Targeted Blood Lead Level Screening Among Selected Hospital Attendees and High-Risk Groups in Bhutan:

A Programmatic Assessment



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INTRODUCTION

Lead is a toxic heavy metal with no known physiological role in the human body and remains a significant environmental and public health concern worldwide. Human exposure occurs through contaminated air, water, soil, food, household dust, and consumer products including paints, cookware, cosmetics, and traditional or cultural items. Due to its persistence in the environment and its ability to accumulate in biological tissues, even low levels of lead exposure can result in harmful health effects. The National Blood Lead Level Survey (2024) conducted by the Ministry of Health, Bhutan, identified lead exposure as an emerging public health issue, demonstrating widespread exposure across multiple population groups within the country. [1,2]

Findings from the national survey showed that 75.9% of children aged 1–6 years had blood lead levels (BLLs) ≥3.5 µg/dL, exceeding the US CDC blood lead reference value (BLRV) used to identify children with BLLs higher than those of most children in the U.S. reference population. More than half of the children had BLLs ≥5 µg/dL, the WHO-recommended concentration at which the source of exposure should be identified and appropriate action taken to reduce or terminate exposure. BLLs ≥3.5 µg/dL were also observed among 58.9% of pregnant and breastfeeding women, while a notably higher prevalence (86.0%) was detected among children residing in monastic institutions. Although the latter two percentages are not nationally representative data, these results suggest that lead exposure in Bhutan is multifactorial and not confined to specific geographic or socioeconomic settings. The survey further identified potential exposure sources including Jinlab Mendrup (jinlab/mendrup/damzey/rilbu) (religious blessed substances), contaminated spices and foods, kitchen cookware and utensils, toys, and other household materials, indicating diverse environmental and behavioral pathways contributing to exposure. [2–5]

Lead toxicity can be acute or chronic and affects multiple organ systems. It is particularly harmful to children because of increased gastrointestinal absorption and the heightened vulnerability of the developing nervous system. Early-life exposure to lead is associated with irreversible neurodevelopmental impairment, reduced intelligence quotient (IQ), behavioral disorders, learning difficulties, and impaired growth. Exposure to lead begins during pregnancy as lead freely crosses the placenta affecting the developing fetus. Lead crosses the placenta, and fetal exposure is closely related to maternal blood lead concentrations. In adults, both

current and past lead exposure cause pregnancy complications, anemia, renal dysfunction, hypertension and increased cardiovascular morbidity and mortality. [1,6,7]

Evidence from the national survey demonstrated associations between elevated BLLs and anemia as well as developmental delays among children. Given that no safe level of lead level has been identified, early detection through targeted screening and strengthened surveillance systems is essential to guide clinical management and inform preventive public health interventions aimed at reducing exposure and protecting population health. [1,4]

Furthermore, a National Lead Poisoning Clinical Guideline (NLPCG) is anticipated to be developed for Bhutan, adapted from WHO's guideline for clinical management of lead exposure (2021). To develop this guideline, local data is needed on how many sick patients have high blood lead levels (BLLs), particularly levels that may require chelation therapy. The goal of this assessment was to identify patients with the highest BLLs. However, since symptoms for lead poisoning are vague and nonspecific, a wide net was cast to gain a good understanding of lead poisoning in sick patients. [4]

OBJECTIVES

1. To analyze blood lead levels among selected hospital attendees and high-risk groups and assess their association with demographic, environmental, occupational, and clinical characteristics.
2. To estimate the proportion of participants requiring clinical intervention, including chelation therapy, based on their blood lead levels.
3. To identify potential household and environmental sources of lead exposure among participants with the highest blood lead levels detected through targeted screening.

METHODOLOGY

This is a secondary analysis of programmatic data from a cross-sectional targeted blood lead level (BLL) screening and clinical profile assessment conducted among selected hospital attendees and metal artisan workers conducted during the months of March and April 2026. Details of the methodology used during the assessment are described below

Assessment Sites

1. Jigme Dorji Wangchuck National Referral Hospital (JDWNRH)
2. Army Hospital, Lungtenphu
3. Paro Dzongkhag Hospital
4. Phuentsholing Hospital
5. National Traditional Medicine Hospital (NTMH)
6. Metal artisan workers (gold smith) at Lungtenzampa, Department of Procurement and Properties, Ministry of Finance

