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# Childhood Blood Lead Surveillance in Bihar

Vital Strategies GiveWell EA Funds Open Philanthropy PURE EARTH

# Table of Contents

# Acknowledgments

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# Acronyms and Abbreviations

BLL: Blood lead level

BRANY: Biomedical Research Alliance of New York

CDC: United States Centers for Disease Control and Prevention

ICMR: Indian Council for Medical Research

ICP-MS: Inductively coupled plasma mass spectrometry

IQ: Intelligence quotient

LOD: Limit of detection

µg/dL: Micrograms of lead per deciliter of whole blood

NABL : National Accreditation Board for Testing and Calibration Laboratories

NGO: Nongovernmental organization

Pb:  Lead

ppb: Parts per billion

ppm: Parts per million

U.S. EPA: United States Environmental Protection Agency

WHO: World Health Organization

# Executive Summary

## Overview

World Health Organization has identified lead as one of the 10 chemicals of major public health concern. Among the major environmental risk factors for premature disease and mortality, lead exposure ranks fourth after ambient particulate matter air pollution, household air pollution from solid fuels, and unsafe household drinking water, sanitation, and handwashing, according to the 2019 Global Burden of Diseases (GBD) study. (1)

According to estimates from the GBD study, India accounted for more than half of the total global morbidity and mortality attributable to lead, despite having only 18% of the global population. Based on modeled estimates, Bihar had the highest blood lead level among all Indian states.(2) However, no statewide monitoring data on children's blood lead level was available in Bihar to verify this concern. In 2023, Vital Strategies, in partnership with Pure Earth and Mahavir Cancer Sansthan and Research Center, conducted the first statewide study to understand blood lead levels (BLLs) in children under the age of 5 and in pregnant women in Bihar, India. This study provides state representative estimates of BLL among children and explores BLL among pregnant women. We found high prevalence of elevated levels in both children and pregnant women in Bihar. Several factors related to lead exposure at home were identified, including living near lead-related industries, cohabiting with someone working with lead, use of cosmetics that may contain lead, and pica behavior.

Findings from this study highlight the urgency to develop a comprehensive strategy to protect children in Bihar from lead poisoning. Strengthening the local health system's capacity to address lead exposure should include ongoing monitoring of childhood blood lead levels, integrating lead exposure assessment into routine pediatric care for early prevention and timely treatment, increasing awareness among health professionals and parents, and regulating lead use in consumer products, industry and manufacturing.

## About Lead Poisoning

Lead is a potent toxin that can severely affect the mental functioning and physical health of children and adults. Children are particularly vulnerable to lead poisoning because they absorb significantly more lead from their environments than adults and their central nervous systems are still developing. Lead exposure can affect children's brain development, even at a low level, and can result in behavioral changes, reduced intelligence quotient (IQ), and reduced educational attainment and lifetime earnings. (3,4)

Globally, known sources of lead exposure include use of leaded paint, recycling of lead-acid batteries, mining, manufacturing, and lead in consumer products. While India has made efforts to regulate lead in gasoline and paint, little is known about the prevalence and extent of exposure from other emerging sources, including spices, metal and ceramic cookware, and the recycling of used lead acid batteries. In addition, population-level data on childhood blood lead levels are limited.

## Summary of Approach

The project aims to understand the baseline blood lead levels and prevalence of elevated blood lead levels among children under the age of 5 and pregnant women in Bihar. Using a multi-stage random sampling design, we selected a state-representative[1] sample of children (n=697) and their pregnant mothers (n=55) from eight districts in Bihar. We visited homes to obtain consent and tested the blood lead levels of participants using capillary blood and a portable analyzer. We collected information on factors related to lead exposures (e.g., take-home exposure, home environment, use of consumer products, behavior and nutrition) and home demographics through interviews with the primary caregivers. We used statistical models to identify factors that might be associated with elevated BLL among children. The results and recommendations for reducing lead exposure were shared with all participating families. The study received full ethical clearance from a local Indian institutional review board as well as a U.S.-based institutional review board.

## Key Findings

Over 90% of the sampled children in Bihar had elevated BLLs (≥5 µg/dL), exceeding the level requiring intervention as recommended by WHO. One in four children had BLL ≥10 µg/dL, a level linked to clinical symptoms like anemia. We observed that the average level of children in Bihar (geometric mean=7.6 g/dL) is higher than the average level estimated for Indian children in previous studies. In all eight districts that were examined, more than 75% of the children tested had elevated BLLs. High prevalence of elevated BLL was observed in both urban and rural areas, in both boys and girls, and across different age groups. We also observed a high prevalence of elevated BLL among sampled pregnant women. Over 80% of these women had BLLs ≥5 µg/dL and more than 20% had BLLs ≥10 µg/dL.

Multiple factors were linked to lead exposure in children within the sampled households, even after controlling for age, sex, and demographics. These factors include living with a member with a lead-related occupation, living near a lead-related industry, consuming spices of bright colors, and using traditional eyeliners and skin lightening products.

| Children with the following factors are more likely to have BLL ≥5 µg/dL. | Children with the following factors are more likely to have BLL ≥10 µg/dL. |
|---|---|
| • Living near an industry that may involve lead such as mining, manufacturing plants, and smelters<br>• Living in a household where someone uses skin lightening products and eyeliners such as kohl, kajal, and surma<br>• Having pica behavior (frequently consuming soil) | • Living near a lead-related industry such as mining, manufacturing plants and smelters<br>• Living with a family member with an occupation potentially involving lead such as construction, demolition and automobile repair |

1 The state-representative sample only refers to children. This study is not intended to be representative for pregnant women and at district level.

# Introduction

## Lead Poisoning as a Public Health Issue in India

Lead poisoning is a severe public health problem affecting children in India. As per the Toxic Truth Report 2020 of UNICEF and Pure Earth, 275 million children in India (out of 800 million globally) had blood lead levels (BLLs) that were abnormally high, i.e., ≥5 µg/dL.(2) This is the highest number of children with elevated BLL estimated in any nation. Lead exposure causes harm to several organ systems, which in turn affects behavior, lowers performance in school, stunts physical growth, hinders cerebral development, and eventually lowers productivity.(5) Studies have shown that lead exposure is associated with significant deficit in children's IQ.(6) According to modeled data, lead-attributable loss of IQ in children 0-5 years accounts for a loss of 3.3% of India's GDP.(1)

Compared to adults, children are at a greater risk for lead toxicity due to hand-to-mouth behavior, ingestion of non-edible items, and also because the proportion of ingested lead that is absorbed is much greater in children than in adults.(7) Lead competes and interferes with critical micronutrients such as iron, zinc and calcium needed for hemoglobin synthesis, mitochondrial function, nerve cell conduction and muscle activation. In India, as per the recent demographic health survey (Fifth National Family Health Survey 2019–21), the anemia rate among children and adults has worsened, with more than half of women and children being anemic. However, in India, fewer studies have researched how lead exposure may contribute to anemia.

## Why Blood Lead Surveillance Is Needed in Bihar

According to the report from the National Institution for Transforming India (NITI Aayog) and the Council of Scientific and Industrial Research, "Assessment of Lead Impact on Human and India's Response" published in 2022, Bihar had the highest statewide blood lead level (10.42 µg/dL) among all Indian states. However, this estimate was based on modeled data. Earlier studies in Bihar focused on measuring BLL in children living in high-risk communities (e.g., near battery recycling sites and mining). These studies were highly localized with small populations known to be at risk of exposure from a particular source. In contrast, our study is representative of the broader population of children under the age of 5 in Bihar.

