**	**2,959**

Table 8.8: Percentage of children 1-6 years old with blood lead levels by exposure to lead (Behaviour); [National Blood Lead Level Survey 2024]

Characteristics	Blood lead levels (µg/dL)						Number of children
	<3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Usual place of residence							
Most of the time at this house	21.7	78.3	75.7	50.8	5.7	0.7	2,830
More time at another house	16.6	83.4	81.9	61.9	5.9	1.1	129
Khol/kaja/...							
Yes	28.7	71.3	68.3	46.6	2.5	0.6	295
No	20.6	79.4	76.8	51.9	6.1	0.7	2,664
Eat from metal place							
Yes	22.0	78.0	75.3	51.1	6.6	0.7	457
No	21.4	78.6	76.0	51.4	5.6	0.7	2,502
Eat with hand							
Most of the time	20.0	80.0	76.3	50.9	5.4	0.3	1,067
Some of the time	22.8	77.2	75.3	50.6	6.1	0.9	1,273
Seldom or Rarely	21.0	79.0	76.7	53.6	5.5	0.9	619

Characteristics	Blood lead levels (µg/dL)						Number of children
	<3.3	≥3.3	≥3.5	≥5	≥10	≥20	
Hand washing							
Most of the time	20.9	79.1	76.6	50.7	5.4	0.7	2,204
Some of the time	23.4	76.6	73.4	52.9	6.4	0.8	689
Seldom or Rarely	19.2	80.8	79.8	54.5	10.7	0.0	66
Traditional medicine							
Yes	28.4	71.6	69.8	41.3	7.4	0.0	55
No	21.3	78.7	76.1	51.5	5.7	0.7	2,904
Even been given any religious pills/*Jinlab*							
Yes	19.6	80.4	78.0	53.9	6.2	0.8	1,965
No	25.0	75.0	72.1	46.5	4.9	0.5	994
Frequency (No. of times given *Jinlab* in past 6 months)							
Not Given	23.5	76.5	73.9	47.8	4.9	0.6	1,438
<16	20.9	79.1	76.1	52.8	6.5	0.9	1,176
16-30	16.2	83.8	83.1	59.4	5.9	0.4	259
31-60	6.5	93.5	92.3	71.7	11.9	0.0	46
61-180	15.4	84.6	81.5	61.4	5.1	0.0	40
Recency (Last time *Jinlab* was given in past 6 months)							
Not Given	23.5	76.5	73.9	47.8	4.9	0.6	1,438
0-15 days ago	12.5	87.5	84.0	64.2	8.2	0.7	368
16-30 days ago	21.0	79.0	78.0	55.5	7.0	1.4	375
1-3 months ago	21.9	78.1	75.7	50.1	4.7	0.6	477
4-6months ago	23.2	76.8	74.0	50.0	7.9	0.4	231
Not sure	22.2	77.8	73.5	46.6	2.2	0.0	70
Total	**21.5**	**78.5**	**75.9**	**51.3**	**5.7**	**0.7**	**2,959**

Table 8.9: Prevalence of blood lead level of concern (≥3.5 µg/dl) and its associated socio-demographic factors among children aged 1-6 years in Bhutan: Odds Ratio (weighted analysis) n=2959 [National Blood Lead Level Survey 2024]

Characteristics	Percentage of children with BLL of concern[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Age (in completed years)								
1 year	78.8	Base		0.3715	Base		0.3497	411
2 year	78.5	0.98	0.70, 1.37		0.99	0.71, 1.38		464
3 year	74.0	0.76	0.54, 1.07		0.76	0.54, 1.06		522
4 year	73.9	0.76	0.55, 1.04		0.76	0.55, 1.05		465
5 year	75.2	0.82	0.58, 1.14		0.81	0.58, 1.13		516
6 year	75.9	0.85	0.62, 1.15		0.85	0.62, 1.16		581
Sex								
Female	71.7	Base		<0.0001	Base		<0.0001	1415
Male	79.9	1.57	1.31, 1.89		1.58	1.31, 1.89		1544
Material (External Wall)								
Cemented	73.8	Base		0.0003	Base		0.0002	1,680
Mud-based/rammed earth	81.9	1.60	1.27, 2.02		1.62	1.28, 2.04		925
Wood/bamboo/plywood	71.1	0.87	0.63, 1.20		0.87	0.63, 1.20		312
Others	75.9	1.11	0.50, 2.49		1.10	0.48, 2.52		42
Material (Interior Wall)								
Cemented	74.6	Base		0.0490	Base		0.0271	2,062
Mud-based/rammed earth	80.4	1.40	1.09, 1.78		1.42	1.11, 1.82		709
Wood/bamboo/plywood	73.7	0.96	0.59, 1.55		0.95	0.58, 1.55		152
Others	83.5	1.73	0.71, 4.24		1.67	0.68, 4.13		36