Target Population/Patients

1. Sick children aged ≥1 year (both IPD and OPD)
2. Pregnant women between 30 to 41 weeks' gestational age visiting for ANC
3. Lactating women attending their 2nd and 3rd PNC visit
4. Adults from Dialysis Unit (both IPD and OPD)
5. Adults admitted to IPD (Medical, Gynecology, Psychiatric, Onco, and Orthopedic wards, as well as in the AICU)
6. Adult patients visiting National Traditional Medical Hospital (NTMH)
7. Metal artisan workers (gold smith) at Lungtenzampa, Department of Procurement and Properties, Ministry of Finance
8. Military personnel

Inclusion Criteria

Pediatric patients admitted to hospitals

- Children, 1-12 years old admitted to the pediatric ward or pediatric ICU

Pediatric patients in the OPD

Children with the following symptoms or exposures were prioritized during the hospital lead assessment, however some children without these were also included.

- For younger children only:
  - Irritability in young children, not explained by other symptoms (1-2 years old)
  - Severe Stunting or wasting (1-5 years old) (from MCH growth charts)
- Children 1-12 years old in the pediatric OPD with the any of the following complaints/symptoms/potential exposures (patients selected by a healthcare worker):
  - Anemia (moderate or severe)
  - Abdominal pain, constipation, vomiting, diarrhea, or anorexia
  - Clumsiness, agitation, altered mental state, or neurological symptoms
  - Developmental delay
    - » Delays needing a referral (1-5 years old) in MCH handbook
    - » Children referred from the physio department, or
    - » At the discretion of OPD chambers
  - Hearing loss/difficulty
  - Renal failure
  - Sluggishness, fatigue, or more than 10% weight loss
  - Seizure or coma
  - Any child given Jinlab Mendrup (jinlab, mendrup, damzey, or rilbu), or traditional, natural, alternative, Tibetan, or ayurvedic medicine for 3 or more days in the past week
  - Any child where an adult in the household may work with lead
    - » (metal artisan worker, vehicle repair worker, handling bullets or guns, handling of lead, handling of waste collection or recycling)

Pregnant women

- Pregnant women who came to MCH for routine care from ≥26 weeks of pregnancy
- Pregnant women during any trimester with
  - Gestational hypertension
  - Preeclampsia, eclampsia
  - Miscarriage or spontaneous abortion
  - Infertility problems
  - Any pregnant woman taking Jinlab Mendrup (jinlab, mendrup, damzey, or rilbu), or traditional, natural, alternative, Tibetan, or ayurvedic medicine for 3 or more days in the past week
- Any woman who may work with lead, or who lives with an adult in the household who may work with lead
  - (metal artisan worker, vehicle repair worker, handling bullets or guns, handling of lead, etc. municipal waste collectors)

Lactating women

- Women attending their second or third (3 days or 7 days) postnatal care (PNC) visit at the MCH clinic on the day of testing.

Dialysis OPD/ IPD-

- Patients with chronic kidney disease (CKD) who are undergoing dialysis will be tested for blood lead levels (BLL) visiting on the day of testing.

Medical Ward -

- Patients presenting with one or more of following symptoms will be considered for testing;

Abdominal pain, nausea, or vomiting; diarrhea or constipation; headache, fatigue, irritability, or generalized weakness, stroke and seizures; loss of appetite; memory impairment; and pain, numbness, or tingling sensations in the hands or feet.

Ob/Gyn ward

- Patients admitted with eclampsia, preeclampsia and miscarriage will be tested.

Adult ICU patients

- Adult medical ICU patients will be tested.

Psychiatric ward

- Patients admitted to the Psychiatric ward will be tested.

Oncology ward/OPD

- Patients admitted to the Onco ward will be tested.

Orthopedic ward

- Patients admitted to the ward with chronic orthopedic conditions.

Other adults in OPD or admitted to the hospitals including NTMH

- Adults who are admitted to any ward with any of the following complaints/symptoms/potential exposures (patients selected by a physician):
  - Anemia (moderate or severe)
  - Abdominal pain, constipation, vomiting, diarrhea, or anorexia
  - Cancer
  - Coronary heart disease / cardiovascular disease
  - Clumsiness, agitation, altered mental state, or neurological symptoms
  - Renal failure
  - Seizure or coma
  - Stroke
  - Any adult patient taking Jinlab Mendrup (jinlab, mendrup, damzey, or rilbu), or traditional, natural, alternative, Tibetan, or ayurvedic medicine for 3 or more days in the past week
  - Adults with potential professional exposure (metal artisan worker, vehicle repair worker, handling bullets or guns, handling lead, etc.)