# Objectives

Determine the baseline BLLs and the prevalence of elevated lead levels in young children (those under 5 years of age) and pregnant women in Bihar

Evaluate personal, behavioral, home environment and occupational risk factors that are predictive of BLLs

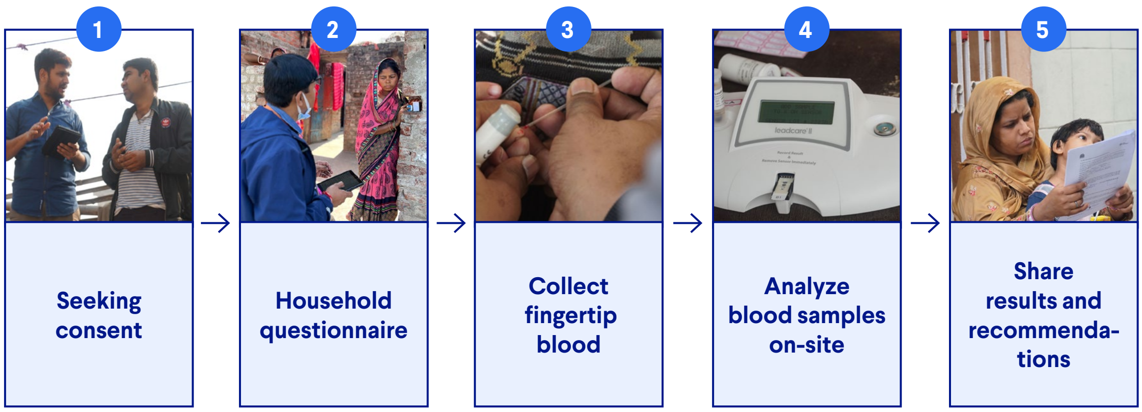
Demonstrate the feasibility and viability of a future blood lead surveillance system

# Overview of Approach

## Study Design and Implementation

Vital Strategies led the design of this surveillance and supported the data collection and analysis in collaboration with the Mahavir Cancer Sansthan and Research Centre. The study was approved by institutional review boards at the Rajendra Memorial Research Institute of Medical Sciences, Indian Council for Medical Research (ICMR), New Delhi in India, and the Biomedical Research Alliance of New York (BRANY) in the U.S. The study also complies with the U.S. federal and Indian regulations and laws concerning research on human subjects. Home visits to assess BLL were carried out from December 2022 to March 2023.

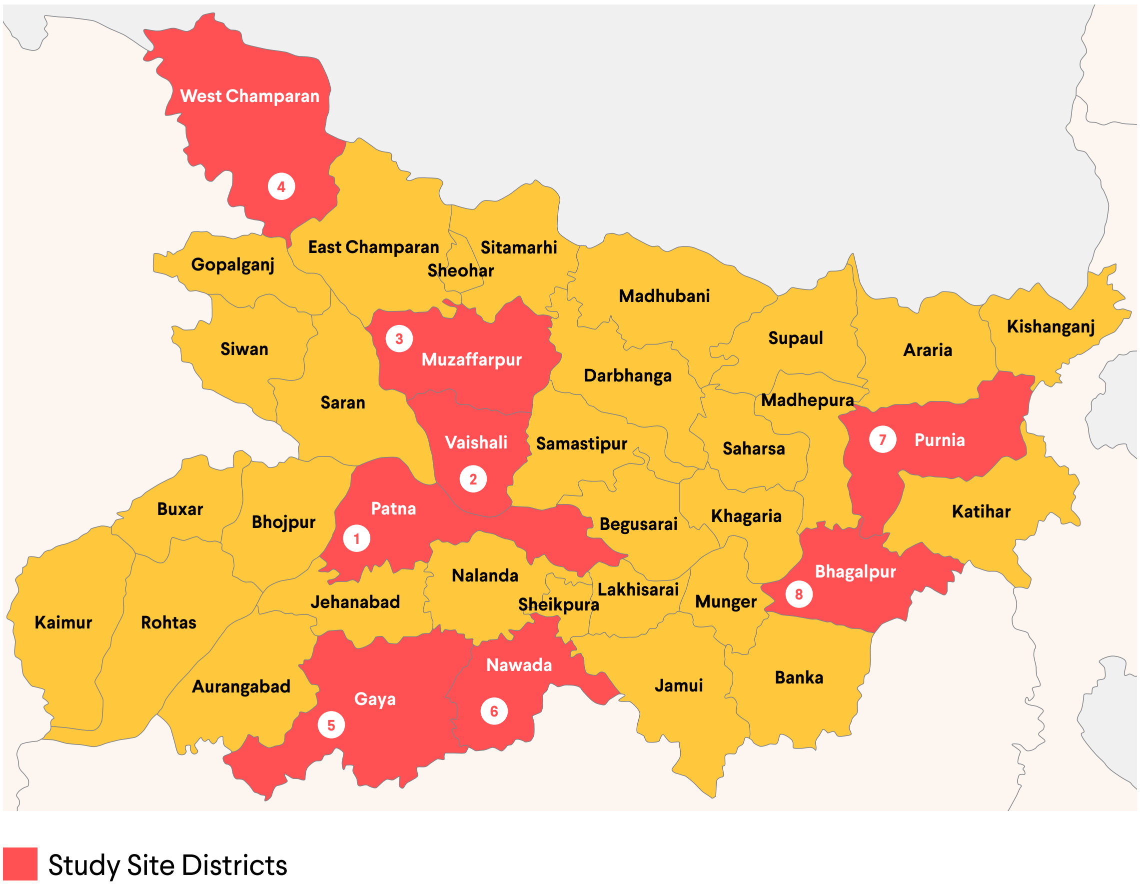
**Figure 1: Overview of study procedure**



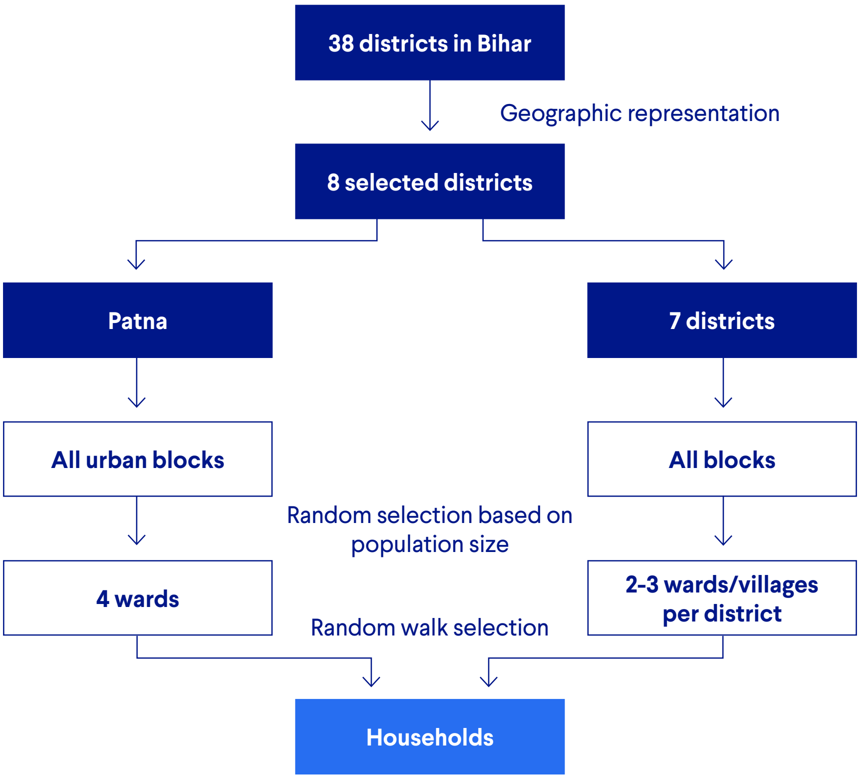

## Recruitment of Participants

We used multi-stage random sampling to draw a state-representative sample of children aged between 13 and 60 months and a convenience sample of pregnant mothers of participating children in eight districts across Bihar, as shown in Figure 1.

### Figure 2: Study Area




### Figure 3: Sampling Procedure



First, we grouped all districts in the state into four regions (north, south, east, and west regions) and selected two districts from each region. Second, villages or wards were randomly selected from the districts based on their population using probability proportional to size. Finally, households were selected using the random walk approach and screened for their eligibility. The sampling procedure for surveillance is shown in Figure 2.

Screening questions were used to ensure consistent current residency, to confirm that the subjects' general health allowed their participation, and determine their willingness to participate in this study. The study team explained the purpose and procedure in the local language (Hindi) and obtained consent from the child's primary caregiver and the pregnant woman.