Characteristics	Percentage of children with BLL of concern[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Floor Material								
Concrete/tiles/marbles	70.3	Base		<0.0001	Base		<0.0001	
Wood/bamboo	84.8	2.37	1.88, 2.99		2.42	1.92, 3.06		
Mud/Clay	82.0	1.93	1.06, 3.50		1.91	1.06, 3.47		90
Others	62.9	0.72	0.48, 1.07		0.72	0.49, 1.08		144
Roof Material								
CGI/Tin	76.8	Base		0.0683	Base		0.0354	2,650
Wood/bamboo/thatch	75.0	0.91	0.58, 1.43		0.89	0.56, 1.41		143
Concrete/slates	67.1	0.62	0.38, 1.00		0.59	0.36, 0.95		141
Others	57.2	0.40	0.17, 0.96		0.37	0.16, 0.88		25
Age of the house (building)								
<10 years	74.3	Base		0.1213	Base		0.1897	1,107
≥10 years	77.0	1.16	0.93, 1.44		1.16	0.93, 1.44		1,852
Religion								
Christianity	57.4	Base		<0.0001	Base		<0.0001	60
Buddhism	78.5	2.71	1.59, 4.61		2.85	1.69, 4.8		2,530
Hinduism	62.1	1.22	0.68, 2.16		1.26	0.72, 2.2		369
Household member practice metal artisan work								
No	75.7	Base		0.2155	Base		0.1801	2,858
Yes	82.9	1.56	0.77, 3.16		1.60	0.81, 3.17		101
Household member use fishing weights to catch fish								
No	76.1	Base		0.3798	Base		0.3526	2,888
Yes	70.3	0.74	0.39, 1.44		0.74	0.39, 1.39		71

Characteristics	Percentage of children with BLL of concern[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Household member use or handle bullets								
No	75.4	Base		0.0727	Base		0.0836	2,736
Yes	82.0	1.49	0.96, 2.29		1.46	0.95, 2.24		223
Accessible car batteries or a solar system batteries in the house[3]								
No	76.0	Base		0.4167	Base		0.4225	2,782
Yes, Car Batteries	72.8	0.85	0.53, 1.35		0.88	0.55,1.39		134
Yes, Solar System Batteries	84.0	1.66	0.67, 4.12		1.69	0.69,4.12		39
A place to recycle or throw away old car batteries near house								
No	76.0	Base		0.9210	Base		0.9987	2,890
Yes	75.2	0.96	0.44, 2.09		1.00	0.48, 2.09		69
Aluminium cooking pots used for the preparation of food[4]								
No	73.7	Base		0.3201	Base	0.88, 1.52	0.3064	403
Yes	76.3	1.15	0.87, 1.51		1.15			2,556
Brass/bronze/copper cooking pots used for the preparation of food[4]								
No	77.7	Base		0.0001	Base	0.51, 0.80	0.0001	2,355
Yes	69.1	0.64	0.51, 0.8		0.64			604
Aluminium ladles/spoons used for cooking or serving food[4]								
No	68.6	Base		0.0127	Base		0.0095	267
Yes	76.7	1.51	1.09, 2.08		1.53	1.11, 2.10		2,692
Brass/bronze/copper ladles/spoons used for cooking or serving food[4]								
No	76.9	Base		0.0030	Base	0.47, 0.84	0.0019	2,617
Yes	68.0	0.64	0.47, 0.86		0.63			342