High risk professions

- Metal artisan workers (gold smith) working in the Department of Procurement and Properties, Ministry of Finance on the day of testing.
- Military personnel with high exposure to lead ammunition.

Blood Lead Level Assessment

Blood lead level assessment was carried out using LeadCare II analyzers & reagents. 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. [8]

Hemoglobin Measurement

A non-invasive hemoglobin measurement was performed using a Masimo Rad-67 Pulse CO-Oximeter for all population groups except pregnant and lactating women. For pregnant and lactating women, hemoglobin reading from the most recent blood investigation from the MCH handbook was recorded.

Masimo Rad-67 Pulse CO-Oximeter, a non-invasive point-of-care device that estimates hemoglobin levels through multi-wavelength spectrophotometry. The device uses Masimo Signal Extraction Technology (SET®) to analyze light absorption characteristics through a fingertip sensor and provides rapid hemoglobin measurements without requiring a blood sample. The Rad-67 provides non-invasive spot-check estimation of hemoglobin and was used in this assessment as a screening tool. [9]

Household source investigation

Households of participants identified with blood lead levels ≥20 µg/dL underwent a targeted household investigation to identify potential sources of lead exposure. A Evident/Olympus Vanta C portable X-Ray Fluorescence (pXRF) analyzer with a silver (Ag) anode was used for household source investigation. 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. [10]

Sample Size

A formal sample size calculation was not performed because the activity was designed as a targeted programmatic screening intervention rather than a population-based prevalence study. There were around 2100 test kits and testing was done as per the details presented in table 1 below.

Table 1: Sample size distribution

Sl. No.	Population Groups	Target Sites	Sample Size (n)
1	Children	Paed OPD and Paed Ward	931
2	Pregnant & Lactating Women	MCH Clinic	531
3	Other Adults	Adult Dialysis patients	112
		Adult Medical Ward	120
		Adult Oncology Ward	27
		Adult Ortho Ward	44
		Adult Psychiatric Ward	41
		Adult ICU Ward	9
		General Ward	27
		OB/Gyn OPD & Ward	43
		Other Adult OPD	22
		NTMH	48
4	High Risk Groups	Military Personnel	23
		Metal Artisan Worker	39
Total			**2,017**

Data Collection

Data were collected using computer-assisted personal interviewing (CAPI) using the Survey Solutions platform by health workers trained in the assessment protocol. The health workers were organized into eight teams of three members each to conduct daily activities, including data collection, blood lead level measurement, and non-invasive hemoglobin measurement or recording of the most recent hemoglobin result, as applicable.

This was followed by targeted identification of potential lead exposure sources in the homes using X-ray fluorescence (XRF) testing for patients with a blood lead level ≥20 µg/dL.

Administrative and Ethical Clearance

Administrative approval for the conduct of the assessment has been approved by the Department of Public Health, Ministry of Health. Since lead poisoning has become an urgent public health priority, the activity was being undertaken as a public health intervention, therefore ethical clearance is not requested. However, a verbal consent was taken from every patient after explaining the purpose, risks and benefits of the assessment, including the use of aggregated data in reports, presentations and scientific publications. The verbal consent was recorded by the interviewer in CAPI.

Data Analysis

Data was analysed using SPSS. Categorical variables have been presented as frequency and percent. Mean, median and standard deviation for continuous variables. Statistical associations were assessed using the Chi-Square test for categorical variables and correlation for continuous variables. The LeadCare II analyzer has a reporting range of 3.3-65 µg/dL. There were 749 individuals whose blood reports were below the reporting range which the analyzer reports as 'LOW'. A value of 1.6 µg/dL was assigned for all BLLs below the level of detection for statistical analysis. There were no individuals whose blood lead level was above the reporting range. [5,8]

RESULTS

General Characteristics

A total of 2,017 participants were included in the assessment. Around 59 % of the participants were female. The participants' ages ranged from 1 to 92 years, with a mean age of 23.36 years (SD = 21.24). Data were collected from six data collection sites, covering participants who had resided in 19 of Bhutan's 20 dzongkhags during the 30 days preceding the assessment.