## Household Questionnaire

The study team conducted an interview with the child's primary caregiver or the pregnant woman in Hindi and recorded responses on a tablet. The interview gathered information on the potential take-home lead exposure (e.g., parental lead-related occupation or hobby), home environment (e.g., source of drinking water, chipping paint), use of consumer products that might contain lead (e.g., spice, cosmetics), behavioral and nutritional factors that might modify the exposure (e.g., pica behavior, nutrition, household, and personal hygiene), and household demographics (e.g., age, sex, primary caregiver's educational attainment).

## Measurement of Blood Lead Levels

Blood lead levels were determined using capillary blood samples analyzed by a portable analyzer. After cleaning the participant's hand and finger, a trained team member drew a few drops of blood by pricking the finger following the WHO guidelines.(8) The capillary blood was then analyzed by LeadCare II analyzer, which was placed in an undisturbed and clean area inside the house. This portable analyzer is certified for clinical use by the United States Food and Drug Administration and measures BLL in three minutes. It is considered a good screening tool and provides comparable results with laboratory methods within its testing range (3.3-65 µg/dL). Test results were shared with the caregivers and pregnant women along with recommendations tailored to BLL levels to reduce lead exposure and needs for clinical visits. Venous blood samples were drawn from a subset of pregnant women in addition to capillary blood samples for quality assurance and validation purposes. Venous blood samples were analyzed in a private laboratory certified by the National Accreditation Board for Testing and Calibration Laboratories (NABL) using inductively coupled plasma mass spectrometry (ICP-MS). An overview of the study procedure is shown in Figure 3.

## Data Analysis and Dissemination

Due to the complex sampling design, sampling weights were calculated and applied when analyzing children's data. We calculated geometric means of BLL which is preferred when analyzing exposures with a skewed distribution. Spearman's correlation coefficients were calculated to assess the correlation between maternal and child BLL. The prevalence of participants with elevated BLLs was also assessed using two different thresholds:

1. BLL ≥5 μg/dL: the threshold that WHO recommends for initiating clinical intervention for children and pregnant women
2. BLL ≥10 μg/dL: the exposure level thought to contribute to anemia.(9)

We used statistical models to assess the associations between each risk factor and the probability of elevated BLL among children. The final model accounted for the influence of demographic factors including children's age and sex, maternal education, urbanicity, and socio-economic status (indicated by a binary poverty indicator, namely the possession of a BPL certification card[2]).

## Limitations

- While the portable analyzer is designed to screen for elevated BLL, it cannot detect extremely low levels (below 3.3 μg/dL). We assigned a value of 2.3 μg/dL for BLLs below the limit of detection, consistent with recommendations from the literature. (10)
- Testing BLLs using capillary blood and the portable analyzer can be more vulnerable to environmental contamination. The performance of the portable analyzer may be affected by temperature and strong airflow. We enforced several quality control procedures to minimize contamination during home visits and validated the measurements obtained by the analyzer using laboratory tests. Results from the portable analyzer and the laboratory were consistent, with the former sometimes reporting slightly higher values than the latter.
- Our findings at the district level and for pregnant women should be seen as indicative rather than definitive since the sample size was too small to estimate statistically significant district-level differences.

2 Below the Poverty Line is a certification issued by the Government of India to individuals or families who fall under the category of poverty.

# Summary of Findings

## Surveillance Sample

Overall, 697 children and 55 pregnant women participated in the study. Table 1 and Table 2 summarize the demographics of participants. The average age of the children in our sample was 38 months with a slightly higher proportion of male children (55%). An estimated 86% of children were from rural households. The majority of primary caregivers in the household (75%) had some school education. More than half of the children (61%) in our sample were from households below the poverty line. The average age of pregnant women in the sample was 25 years, and the average gestational age was 22 weeks. Most of the sampled pregnant women had some school education (87%).

**Table 1: Demographics of sampled children**

| Characteristics | Weighted Percentage, % |
|---|---|
| **Age group** | |
| 12-24 months | 22.3 |
| 25-36 months | 24.0 |
| 37-48 months | 23.8 |
| 49-60 months | 29.9 |
| **Sex** | |
| Female | 44.4 |
| Male | 55.2 |
| Missing | 0.4 |
| **Urbanicity** | |
| Urban | 14.0 |
| Rural | 86.0 |
| **Primary caregiver education level** | |
| Illiterate | 15.9 |
| Some school education (Grade 1-12th) | 75.1 |
| Higher education | 8.8 |
| Missing | 0.1 |

| | |
|---|---|
| **Socio-economic status** | |
| Low (BPL card) | 61.6 |
| Not low (No BPL card) | 38.3 |
| Missing | 0.1 |
| **District** | |
| Patna | 7.6 |
| Nawada | 8.3 |
| Vaishali | 13.0 |
| Bhagalpur | 11.0 |
| Muzaffarpur | 17.9 |
| Purnea | 11.5 |
| West Champaran | 14.7 |
| Gaya | 16.0 |

**Table 2: Demographics of sampled pregnant women**

| Characteristics | N (Percentage, %) |
|---|---|
| **Pregnancy Trimester** | |
| 1st | 14.0 (26) |
| 2nd | 17.0 (31) |
| 3rd | 24.0 (44) |
| **Urbanicity** | |
| Urban | 12.0 (22) |
| Rural | 43.0 (78) |
| **Education** | |
| Illiterate | 5.0 (9) |
| Some education (Grade 1-12) | 46.0 (84) |
| Higher education | 4.0 (7) |
| **Socio-economic status** | |
| Low (possession of BPL card) | 32.0 (58) |
| Not low (No BPL card) | 23.0 (42) |

