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Potential sources of lead in children's environments, Thimphu, Bhutan

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ABSTRACT

Introduction: There is no level of lead in one's blood that is known to be safe. Infants and children are exposed to lead through various sources in the environment. Lead-based paint, toys, play equipment, dust, and soil may all be potential sources of lead. Preventing lead exposure is essential to eliminate the permanent and life-long disability caused from lead poisoning. Previous work showed that 44% of children aged 2 - 60 months in a Bhutanese population have dangerously high (≥ 5µg/dL) levels of lead. The sources of this lead toxicity, however, are unknown. This study was carried out to identify potential sources of lead in infants' and children's environments at health facilities, early childhood care and development and creche centers, public playgrounds, and schools in Thimphu Dzongkhag. **Methods:** An environmental survey using a portable X-ray Fluorescence (pXRF) was conducted from May 2021 to April 2022 to identify potential sources of lead in the environment in and around Thimphu, Bhutan. **Results:** A total of 777 tests were done to identify excessive amounts of lead from various items, including: toys, playground equipment, furniture, paints, and soil. A total of 16 tests had excessive amounts of lead, of which 15 were detected from playground equipment at public playgrounds. The most common color with excessive lead was yellow. **Conclusions:** Excessive amounts of lead were found in playground equipment as a possible source of lead exposure in children.

Keywords: Bhutan; Environment; Fluorescence; Lead.

INTRODUCTION

In the first pediatric blood lead study in Thimphu and Phuentsholing, 44% of infants and children tested had blood lead levels (BLLs) ≥5 µcg/dL and 80% had BLLs ≥3.3 µcg/dL[1]. There is no known safe level of lead, and there is no treatment to remove all lead from one's body. Preventing the exposure to lead is critical.

Lead is a naturally occurring metal which has been used for centuries and is still used today. Lead can be found in a host of products globally, including some paints, batteries, petroleum products, toys, pipes, ceramics, spices, cosmetics, and traditional medicines. However, sources of lead are geographically unique, varying with historical or ongoing use of products containing lead. For example, the use of lead is associated with certain industries, cultural practices, and artisan work. For this reason, when lead poisoning is present, local environmental data is necessary to determine the sources of lead in a community or region.

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Lead is highly poisonous and is a potent neurotoxin. Studies have shown that children who even have blood lead levels below 5 µcg/dL can have neurological impairment, revealed in learning problems, poor school performance, and behavioral changes[2,3]. A 2017 Lancet article found that children with BLLs ≥5 µcg/dL had lower IQ scores and a lower socioeconomic status three decades later as adults[3]. In 2020, UNICEF published a comprehensive report on lead poisoning in developing countries among children, which highlights how extensive the problem is[4].

Multiple medical problems in adults and economic problems are also associated with lead exposure. Lead has been associated with cardiovascular, immunological, renal, reproductive, and endocrine problems[5-8]. A 2018 article in Lancet Public Health concluded that low-level environmental lead exposure is an overlooked risk factor for cardiovascular disease and death. It stated that lead prevention programs were necessary to further lower cardiovascular disease rates in developed countries[9]. The damage lead causes is irreversible and long-lasting.

Infants and children often put their fingers, toys or other objects in their mouths. When lead is present in the environment, this behavior results in direct ingestion of lead. Eating with hands contaminated by lead can also result in ingestion of lead. If lead is present in dust, it can also be inhaled.

Prevention is critical to reducing and eliminating lead poisoning. For this reason, when lead poisoning is present, local environmental data is necessary to determine the potential sources of lead in a community. In other countries, lead poisoning has been traced to excessive amount of lead in paints, toys, spices, and other items. However, the lack of local data on the potential sources of lead in Bhutan makes prevention nearly impossible.

As infants and children absorb the most lead and have the longest duration of disability, local data is needed to design and implement effective prevention strategies. The objective of this study was to search for potential sources of lead in the environments of children in and around Thimphu.

METHODS

Design

An environmental surveillance study using a portable X-ray Fluorescence (pXRF) analyzer was conducted to search for potential sources of lead in the environments of children. Environmental studies from other countries searching for the sources of lead in children's environments were reviewed to find items to test in this study. Paint on walls, furniture and other painted items, toys, playground equipment, and soil were analyzed in this study.

Study setting/sites

Bhutan is a developing landlocked country nestled in the Himalayan mountains between India and China. The projected 2022 population of Bhutan was approximately 763,000 and Thimphu Dzongkhag is 158,000. Due to Covid-19 travel restrictions, convenient sampling was used to select 28 testing sites in and outside of Thimphu thromde (city limits) where children typically visit. Hospitals, primary health centers, early childhood care and development (ECCD) & daycare centers, crèche facilities, schools, and public parks were selected for inclusion in the study.

Data collection

Prior to data collection, all researchers using the portable XRF were given radiation safety and XRF testing training. Researchers were divided into two teams for testing at different sites. At each site, XRF analysis was done on painted walls, furniture, painted items accessible to children, and to soil. At sites where toys and playground equipment were present, XRF testing was also done on those items.

The XRF results were recorded on a data collection form to document the location of paint or item tested, color of paint, and a description of any test that had elevated levels of lead. Testing was conducted between May 2021 and April 2022.