Table 2: Distribution of participants by sex

Sex	Frequency (n)	Percentage (%)
Female	1,193	59.1
Male	824	40.9
Total	**2,017**	**100.0**

Table 3: Age distribution of the participants

Age Group	Frequency (n)	Percent (%)	
1–6 years	689	34.2	
7–12 years	242	12.0	Mean ± SD: 23.36 ± 21.24
13–30 years	387	19.2	Minimum: 1
31–50 years	455	22.6	Maximum: 92
51 years and older	244	12.1	
Total	**2,017**	**100.0**	

Of the total 2,017 participants, over two-third (68.5%) were recruited from JDWNRH (68.5%), followed by Paro Hospital (10.6%) and Phuentsholing Hospital (9.7%). Participants from Army Hospital accounted for 6.9%, while NTMH contributed 2.4% and metal artisan workers accounted for 1.9%.

Table 4: Distribution of participants by data collection site

Data collection site	Frequency (n)	Percent (%)
JDWNRH	1,381	68.5
Paro Hospital	214	10.6
Phuentsholing Hospital	195	9.7
Army Hospital	140	6.9
NTMH	48	2.4
Metal Artisan Worker	39	1.9
Total	**2017**	**100**

Table 5: Distribution of participants by Dzongkhag of residence in the last 30 days

Dzongkhag	Frequency	Percent
Bumthang	16	0.8
Chhukha	235	11.7
Dagana	22	1.1
Haa	8	0.4
Lhuntse	3	0.1
Mongar	4	0.2
Paro	280	13.9
Pemagatshel	10	0.5
Punakha	17	0.8
Samdrup Jongkhar	10	0.5
Samtse	35	1.7
Sarpang	11	0.5
Thimphu	1272	63.1
Trashigang	8	0.4
Trashiyangtse	6	0.3
Trongsa	16	0.8
Tsirang	15	0.7
Wangdue	38	1.9
Zhemgang	9	0.4
Outside Bhutan	2	0.1
Total	**2017**	**100.0**

Around two-thirds (63.1 %) of the participants lived their last 30 days preceding the assessment in Thimphu, followed by Paro (13.9 %) and Chhukha (11.7 %). Participants who lived their last 30 days preceding the assessment in Wangdue (1.9%) and Samtse (1.7%) accounted for a smaller percentage proportion, while each of the remaining dzongkhags had less than 1% of the participants.

Table 6: Distribution of participants by location

Population Groups	Frequency	Percent
Paed OPD	874	43.3
Paed Ward	57	2.8
MCH Clinic	531	26.3
OB/Gyn OPD/ Ward	43	2.1
Adult Dialysis ward	112	5.6
Adult ICU	9	.4
Adult Medical Ward	120	5.9
Adult Oncology Ward	27	1.3
Adult Ortho ward	44	2.2
Adult Psychiatric Ward	41	2.0
General ward	27	1.3
Other adult OPD	22	1.1
NTMH	48	2.4
Metal Artisan worker	39	1.9
Military personnel	23	1.1
Total	**2017**	**100.0**

Close to half of participants were recruited from the Pediatric OPD (43.3%) followed by MCH Clinic (26.3%), together comprising 69.6% of the total participants. The Adult Medical Ward had 5.9% and Adult Dialysis Ward 5.6% had the next highest proportion of participants. The remaining participants were distributed among the other locations, each comprising less than 3% of the study population.

Table 7: Distribution of blood lead levels

BLL Category (µg/dL)	Frequency (n)	Percent (%)	
Less than 3.5	826	41.0	Mean ± SD: 4.2 ± 3.5 Minimum: 1.6 Maximum: 42.4
3.5–4.9	625	31.0	
5.0–7.4	377	18.7	
7.5–9.9	94	4.7	
10.0–19.9	84	4.2	
20 and above	11	0.5	
**BLL value of 1.6 µg/dL was assigned for analysis purposes for all values below the limit of detection*			

Table 7 shows the distribution of participants according to blood lead level (BLL). The mean BLL was 4.2 ± 3.5 µg/dL, with values ranging from "LOW" (below the limit of detection of the LeadCare II analyzer) to 42.4 µg/dL. Over half of the participants (59%) had a BLL of above ≥3.5 µg/dL. Almost 5% of participants had a BLL of 10 µg/dL or higher.