# Blood Lead Levels Among Children

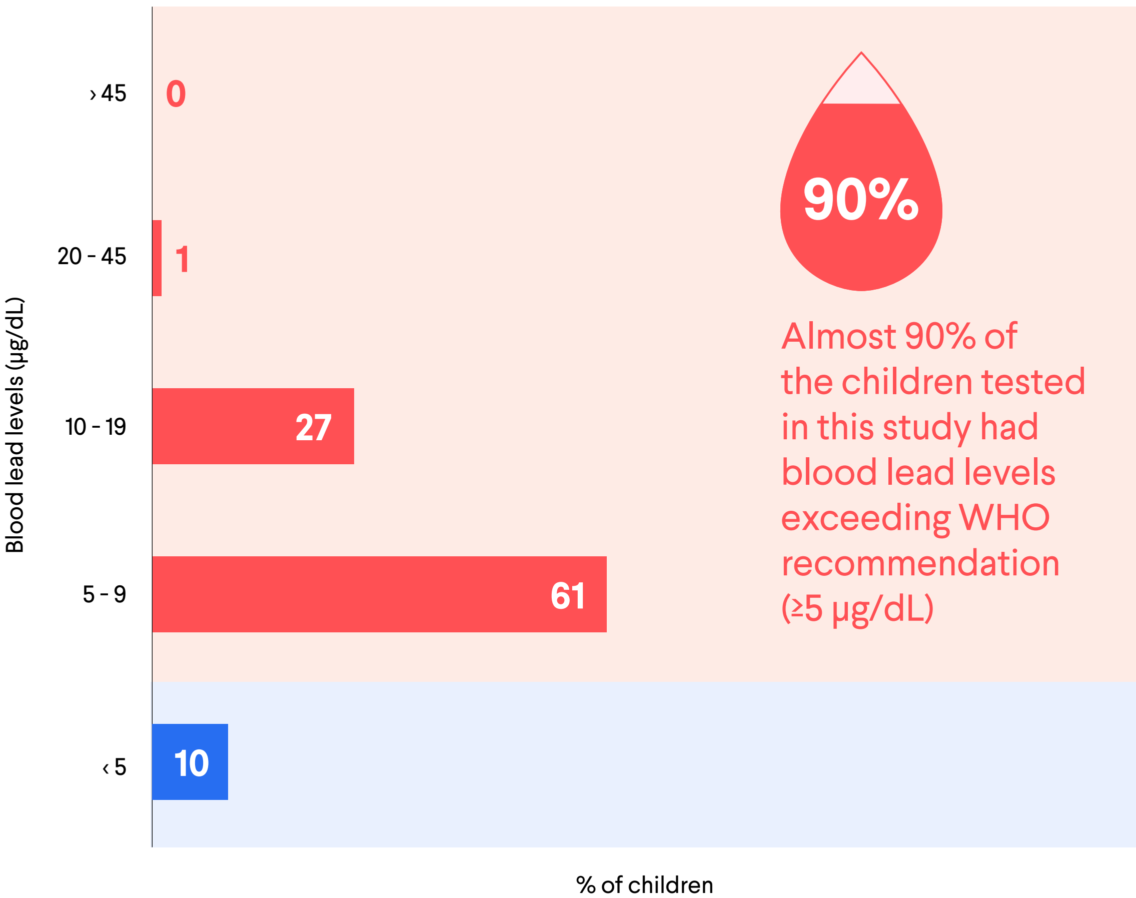
## Overview

Almost 90% of the children tested in this study had blood lead levels exceeding WHO recommendation (≥5 µg/dL). Table 3 summarizes the BLLs among children in Bihar. One in five children tested had BLLs ≥10 µg/dL (Figure 4). In comparison, fewer than 3% of children under 6 in the USA have BLLs exceeding 5 µg/dL and less than 0.4% have levels exceeding 10 µg/dL.

**Table 3: Blood lead levels among sampled children in Bihar (n=697)**

| Geometric mean, µg/dL (95%CI) | Median BLL measured | Minimal BLL measured | Maximum BLL measured |
|---|---|---|---|
| 7.6 (7.3, 8.0) | 7.4 | 2.3 | 40.5 |
| **90th percentile** | **95th percentile** | **Children with BLL ≥ 5 µg/dL, %** | **Children with BLL ≥ 10 µg/dL, %** |
| 11.9 | 14.1 | 89.7 | 20.2 |

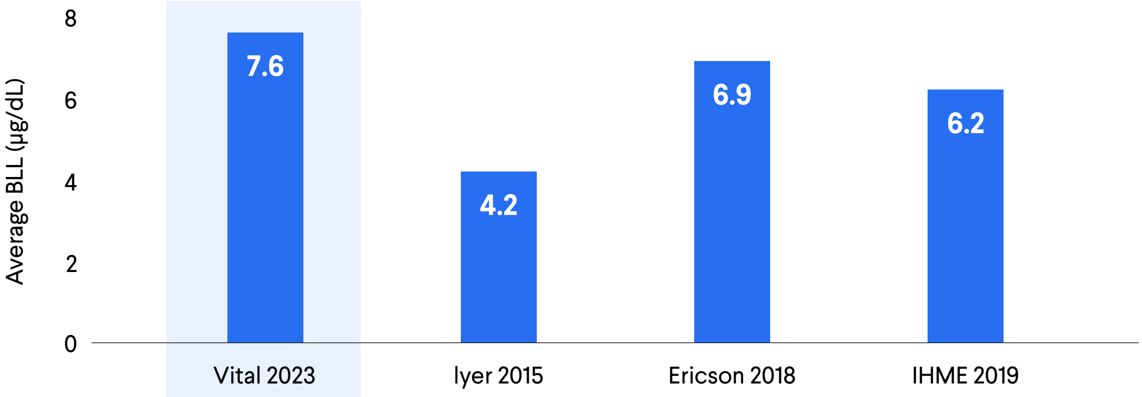
**Figure 4: Distribution of BLL among sampled children in Bihar[3]**




3 Percentages may not total 100 due to rounding

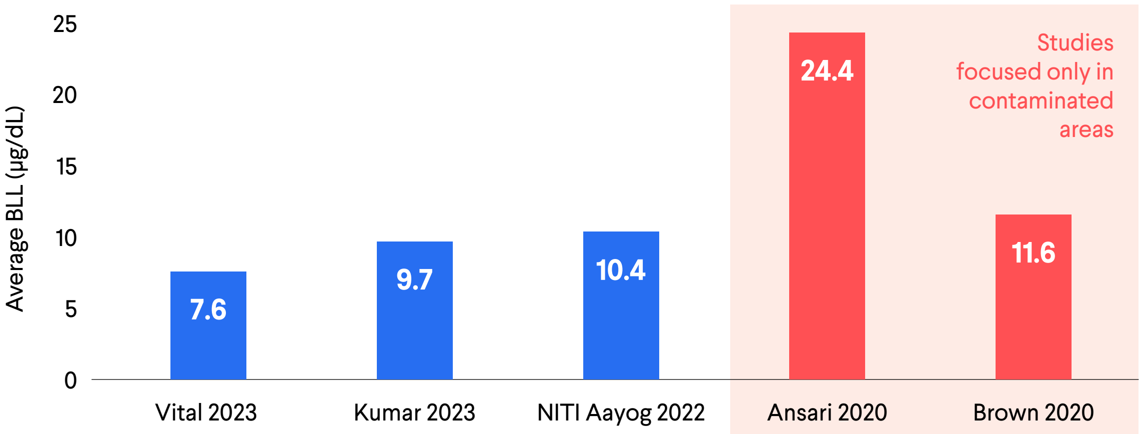
The average BLL of children living in Bihar is higher than the average estimated for children in India in previous studies (Figure 5).(11–13) BLLs of children in Bihar ranged from 2.3 µg/dL to 40.5 µg/dL with a geometric mean of 7.6 µg/dL. As shown in Figure 5, the average BLL observed in our study is higher than the average BLL modeled by IHME in 2019 (6.2 µg/dL) and estimated based on reviewing previous studies conducted in India by Iyer et al (4.2 µg/dL) and Ericson et al (6.9 µg/dL).

**Figure 5: Comparison of average BLL among children with previous studies in India**




The high average BLL we observed is particularly concerning as it is representative of the child population living in Bihar and not just children living in high-risk communities (e.g., communities living near a used lead acid batteries (ULAB) recycling site). Figure 6 presents a comparison of average BLLs with previous studies in Bihar including children. As expected, the average BLL reported in our study was a better representation of the population level and lower than the studies focused on children living in areas in Bihar near known lead pollution activities (e.g., ULAB) reported by Ansari et al (14) and Brown et al (15). The average BLL observed in our study was similar to the average measured in a representative sample of school-age children living in Patna (9.7 µg/dL). (16) It is slightly lower than the BLL estimated for the Bihar population based on the GBD model (10.4 µg/dL), which includes adults, who tend to have higher BLL than children. (2)

**Figure 6: Comparison of average BLLs with previous studies in Bihar including children (shaded bars indicating studies focused only in contaminated areas)**