Characteristics	Percentage of children with BLL of concern[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Brass/bronze/copper plates used for eating[4]								
No	79.0	Base		<0.0001	Base		<0.0001	691
Yes	66.3	0.52	0.42, 0.65		0.52	0.41, 0.65		2,268
Stainless Steels plates used for eating[4]								
No	78.6	Base		0.0004	Base		0.0008	1,742
Yes	72.0	0.70	0.58, 0.85		0.71	0.59, 0.87		1,217
Decorative metal spoons used for eating[4]								
No	76.7	Base		0.2258	Base		0.2007	905
Yes	74.2	0.87	0.70, 1.09		0.86	0.69, 1.08		2,054
Metal jug or cup or Lota used for drinking[4]								
No	76.9	Base		0.0059	Base		0.0045	2,616
Yes	68.7	0.66	0.49, 0.89		0.65	0.48, 0.87		343
Area								
Urban	77.0	Base		0.3389	Base		0.4262	1,153
Rural	75.2	0.91	0.74, 1.11		0.92	0.75,1.13		1,806
Income quintile								
Lowest	76.5	Base		0.8215	Base		0.8284	605
Second	77.6	1.06	0.77, 1.46		1.06	0.77,1.46		577
Middle	74.2	0.88	0.66, 1.17		0.88	0.66,1.18		593
Fourth	76.0	0.97	0.72, 1.31		0.97	0.72,1.32		631
Highest	75.6	0.95	0.67, 1.34		0.96	0.68,1.35		553

[1] Blood Lead Level (BLL) ≥3.5 µg/dl
[2] Adjusted Wald test
[3] Four households had both types of batteries and all four had elevated BLL
[4] Caveat: The child may or may not have used these utensils. The information were about household use of these utensils.

Table 8.10: Prevalence of elevated blood lead level (≥5 µg/dl) and its associated socio-demographic factors among children aged 1-6 years in Bhutan: Odds Ratio (weighted analysis) n=2959 [National Blood Lead Level Survey 2024]

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Age (in completed years)								
1 year	55.2	Base		0.1031	Base		0.0960	411
2 year	55.2	1.00	0.75, 1.35		1.01	0.75, 1.35		464
3 year	50.4	0.83	0.63, 1.09		0.82	0.62, 1.08		522
4 year	52.1	0.88	0.67, 1.18		0.89	0.67, 1.18		465
5 year	49.2	0.79	0.59, 1.04		0.78	0.59, 1.03		516
6 year	47.5	0.74	0.57, 0.95		0.74	0.57, 0.96		581
Sex								
Female	47.1	Base		<0.0001	Base		<0.0001	1415
Male	55.2	1.39	1.19, 1.61		1.39	1.20, 1.62		1544
Material (External Wall)								
Cemented	50.1	Base		0.5270	Base		0.4844	1,680
Mud-based/rammed earth	53.8	1.16	0.95, 1.42		1.17	0.96, 1.44		925
Wood/bamboo/plywood	51.3	1.05	0.79, 1.40		1.06	0.80, 1.42		312
Others	51.7	1.07	0.51, 2.22		1.09	0.50, 2.34		42
Material (Interior Wall)								
Cemented	50.4	Base		0.6431	Base		0.5554	2,062
Mud-based/rammed earth	53.7	1.14	0.93, 1.40		1.16	0.94, 1.43		709
Wood/bamboo/plywood	53.0	1.11	0.75, 1.63		1.11	0.75, 1.65		152
Others	51.2	1.03	0.51, 2.10		1.02	0.50, 2.08		36

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Floor Material								
Concrete/tiles/marbles	46.5	Base		<0.0001	Base		<0.0001	1,540
Wood/bamboo	59.8	1.71	1.42, 2.06		1.74	1.44, 2.10		1,185
Mud/Clay	39.9	0.76	0.48, 1.21		0.76	0.48, 1.22		90
Others	44.1	0.91	0.62, 1.32		0.91	0.62, 1.33		144
Roof Material								
CGI/Tin	51.3	Base		0.6877	Base		0.6744	2,650
Wood/bamboo/thatch	55.8	1.20	0.81, 1.77		1.18	0.80, 1.74		143
Concrete/slates	47.7	0.87	0.54, 1.38		0.84	0.52, 1.35		141
Others	47.0	0.84	0.36, 1.97		0.81	0.34, 1.92		25
Age of the house (building)								
Less than 10 years	49.6	Base		0.1959	Base		0.1818	1,107
10 or more years	52.4	1.12	0.94, 1.33		1.13	0.95, 1.34		1,852
Religion								
Christianity	30.0	Base		<0.0001	Base		<0.0001	60
Buddhism	54.2	2.76	1.54, 4.93		2.81	1.58, 5.02		2,530
Hinduism	36.0	1.31	0.71, 2.42		1.32	0.71, 2.43		369
Household member practice metal artisan work								
No	51.0	Base		0.1731	Base		0.1500	2,858
Yes	59.1	1.39	0.87, 2.23		1.41	0.88, 2.26		101
Household member use fishing weights to catch fish								
No	51.4	Base		0.4577	Base		0.4281	2,888
Yes	46.6	0.82	0.49, 1.37		0.81	0.49, 1.36		71