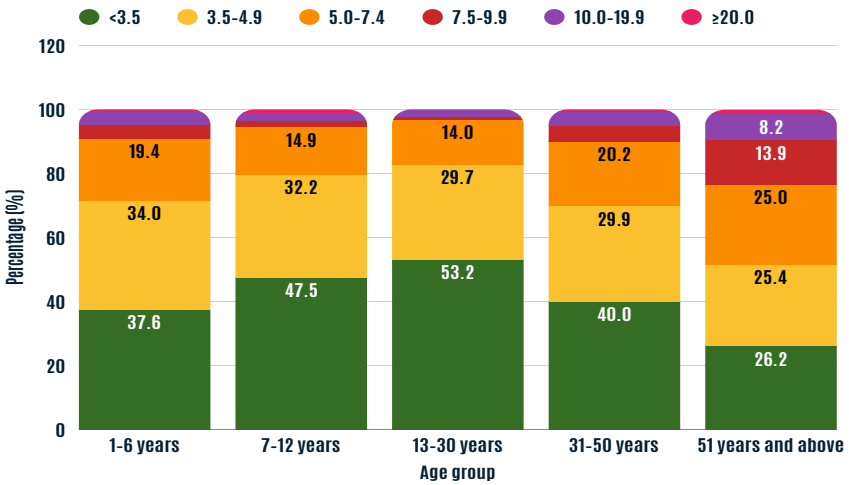


Figure 1: Distribution of blood lead level by age groups

Table 8. Distribution of blood lead levels by age categories

Age group	Total (n)	<3.5 n (%)	3.5–4.9 n (%)	5.0–7.4 n (%)	7.5–9.9 n (%)	10.0–19.9 n (%)	≥20 n (%)	Mean ± SD
1–6 years	689	259 (37.6)	234 (34.0)	134 (19.4)	29 (4.2)	30 (4.4)	3 (0.4)	4.2 ± 3.1
7–12 years	242	115 (47.5)	78 (32.2)	36 (14.9)	5 (2.1)	6 (2.5)	2 (0.8)	3.8 ± 3.8
13–30 years	387	206 (53.2)	115 (29.7)	54 (14.0)	4 (1.0)	8 (2.1)	0 (0.0)	3.3 ± 2.2
31–50 years	455	182 (40.0)	136 (29.9)	92 (20.2)	22 (4.8)	20 (4.4)	3 (0.7)	4.3 ± 3.7
51 years and above	244	64 (26.2)	62 (25.4)	61 (25.0)	34 (13.9)	20 (8.2)	3 (1.2)	5.7 ± 4.5

Table 8 presents the distribution of blood lead levels across different age groups. Among the 1–6-year-old children (n=689), 37.6% had blood lead levels below 3.5, while 34.0% had levels between 3.5–4.9. Overall, 28.4% had blood lead levels of ≥5.0, including 4.4% with levels of 10.0–19.9 and 0.4% with levels ≥20. The mean blood lead level in this age group was 4.2 ± 3.1.

Among children aged 7–12 years (n=242), nearly half (47.5%) had blood lead levels below 3.5, while 32.2% had levels of 3.5–4.9. A total of 20.3% had levels ≥5.0, including 2.5% with levels of 10.0–19.9 and 0.8% with levels ≥ 20. The mean blood lead level was 3.8 ± 3.8.

The highest mean blood lead levels were observed among participants aged 51 years and above (n=244). Only 26.2% had levels below 3.5, while 25.4% had levels of 3.5–4.9 and 25.0% had levels of 5.0–7.4. Overall, 48.4% had blood lead levels ≥ 5.0, including 8.2% with levels of 10.0–19.9 and 1.2% with levels ≥20. This group also had the highest mean blood lead level (5.7 ± 4.5).

Overall, 28.4% had BLLs ≥5.0 µg/dL, including 4.4% with BLLs of 10.0–19.9 µg/dL and 0.4% with BLLs ≥20 µg/dL.

Table 9: Blood lead levels by participant categories

Patient Group	Total (n)	<3.5 n (%)	3.5–4.9 n (%)	5.0–7.4 n (%)	7.5–9.9 n (%)	10.0–19.9 n (%)	≥20 n (%)	Mean ± SD
Children (1–12 years)	931	374 (40.2)	312 (33.5)	170 (18.3)	34 (3.7)	36 (3.9)	5 (0.5)	4.1 ± 3.3
MCH and OBGYN, IPD & OPD	574	322 (56.1)	169 (29.4)	71 (12.4)	5 (0.9)	6 (1.0)	1 (0.2)	3.2 ± 2.3
Dialysis Patients	112	9 (8.0)	17 (15.2)	46 (41.1)	21 (18.8)	17 (15.2)	2 (1.8)	7.5 ± 4.7
Other Adult Patients	338	115 (34.0)	110 (32.5)	69 (20.4)	24 (7.1)	17 (5.0)	3 (0.9)	4.7 ± 4.1
Metal Artisan Worker	39	3 (7.7)	10 (25.6)	15 (38.5)	5 (12.8)	6 (15.4)	0 (0.0)	6.4 ± 2.9
Military Personnel	23	3 (13.0)	7 (30.4)	6 (26.1)	5 (21.7)	2 (8.7)	0 (0.0)	6.2 ± 3.4
Total	**2,017**	**826 (40.9)**	**625 (31.0)**	**377 (18.7)**	**94 (4.7)**	**84 (4.2)**	**11 (0.5)**	**4.2 ± 3.5**