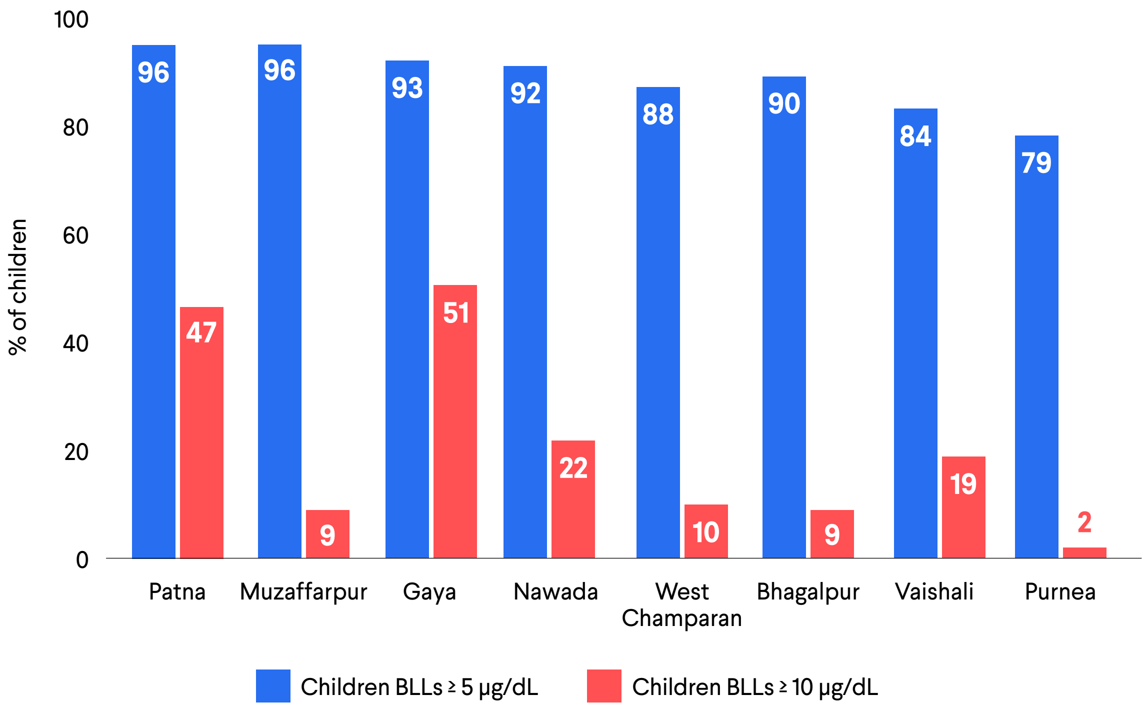
## Blood Lead Levels by District

Elevated BLL was common among children across all eight sampled districts in Bihar with over 75% of children with BLLs ≥ 5 µg/dL (Figure 7). Table 4 summarizes the BLLs among children by districts. The highest average levels were observed in children living in Patna, followed by Gaya and Nawada. In Patna and Gaya, almost 1 in 2 children had levels ≥ 10 µg/dL. We observed a large variation in the percentage of children living near an industrial site across different districts, ranging from 9% to 97%.

**Table 4: Blood lead levels among children by district**

| District | Geometric mean, µg/dL (95% CI) | Children with BLL ≥ 5 µg/dL, % | Children with BLL ≥ 10 µg/dL, % |
|---|---|---|---|
| **Patna** | 9.8 (8.7, 11.0) | 96.2 | 47.3 |
| **Muzaffarpur** | 7.2 (6.9, 7.5) | 95.7 | 8.5 |
| **Gaya** | 9.7 (8.3, 11.2) | 92.9 | 51.2 |
| **Nawada** | 8.0 (6.9, 9.4) | 91.7 | 22.2 |
| **West Champaran** | 6.9 (6.5, 7.4) | 88.1 | 9.9 |
| **Bhagalpur** | 7.4 (6.7, 8.1) | 89.6 | 8.6 |
| **Vaishali** | 7.0 (5.3, 9.2) | 83.6 | 18.8 |
| **Purnea** | 6.4 (5.6, 7.2) | 79.2 | 1.7 |

**Figure 7: Percentage of children with elevated BLL by district**



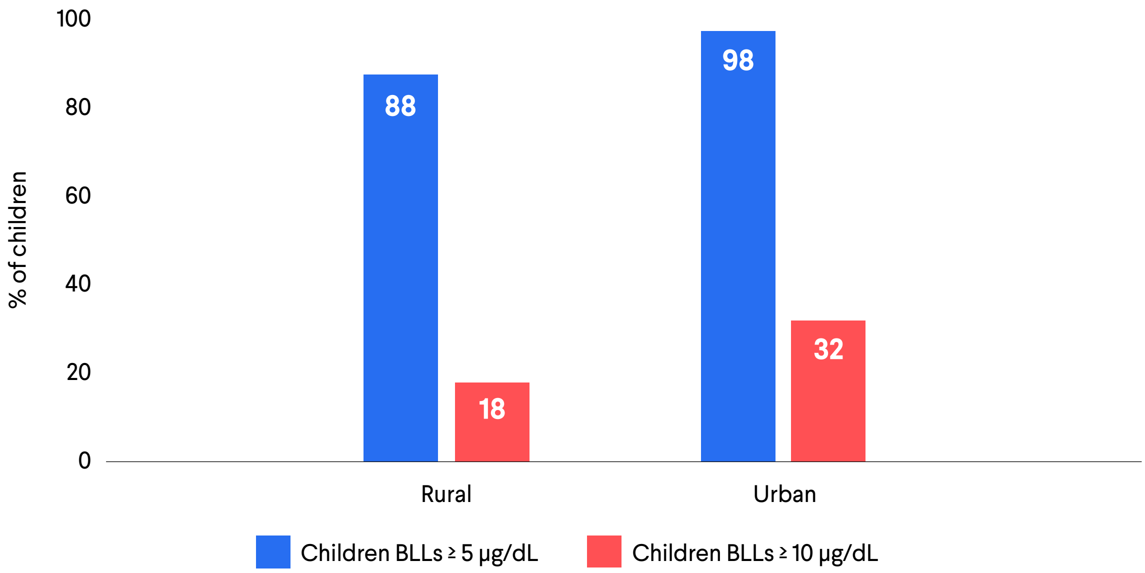
## Blood Lead Levels by Urbanicity

Most children had BLLs exceeding the WHO recommendations, whether they lived in rural or urban areas. Table 5 summarizes levels among children by urbanicity. We observed more children in urban areas with BLL ≥10 μg/dL than those in rural areas. We observed a slightly higher average BLL among children living in urban communities than those living in rural communities as well as more children with elevated levels (Figure 8).

**Table 5: Blood lead levels among children by urbanicity**

| Character | Geometric mean, μg/dL (95% CI) | Children with BLL ≥ 5 μg/dL, % | Children with BLL ≥ 10 μg/dL, % |
|---|---|---|---|
| Rural | 7.5 (7.1, 8.0) | 88.4 | 18.3 |
| Urban | 8.4 (6.8, 10.4) | 97.9 | 32.0 |

**Figure 8: Percentage of children with elevated BLLs by urbanicity**



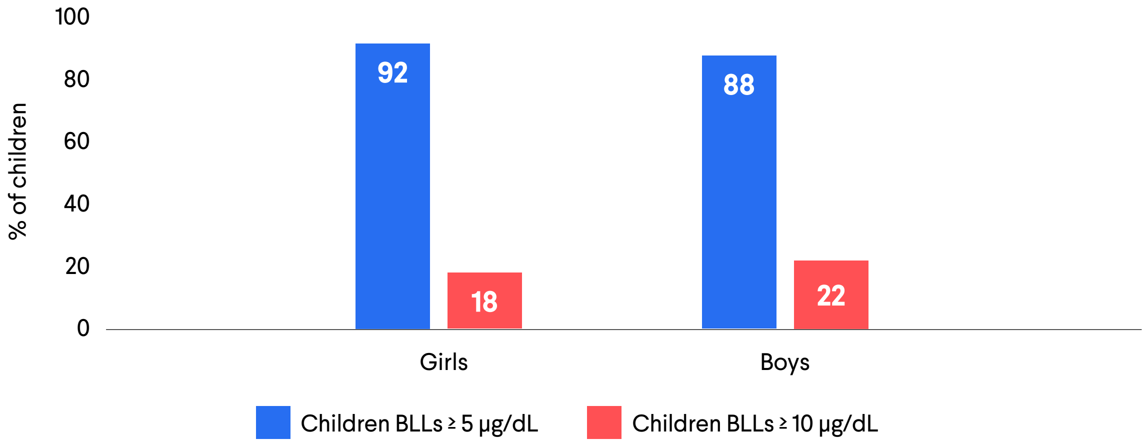

## Blood Lead Levels by Sex

Over 80% of children had BLLs exceeding 5 μg/dL (Table 6). Average BLLs were similar between girls and boys living in Bihar, with more boys reporting BLLs ≥10 μg/dL (Figure 9).