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Household member use or handle bullets								
No	50.0	Base		0.0017	Base		0.0019	2,736
Yes	64.5	1.81	1.25, 2.62		1.80	1.24, 2.62		223
Accessible car batteries or a solar system batteries in the house[3]								
No	51.1	Base		0.5268	Base		0.4957	2,782
Yes, Car Batteries	52.1	1.04	0.70, 1.54		1.07	0.72,1.59		134
Yes, Solar System Batteries	63.6	1.67	0.85, 3.30		1.66	0.86,3.22		39
A place to recycle or throw away old car batteries near house								
No	51.4	Base		0.5973	Base		0.6357	2,890
Yes	47.9	0.87	0.52, 1.46		0.88	0.52, 1.49		69
Aluminium cooking pots used for the preparation of food[4]								
No	50.0	Base		0.6238	Base		0.6229	403
Yes	51.6	1.07	0.83, 1.37		1.07	0.83, 1.38		2,556
Brass/bronze/copper cooking pots used for the preparation of food[4]								
No	53.8	Base		<0.0001	Base		<0.0001	2,355
Yes	41.9	0.62	0.50, 0.77		0.61	0.5, 0.76		604
Aluminium ladles/spoons used for cooking or serving food[4]								
No	46.5	Base		0.1425	Base		0.1238	267
Yes	51.8	1.24	0.93, 1.65		1.25	0.94, 1.67		2,692
Brass/bronze/copper ladles/spoons used for cooking or serving food[4]								
No	52.2	Base		0.0155	Base		0.0135	2,617
Yes	44.1	0.72	0.55, 0.94		0.72	0.55, 0.93		342

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	OR	95% CI	p-value[2]	
Brass/bronze/copper plates used for eating[4]								
No	54.8	Base		<0.0001	Base		<0.0001	691
Yes	40.3	0.56	0.45, 0.69		0.55	0.44, 0.68		2,268
Stainless Steels plates used for eating[4]								
No	54.6	Base		0.0004	Base		0.0006	1,742
Yes	46.5	0.72	0.60, 0.86		0.73	0.61, 0.87		1,217
Decorative metal spoons used for eating[4]								
No	50.6	Base		0.3455	Base		0.3803	905
Yes	53.0	1.10	0.90, 1.34		1.09	0.90, 1.34		2,054
Metal jug or cup or Lota used for drinking[4]								
No	52.6	Base		0.0029	Base		0.0017	2,616
Yes	42.1	0.66	0.50, 0.87		0.64	0.49, 0.85		343
Area								
Urban	52.7	Base		0.3535	Base		0.4736	1,153
Rural	50.4	0.91	0.75, 1.11		0.93	0.77, 1.13		1,806
Income quintile								
Lowest	49.0	Base		0.7646	Base		0.7428	605
Second	52.5	1.15	0.89, 1.50		1.16	0.89, 1.50		577
Middle	50.4	1.06	0.82, 1.37		1.05	0.82, 1.36		593
Fourth	52.9	1.17	0.90, 1.52		1.17	0.90, 1.52		631
Highest	51.6	1.11	0.83, 1.48		1.11	0.83, 1.49		553

[1] Blood Lead Level (BLL) ≥5 µg/dl
[2] Adjusted Wald test
[3] Four households had both types of batteries and all four had elevated BLL
[4] Caveat: The child may or may not have used these utensils. The information were about household use of these utensils.

Table 8.11: Prevalence of blood lead level of concern (≥3.5 µg/dl) and its associated behavioural factors among children aged 1-6 years in Bhutan: Odds Ratio (weighted analysis) n=2959 [National Blood Lead Level Survey 2024]