Table 9 presents the distribution of blood lead levels by participant category. Overall, among 2,017 participants, 28.1% had blood lead levels ≥5.0, while the mean blood lead level was 4.2 ± 3.5. The highest mean blood lead level was observed among dialysis patients (7.5 ± 4.7), followed by metal artisan workers (6.4 ± 2.9) and military personnel (6.2 ± 3.4).

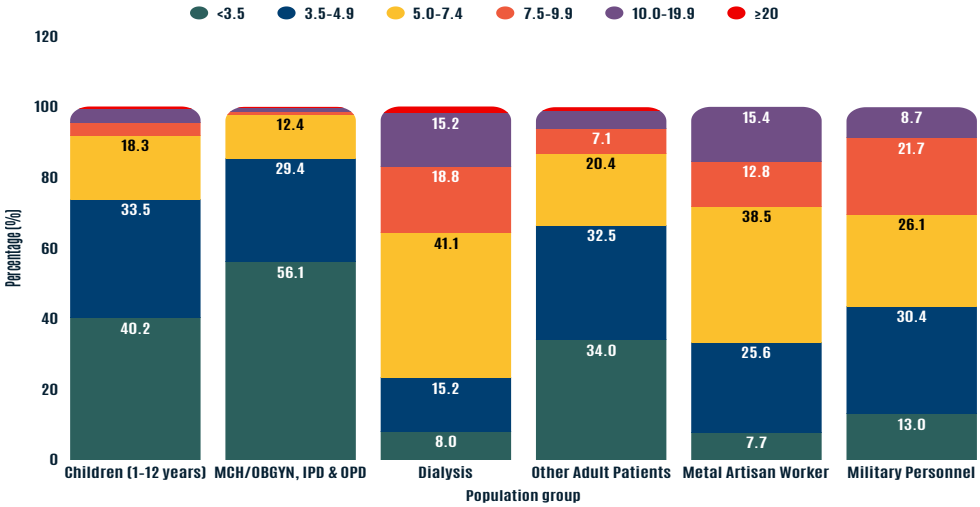


Figure 2: Blood lead levels by population groups

Table 10: Distribution of blood lead levels ≥3.5 µg/dL among children aged 1–6 years

Age	Total (n)	BLL <3.5 n (%)	BLL ≥3.5 n (%)
1	156	56 (35.9)	100 (64.1)
2	111	25 (22.5)	86 (77.5)
3	133	49 (36.8)	84 (63.2)
4	110	40 (36.4)	70 (63.6)
5	112	59 (52.7)	53 (47.3)
6	67	30 (44.8)	37 (55.2)

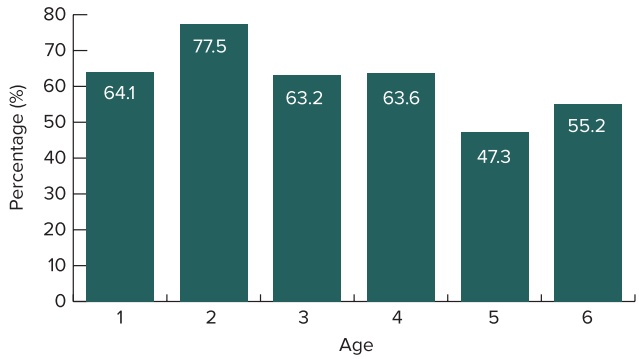


Figure 3: Blood lead level among children aged 1-6 years

Table 10 presents the distribution of blood lead levels (BLL) by age among children aged 1–6 years. The highest proportion was observed among 2-year-olds, followed by 4-year-olds (63.6%), 1-year-olds (64.1%), and 3-year-olds (63.2%). The lowest proportion was observed among 5-year-olds (47.3%), while 55.2% of 6-year-olds had BLL ≥3.5 µg/dL.