**Table 6: Blood lead level among children by sex**

| Character | Geometric mean, μg/dL (95% CI) | Children with BLL ≥ 5 μg/dL, % | Children with BLL ≥ 10 μg/dL, % |
|---|---|---|---|
| Girls | 7.6 (7.1, 8.0) | 91.5 | 18.2 |
| Boys | 7.7 (7.3, 8.1) | 88.3 | 21.6 |

**Figure 9: Average BLL among children by sex**



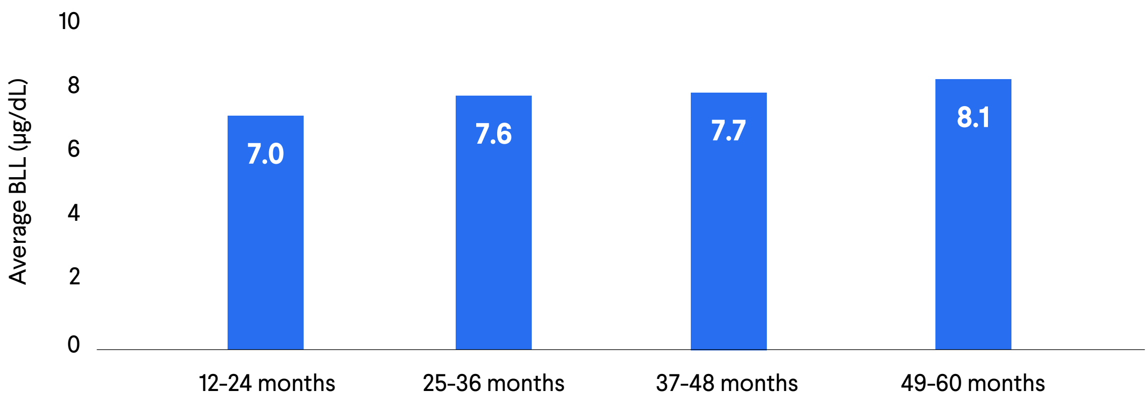

## Blood Lead Levels by Age Group

Elevated BLLs were prevalent across all age groups of young children in Bihar (Table 7). As presented in Figure 10, we observed higher average BLLs among the older age groups. This observation is consistent with what has been observed previously in Indian children and other child populations in Asia.(17,18) This trend is different from what has been observed in the U.S., where BLL tends to peak in children aged 12-24 months and is likely associated with more active hand-to-mouth behavior and ingestion of non-edible items like soil or paint chips. (19)

**Table 7: Blood lead level among children by age group**

| Character | Geometric mean, µg/dL (95% CI) | Children with BLL ≥ 5 µg/dL, % | Children with BLL ≥ 10 µg/dL, % |
|---|---|---|---|
| **12-24 months** | 7.0 (6.6, 7.5) | 85.9 | 9.2 |
| **25-36 months** | 7.6 (6.9, 8.3) | 92.6 | 20.1 |
| **37-48 months** | 7.7 (7.4, 8.0) | 91.4 | 21.0 |
| **49-60 months** | 8.1 (7.3, 9.0) | 88.8 | 27.8 |

**Figure 10: Average BLL among children by age group**



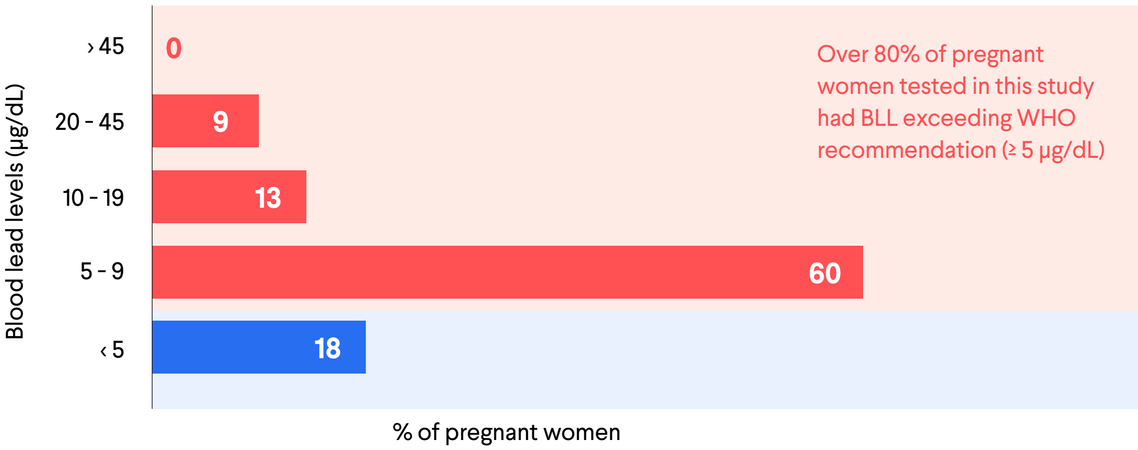
# Blood Lead Levels Among Pregnant Women

Over 80% of pregnant women tested had BLLs exceeding the WHO threshold for clinical response. Table 8 summarizes the levels among pregnant women in Bihar. One in five pregnant women tested had BLLs ≥ 10 µg/dL (Figure 11). We found a moderate correlation between BLLs of pregnant women and their young children (r=0.68).

**Table 8: Blood lead level among pregnant women sampled in Bihar (n=55)**

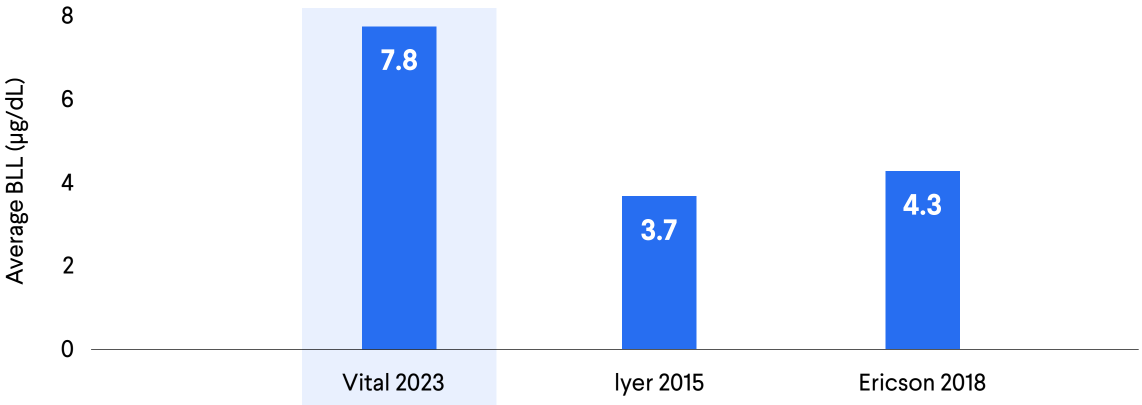
| Geometric mean, µg/dL (95%CI) | Median BLL measured | Minimal BLL measured | Maximum BLL measured | 90th percentile | 95th percentile | Women with BLL ≥ 5 µg/dL, % | Women with BLL ≥ 10 µg/dL, % |
|---|---|---|---|---|---|---|---|
| 7.8 (6.8, 8.9) | 7.1 | 3.4 | 33.1 | 15.4 | 21.3 | 81.8 | 21.8 |

**Figure 11: Distribution of BLL among sampled pregnant women (n=55)**




The average BLL of pregnant women living in Bihar is higher than the average levels observed in Indian women (Figure 12). BLLs of pregnant women in Bihar ranged from 3.4 µg/dL to 33.1 µg/dL with a geometric mean of 7.8 µg/dL. This was higher than the average BLL estimated for women in India reported by Ericson et al (12) (4.3 µg/dL) and Iyer et al (11) (3.7 µg/dL).