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	aOR	95% CI	p-value[2]	
Kohl, Kajal, Surma, eyeliner, eye shadow, or other home-made cosmetics used on child								
No	76.8	Base		0.0130	Base		0.1167	2,664
Yes	68.3	0.65	0.46, 0.91		0.76	0.55, 1.07		295
Child eat from a metal plate								
No	76.0	Base		0.7634	Base		0.6891	2,502
Yes	75.3	0.96	0.74, 1.24		0.95	0.73, 1.23		457
Child eat with his/her fingers or hands								
Seldom or Rarely	76.7	Base		0.8069	Base		0.7647	619
Some of the time	75.3	0.93	0.72, 1.2		0.93	0.72, 1.21		1,273
Most of the time	76.3	0.98	0.75, 1.28		1.00	0.77, 1.30		1,067
Hand Washing before eating								
Most of the time	76.6	Base		0.2216	Base		0.2682	2,204
Some of the time	73.4	0.84	0.68, 1.05		0.84	0.68, 1.05		689
Seldom or Rarely	79.8	1.21	0.66, 2.21		1.14	0.63, 2.08		66
Given any local or traditional medicines								
No	76.1	Base		0.4638	Base		0.5677	2,904
Yes	69.8	0.73	0.31, 1.7		0.79	0.35, 1.79		55
Ever been given any blessed religious pills								
No	72.1	Base		0.0022	Base		0.0014	994
Yes	78.0	1.38	1.12, 1.69		1.40	1.14, 1.72		1,965

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	aOR	95% CI	p-value[2]	
Recency of being given *Jinlab* prior to the survey								
Never	72.1	Base		0.0162	Base		0.0093	994
Before 6 months	78.3	1.40	1.03, 1.9		1.43	1.05, 1.94		444
4-6months ago	74.3	1.12	0.78, 1.61		1.12	0.78, 1.61		237
1-3months ago	75.7	1.21	0.9, 1.63		1.23	0.91, 1.66		524
16-30 days ago	78.0	1.38	0.97, 1.95		1.41	1.00, 2.00		375
0-15 days ago	83.1	1.90	1.31, 2.77		1.94	1.34, 2.80		385

[1] Blood Lead Level (BLL) ≥3.5 µg/dl
[2] Adjusted Wald test

Table 8.12: Prevalence of elevated blood lead level (≥5 µg/dl) and its associated behavioural factors among children aged 1-6 years in Bhutan: crude Odds Ratio (weighted analysis) n=2959 [National Blood Lead Level Survey 2024]

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	aOR	95% CI	p-value[2]	
Kohl, Kajal, Surma, eyeliner, eye shadow, or other home-made cosmetics used on child								
No	51.9	Base		0.1781		Base	0.6423	2,664
Yes	46.6	0.81	0.6, 1.1		0.93	0.68, 1.27		295
Child eat from a metal plate								
No	51.4	Base		0.9389		Base	0.8808	2,502
Yes	51.1	0.99	0.77, 1.27		0.98	0.77, 1.26		457
Child eat with his/her fingers or hands								
Seldom or Rarely	53.6	Base		0.5389		Base	0.5257	619
Some of the time	50.6	0.88	0.71, 1.11		0.88	0.72, 1.15		1,273
Most of the time	50.9	0.90	0.71, 1.13		0.91	0.70, 1.10		1,067

Characteristics	Percentage of children with elevated BLL[1]	Unadjusted			Adjusted for age and sex			Number of children
		OR	95% CI	p-value[2]	aOR	95% CI	p-value[2]	
Hand Washing before eating								
Most of the time	50.7	Base		0.6325		Base	0.7123	2,204
Some of the time	52.9	1.09	0.89, 1.34		1.08	0.88, 1.33		689
Seldom or Rarely	54.5	1.16	0.69, 1.96		1.11	0.66, 1.88		66
Given any local or traditional medicines								
No	51.5	Base		0.1918		Base	0.2359	2,904
Yes	41.3	0.66	0.35, 1.23		0.70	0.38, 1.27		55
Ever been given any blessed religious pills								
No	46.5	Base		0.0014		Base	0.0007	994
Yes	53.9	1.35	1.12, 1.61		1.37	1.14, 1.65		1,965
Recency of being given Jinlab prior to the survey								
Never	46.5	Base		0.0007		Base	0.0003	994
Unsure	51.0	1.20	0.92, 1.57		1.23	0.93, 1.61		444
4-6 months ago	51.0	1.20	0.88, 1.63		1.18	0.87, 1.61		237
1-3 months ago	49.4	1.12	0.87, 1.45		1.15	0.89, 1.48		524
16-30 days ago	55.5	1.43	1.06, 1.93		1.48	1.10, 1.99		375
0-15 days ago	63.3	1.99	1.47, 2.68		2.03	1.51, 2.72		385

[1] Blood Lead Level (BLL) ≥5 µg/dl
[2] Adjusted Wald test

Supporting partners