Table 11: Severity of anemia among pregnant women

Severity of Anemia	Frequency	Percent
Severe Anemia	0	0.0
Moderate anemia	12	2.9
Mild anemia	18	4.4
No anemia	381	92.7
Total	**411**	**100.0**

Table 12: Severity of anemia in children 6-23 months

Severity of Anemia	Total	6–23 months	24–59 months
Severe anaemia, n (%)	0 (0.0)	0 (0.0)	0 (0.0)
Moderate anaemia, n (%)	0 (0.0)	0 (0.0)	0 (0.0)
Mild anaemia, n (%)	7 (2.0)	2 (2.4)	5 (1.8)
No anaemia, n (%)	351 (98.0)	81 (97.6)	270 (98.2)
Total	**358**	**83**	**275**

Table 11 and 12 presents severity of in pregnant women and children 6-23 months respectively. Around 3% of pregnant women had moderate anemia while 4.4 5 had mild anemia. The majority of children (98.0%) were classified as having no anaemia, while 7 children (2.0%) had mild anaemia. No cases of moderate or severe anaemia were identified in the analysed dataset.

Table 13: Association between Mendrup use and blood lead level

Jinlab Use	Total (n)	BLL <3.5 n (%)	BLL ≥3.5 n (%)	p-value
No	1,613	680 (42.2)	933 (57.8)	0.028
Yes	396	143 (36.1)	253 (63.9)	
Total	**2,009**	**823 (41.0)**	**1,186 (59.0)**	

Table 13 shows a statistically significant association between Mendrup use and blood lead levels. Among participants who reported using Mendrup, 63.9% had BLL ≥3.5 µg/dL, compared with 57.8% among those who did not use it. Conversely, 36.1% of Mendrup users had BLL <3.5 µg/dL compared with 42.2% of non-users.

This difference was statistically significant (p=0.028), indicating that Jinlab use was associated with a higher proportion of participants having BLL ≥3.5 µg/dL.

Table 14: Association between household occupational lead exposure and BLL ≥3.5 µg/dL

Household adult occupational lead exposure	Total (n)	BLL <3.5 n (%)	BLL ≥3.5 n (%)	p-value
No	1,624	717 (44.2)	907 (55.8)	<0.001
Yes	278	77 (27.7)	201 (72.3)	
Total	**1,902**	**794 (41.7)**	**1,108 (58.3)**	

Table 14 shows a statistically significant association between household adult occupational lead exposure and elevated blood lead levels. Among participants with household adult occupational lead exposure, 72.3% had BLL ≥3.5 µg/dL, compared with 55.8% among those without such exposure. [11]

This difference was statistically significant ($p<0.001$), indicating that participants living in households where an adult had occupational lead exposure were more likely to have elevated blood lead levels. The finding suggests potential household or take-home exposure to lead from occupational sources.

Household blood lead level and XRF source testing:

Household blood lead level (BLL) and X-ray fluorescence (XRF) source testing was conducted in the homes of people found to have a BLL ≥20 µg/dL during the hospital assessment. After permission was obtained from the head of the household and household members, BLL testing of all consenting household members was conducted by enumerators, followed by XRF testing was conducted searching for potential lead sources.

A total of 42 household members participated in BLL testing, whose age ranged from one week old to 74 years. Among the household members, BLLs ranged from <3.3 µg/dL to a value of 33.4 µg/dL. The average BLL in this cohort was 6.4 µg/dL. Following are the percentages by BLL ranges.

Table 15: Blood lead levels of household members

BLL range	Frequency	Percent
"low" <3.3 µg/dL	4	9.5%
3.3 - 4.9 µg/dL	14	33.3%
5 - 7.4 µg/dL	17	40.5%
7.5 - 9.9 µg/dL	4	9.5%
≥10 µg/dL	3	7.1%
Totals	**42**	**100%**

The one-week old baby was tested using a heel stick collection method because the infant's mother was found to have a BLL of 33.2 µg/dL the day before her scheduled delivery. The baby's BLL at one week of age was found to be 33.4 µg/dL, showing the maternal fetal transfer of lead. [1,7]

XRF source testing was conducted on kitchen cookware and utensils, spices, toys, soil, paint, Mendrup, religious items, and other items which could be a potential source of lead. The items found to contain lead are listed below and represent potential lead sources in these individual homes, but do not necessarily represent population-wide exposure.