**Figure 12: Comparison of average BLL among pregnant women with previous studies in India**



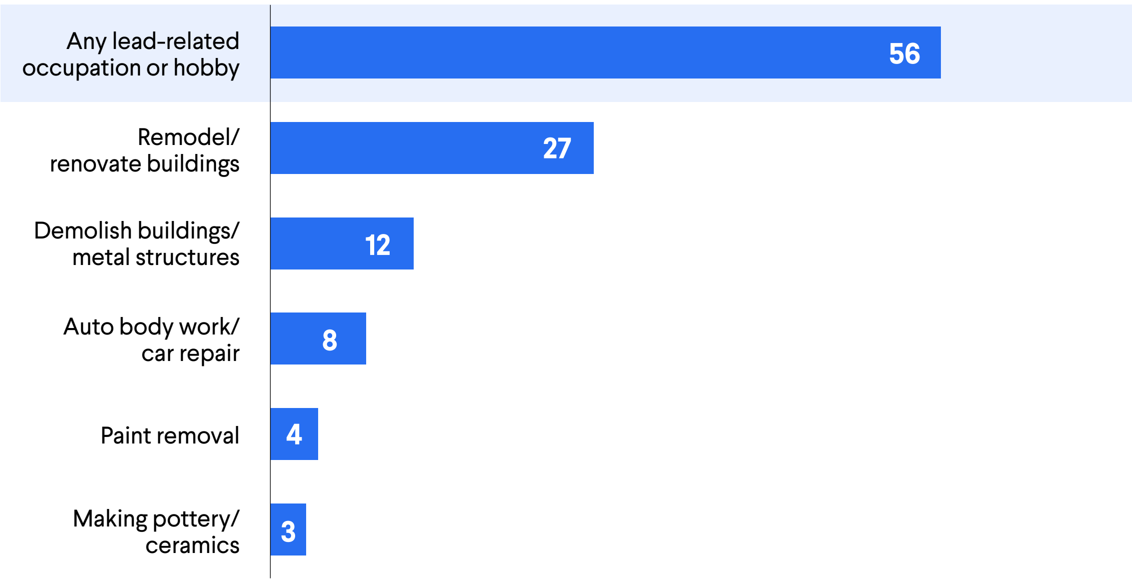
# Risk/Protective Factors for Lead Exposure

## Prevalence of Potential Risk Factors

### Take-Home Exposure

Children can be exposed to lead if their family members carry lead dust home from their workplace or hobby. Adults with an occupation that potentially involves the use of or exposure to lead include construction, manufacturing, smelting and battery recycling. Hobbies may include soldering or applying paints or glazes. Past research has shown this can be an important source of lead exposure for children at home.(20,21) In our study, around 56% of children were living with someone involved in lead-related occupations or hobbies. The most common job or hobby with potential lead exposure reported by participating households is building renovation/repair (27%), followed by building demolition (12%), and car repair (8%). Figure 13 shows the prevalence of any lead-related occupation/hobby with the list of the top five responses from the study.

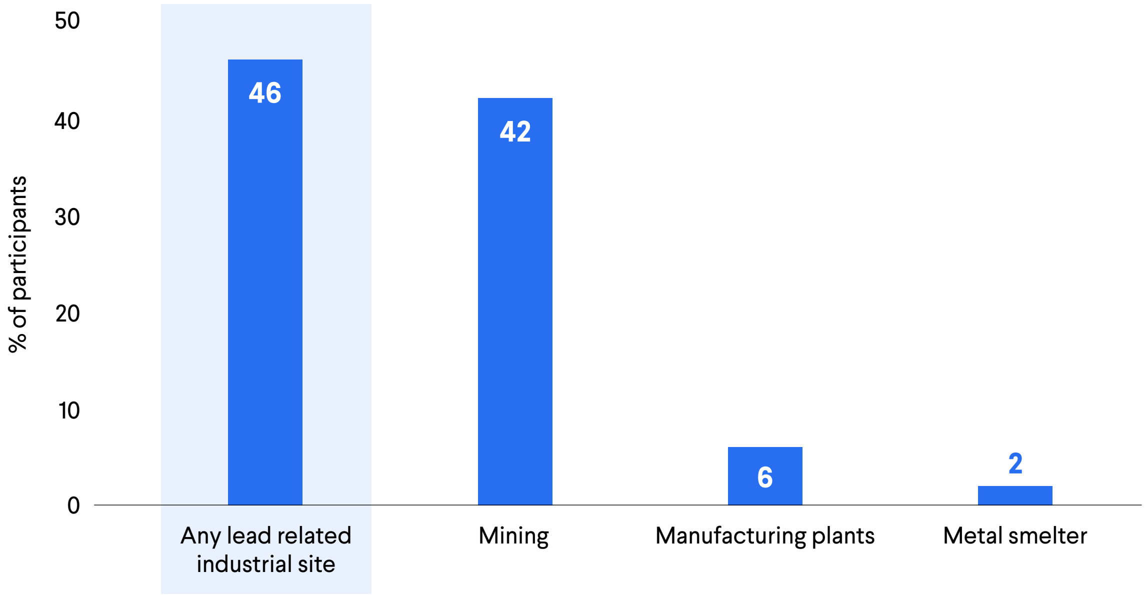
**Figure 13: Prevalence of any lead-related occupation/hobby with the top five responses**




### Home Environment

Industrial activities processing lead may contaminate the soil and result in high concentrations of lead in soil found in communities near industrial sites. Higher BLLs were observed among Indian children living in highly industrialized areas (22,23), ULAB sites (14), and smelters (24), likely due to ingestion of contaminated soil and dust. We found almost half of the children tested (46%) lived in homes located within 1 km of potential lead-related industrial activities. The most common types of potential lead-related industrial site within 1 km of sampled households were mining (42%), followed by manufacturing plants (6%), and smelters (2%) (Figure 14). We found large variations in lead-related industrial activities across different districts.

**Figure 14: Prevalence of lead-related industrial sites**



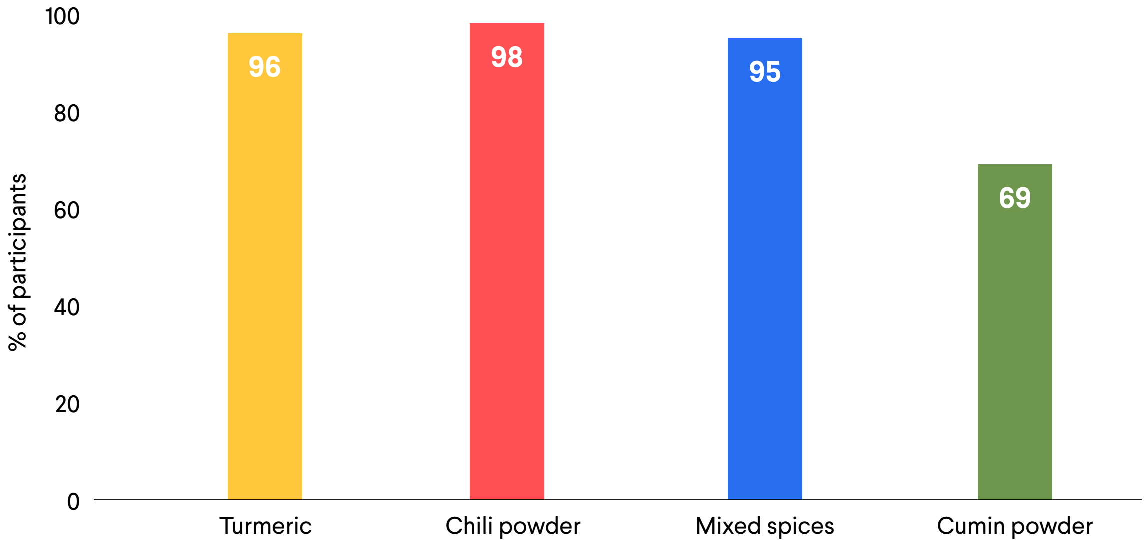

Drinking water can be another potential source of lead exposure, especially if it is contaminated through leaching from pipes or fixtures containing lead in the plumbing system. While India has a strict standard for lead usage as an additive in PVC pipes, the PVC pipes manufactured by the informal sector often use lead-based stabilizers in unregulated quantities that compromise the safety of the pipes.(25) Most children were from households (77%) that reported the hand pump as the source of drinking water and about 28% of households had drinking water supplied by municipal corporations.

Young children exhibit frequent hand-to-mouth activity and may be exposed to lead by ingesting dust or contaminated soil on their hands. Both the type of floor and cleaning practices may affect a child's exposure to lead-contaminated dust or soil at the home. Regularly wet mopping hard floors can reduce lead contamination while dry sweeping should be avoided as it can stir lead dust up into the air. (26) We observed unfinished flooring in most homes (i.e., 60% of the sampled households have a dirt/earthen floor) and only 33% of these households used wet methods for cleaning their floors.