- Aluminium cookware and utensils,
- Counting beads from prayer beads,
- Toys,
- Fishing weights,
- One imported allopathic medicinal product

Information on ways to reduce lead exposure and reduce lead absorption through good nutrition was provided to each household. Items found to contain lead through XRF testing were discussed with household members and were encouraged to avoid or minimize use of these items to reduce lead exposure.

LIMITATIONS

1This was a targeted, cross-sectional assessment conducted among selected hospital attendees and predefined high-risk groups, rather than a population-based survey. Participants were recruited from selected health facilities and occupational groups, and therefore the findings cannot be considered nationally representative or generalized to the population of Bhutan.

The assessment provides a snapshot of blood lead exposure at the time of assessment. Although associations were observed between elevated BLLs and selected exposure characteristics, including household occupational lead exposure and Rib/ Mendrup use, temporal relationships and causality cannot be established from these data.

CONCLUSION

This targeted assessment demonstrates that lead exposure is an important public health concern among selected hospital attendees and high-risk population groups in Bhutan. Among the 2,017 participants assessed, 59.0% had BLLs ≥3.5 µg/dL, while 28.1% had BLLs ≥5 µg/dL. Elevated BLLs were observed across several population groups, with particularly high mean BLLs among dialysis patients, metal artisan workers and military personnel.

Children also demonstrated substantial exposure, with 62.4% of children aged 1–6 years having BLLs ≥3.5 µg/dL. The findings are of particular public health importance given the vulnerability of children to the adverse effects of lead exposure.

The assessment further identified potential environmental and occupational pathways of exposure. Participants reporting household adult occupational exposure had a significantly higher proportion of elevated BLLs than those without such exposure, suggesting the possibility of household or take-home exposure. The association observed between Mendrup use and elevated BLLs also warrants further investigation. Household investigations among participants with BLLs ≥20 µg/dL identified several potentially lead-containing items, including cookware and utensils, prayer beads, toys, fishing weights and a medicinal product. These findings provide important leads for further environmental and product-specific investigation.

The findings underscore the need to strengthen clinical recognition, confirmatory testing, surveillance, exposure assessment and prevention of lead exposure in Bhutan. They also provide useful local evidence to inform development of the proposed National Lead Poisoning Clinical Guideline and to guide targeted interventions for populations and settings where elevated exposure may occur.

RECOMMENDATIONS

1. Strengthen clinical management of lead exposure

Develop and implement a National Lead Poisoning Prevention and Clinical Management Guidelines that provides standardized guidance for the assessment, confirmation, clinical management, referral and follow-up of individuals with elevated BLLs. The guideline should provide age- and risk-specific management pathways for children, pregnant women, adults and occupationally exposed individuals.

2. Establish confirmatory testing and follow-up pathways

Strengthen access to confirmatory blood lead testing and clinical follow-up, particularly for individuals identified with elevated BLLs through point-of-care screening. Clear referral and follow-up pathways should be established for individuals with significantly elevated BLLs and those with compatible clinical findings.

3. Prioritize high-risk population groups

Consider targeted surveillance and screening among groups identified in this assessment as having relatively higher BLLs, particularly dialysis patients, metal artisan workers, military personnel, older adults, pregnant women and children, while ensuring that screening strategies are guided by risk assessment and available evidence.

The particularly high mean BLL observed among dialysis patients (7.5 ± 4.7 µg/dL), metal artisan workers (6.4 ± 2.9 µg/dL) and military personnel (6.2 ± 3.4 µg/dL) warrants further investigation.

4. Strengthen occupational lead exposure prevention

Conduct occupational risk assessments in workplaces where lead exposure may occur, particularly among metal artisans, military personnel and other workers handling lead-containing materials. Appropriate workplace controls, personal protective measures, worker education and periodic health surveillance should be strengthened.

5. Address household and take-home exposure

The significant association between household adult occupational lead exposure and elevated BLLs highlights the need to address potential take-home exposure. Occupationally exposed workers and their households should receive information on appropriate hygiene, changing, washing and storage practices to minimize transfer of lead from workplaces to homes.

6. Strengthen environmental source identification and control

Household environmental investigations should be expanded, where appropriate, for individuals with blood lead levels of 7.5µg/dL or higher. Potential sources identified in this assessment—including kitchenware, prayer beads, toys, fishing weights and mendrup, medicinal products—should be further investigated to determine their lead content and potential contribution to human exposure.

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