## Consumer Products

Lead has been found in consumer products worldwide, including in metal cookware, spices, toys, cosmetics and traditional medicines. A recent study that screened lead in consumer products purchased in Indian markets found lead levels exceeding recommended standards in ceramic and metal cookware, toys, cosmetics and spices. (27) In our study, most participating households use metal cookware (96%) while the use of ceramic or plastic cookware was rare. Spice powders with bright yellow or red color such as turmeric and red chili are commonly used in the participating households and are more likely of concern for lead adulteration. When asked where they purchased their spices, most households purchase loose spices from a local shop (87%) rather than packaged spices sold by local (3%) or national brands (1%). Figure 15 presents the spices commonly used in the sampled households.

**Figure 15: Spice use in participating households**




High concentrations of lead have been detected in some eye cosmetics produced in South Asia, the Middle East and Africa.(27–30) While mercury poisoning is a more common concern related to skin-lightening products, studies in India have also detected considerable levels of lead in these products. (31,32) Use of eye cosmetics such as kajal, kohl and surma was very common (87%) in the sampled households as well as the use of skin lightening cream (35%) for children. The use of traditional medicine in the household or for the child was rare (4%).

## Pica Behavior

Pica is craving and eating non-edible items, commonly observed among children and pregnant women. Children who exhibit pica behavior may eat soil or paint chips, or chew on painted material, and they are particularly at risk of lead exposure. (33,34) Pica behavior was found prevalent among participating children and non-edible items commonly consumed/chewed include paint chips (31%), soil (16%) and toys (11%).

## Nutrition

Diets rich in iron, calcium and vitamin C can reduce the absorption of lead in children. (35) Overall, we observed very low regular use of iron (2%), calcium (1%) and multivitamin (7%) supplements in our participants. A child may be exposed through lead passed into the mother's breast milk when the mother has very high blood lead levels. However, this exposure is generally not significant compared to environmental sources, and breastfeeding is recommended for its overall benefits unless specially advised. (36) Around 28% of children were breastfed in our sample.

## Identified Risk Factors

We used statistical modeling to identify risk factors that may be related to elevated blood lead levels. We observed that children living in households near an industrial site, using skin lightening cream or eye cosmetics, and with frequent soil-eating behaviors are more likely to have BLLs exceeding 5 μg/dL. Meanwhile, living with a family member with a lead-related occupation and near a lead-related industrial site are risk factors for having a BLL exceeding 10 μg/dL. These risk factors are still significant after considering the age and sex of the child, and household socio-demographic factors.

**Children with the following factors are more likely to have BLL above 5 μg/dL in Bihar**

**Live near lead-related industry**

**5 times** more likely

**Lightening cream**

**5 times** more likely

**Eating soil**

**5 times** more likely

**Eye cosmetics**

**3 times** more likely

**Children with the following factors are more likely to have BLL above 10 μg/dL in Bihar**

**Live near lead-related industry**

**3 times** more likely

**Family member with lead-related occupation**

**2 times** more likely

In Table 9, we also summarized the average BLLs and prevalence of elevated levels among children with and without the identified risk factors.

**Table 9: Distribution of BLL and prevalence of elevated BLL by the status of identified risk factors**

| Risk factors | | Geometric mean, µg/dL (95% CI) | Children with BLL ≥ 5 µg/dL, % | Children with BLL ≥ 10 µg/dL, % |
|---|---|---|---|---|
| Living Near Lead-Related Industry | Yes | 8.4 (7.8, 9.1) | 94.8 | 26.8 |
| | No | 7.0 (6.7, 7.3) | 85.4 | 14.6 |
| Lead-Related Occupation or Hobby | Yes | 7.7 (7.2, 8.2) | 88.7 | 22.7 |
| | No | 7.5 (7.1, 8.0) | 91.0 | 17.0 |
| Pica Behavior (Eating Soil) | Yes | 9.0 (8.2, 10.0) | 97.1 | 31.3 |
| | No | 7.4 (6.9, 7.9) | 88.2 | 18.0 |
| Use of eye cosmetics for the child or in the household | Yes | 7.7 (7.3, 8.0) | 91.0 | 19.1 |
| | No | 7.3 (5.9, 9.0) | 81.3 | 27.1 |
| Use of lightening cream for the child | Yes | 7.7 (7.3, 8.1) | 89.9 | 20.3 |
| | No | 7.4 (6.3, 8.7) | 88.7 | 19.6 |

# Communication with Stakeholders

The results from lead poisoning surveillance in Bihar were disseminated through a series of targeted events and dialogues with key stakeholders. We employed a multi-faceted approach, including presentations at roundtable discussions and meetings with think tanks, community representatives, and health care professionals. A roundtable chaired by the minister of industries was organized in Patna, Bihar. Government officials from various departments and civil society representatives participated in this roundtable. The findings were also shared with the members and thought leaders at NITI Aayog in New Delhi. These engagements facilitated the sharing of our findings and encouraged meaningful exchanges of insights, concerns and potential interventions to control and remove lead contamination to safeguard children. Furthermore, these findings will be published as reports and academic papers online to ensure broad accessibility and comprehension of the research outcomes.

We have kept the state health department informed throughout the surveillance design and dissemination process. Findings from this project have helped foster awareness of this public health issue through local data and collaboration to strengthen health systems' capacity to continue monitoring lead exposure. These findings may inform local actions toward regulating and mitigating identified sources of lead exposure associated with childhood lead poisoning in Bihar.

> "We will focus on establishing recycling units for the methodical disposal of the used lead acid batteries in Bihar."
>
> **Minister of Industries, Bihar**

> "Given the high prevalence of BLL ≥5 µg/dL, the government should integrate BLL surveillance of children into routine pediatric care and implement efforts to increase awareness and monitoring of lead content in consumer products, food, and spices."
>
> **Head of the Research Department,**
> **Mahavir Cancer Sansthan and Research Centre**

Source: https://timesofindia.indiatimes.com/city/patna/bihar-on-top-with-alarming-lead-level-in-childrens-blood-report/articleshow/102295672.cms

# Policy Recommendations

## Enable regular screening and monitoring of risk factors for elevated blood lead levels among young children

The high prevalence of elevated blood lead observed among children across different regions and demographic groups stressed the urgent need for screening and monitoring lead exposure among children in Bihar. This pilot project demonstrated the feasibility of actively monitoring blood lead levels and the presence of risk factors among young children using a state representative sample. The state health depart is best positioned to consider establishing a similar statewide lead exposure surveillance system by instructing pediatricians to add lead exposure risk assessment into routine care for children or integrating lead exposure assessment into recurring statewide health surveys or programs that evaluate children's health or nutrition.

## Strengthen laboratory capacity and accessibility to blood lead tests at public health facilities

The number of laboratories that can perform blood lead testing in Bihar are still limited. It is important to improve the capacity for blood lead tests, especially at public health laboratories and hospitals that specialize in care for heavy metal poisoning. Subsidizing the testing cost through health insurance plans is also important as lead poisoning disproportionately affects poorer families. Using screening questions to identify high-risk children with lead exposure history can also help allocate limited testing capacity.

## Raise public awareness of the toxic effects and sources of lead

It is important to raise awareness of lead and its health impacts among health professionals and parents. Health education and communication programs related to lead exposure and health effects should be organized for the community in plain language to have tangible impacts.

## Strengthen health workers' capacity to improve clinical management of lead poisoning

Familiarize healthcare providers (ASHAs, community health officers, medical officers) by adopting or adapting existing WHO clinical guidelines to facilitate early detection, intervention and treatment.

## Identify and regulate sources of lead exposure affecting children

We recommend that the government continue to monitor lead in consumer products such as paint, spices and cosmetics. Strengthening the enforcement of existing and legally binding standards for lead in these products can be effective in preventing the market circulation of lead-contaminated products and materials.

## Monitor and regulate lead pollution from industrial processes

Existing standards should be enforced in industrial and other workplace settings. Monitoring lead in soil can also be important to protect children living in communities near these industrial sites from lead exposure.

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