All testing was conducted using the same Olympus Vanta C-series portable XRF with an Ag X-ray tube with lead paint, RoHS (Restriction of Hazardous Substances), and soil methods. The cut off values used to define excessive amounts of lead in tested items were lead levels greater than: 1 mg/cm2 for lead paint using the lead paint method, 1,300 ppm (parts per million) using the RoHS method, and 400 ppm for soil samples using the soil method.

Data analysis

Test results from each site were manually tabulated and entered into Microsoft Excel. Total counts and percentages of positive results by site and type of item tested were calculated. All tests identifying lead were analyzed to determine any patterns in items which contained lead.

Ethical considerations

The research proposal was submitted to Bhutan's Research Ethics Board of Health, and an exemption (REBH/PO/2021/055) was granted. Before testing, approval was also requested from necessary authorities after providing information about the study and addressing all questions. Care was taken to conduct tests at a safe distance from children and bystanders to prevent any radiation exposure.

RESULTS

A total of 777 XRF analyses were conducted at 28 sites. A distribution of the categories of testing sites, the distribution of sites inside and outside the thromde, and the total number of analyses conducted by category is listed in Table 1. The number of XRF analyses at each testing site ranged from 8–130, depending on the size of the site.

Of the 777 XRF analyses, 2.1% of the analyses found excessive amounts of lead. The distribution of items analyzed

Table 1. Categories of testing sites within and outside Thimphu Thromde, numbers of tests, and tests done in 2021 to 2022

Category of testing site	Testing sites *n*	Sites inside thromde *n*	Sites outside thromde *n*	Tests done *n*
Primary Health Centers	8	3	5	139
Schools	5	1	4	189
Playground/parks	4	4	0	105
Creche facilities	4	4	0	81
ECCD/Daycare*	4	2	2	85
Hospitals	3	2	1	178
Total	28	16	12	777

Note: Testing of playground equipment at ECCD/Daycare centers are included in the ECCD/Daycare category and hospitals are included in the playground/park category.

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as well as the number of analyses which were found to have excessive amounts of lead, above the cut-off value, are shown in Table 2. Paint on walls and other painted items constituted half of the analyses. Of the 16 items found to contain an excessive amount of lead, 15 were from paint or plastic items on playground equipment. Of the testing done at playgrounds, 14.4% of the analyses identified high levels of lead. The only other item with an excessive amount of lead was from a plastic dustpan.

Table 2. Number and percentage of tests and excessive lead found in different items tested by X-Ray Fluorescence, 2021 to 2022

		Excessive lead
Item type	***n**** **(%)**†**	***n**** **(%)**†**
Paint on walls	216 (27.8)	0 (0)
Paint on other items‡	161 (20.7)	1 (0.6)
Toys	130 (16.7)	0 (0)
Furniture	114 (14.7)	0 (0)
Playground equipment	104 (13.4)	15 (14.4)
Soil	52 (6.7)	0 (0)
N§ (%)	777 (100)	16 (2.1)

**number of respective item type;*

†percentage;

‡Included paint on doors, windows, window & door frames, hand railings, and other painted items which were not furniture or walls.

§total number;

Table 3. Excessive lead level measured by colored item of playgrounds in Thimphu, Bhutan, 2021 to 2022

Playground location	Material	Paint color	Value (mg/ cm2)
Centenary	Painted metal pole	Not listed	1.731
Motithang	Painted cement bridge	Green	1.402
		Blue	1.255
JDWNRH*	Painted metal poles for different equipment	Yellow	1.243
		Yellow	1.105
		Yellow	1.123
		Yellow	1.769
Olakha	Plastic of enclosed slide	Red	5.000
		Yellow	3.056
		Green	1.460
	Canopy wall	Yellow	4.800
		Orange	3.055
	Canopy roof	Yellow	5.000
	Round base	Orange	4.450
	Painted metal base	Yellow	1.327

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All four of the playground sites tested had playground equipment that tested positive for excessive amounts of lead. A description of the playground equipment testing positive for elevated lead is shown in Table 3. A majority (8/15) of the playground items with excessive levels of lead in the paint were from yellow colored paint, followed by green (3/15) and orange (2/15).

DISCUSSION

The findings from this initial XRF study searching for potential sources of lead in the environments of children in and around Thimphu were encouraging and concerning at the same time. This XRF study was a necessary first step in finding the sources of lead exposure in the environments of children in and around Thimphu. As all but one of this study's excessive lead levels were found in playground equipment in public locations, one potential source of lead has been identified, however more sources are likely still present and not yet identified.

Overall, 2.1% of the XRF analyses conducted in this study were found to have excessive amounts of lead. Although testing was conducted at a variety of sites, all of the sites were limited to the locations in and around Thimphu due to covid-19 travel restrictions during the duration of data collection.

A study in Jakarta, Indonesia found 2.7% of all XRF analyses in 122 preschools and homes had excessive amounts of lead. Although this number is similar to our finding, testing was carried out in 13 different neighborhoods of varying age and socioeconomic levels, increasing the variety of sampling settings. Because of this diversity in the study design, testing done in 4 of 13 neighborhoods had no excessive lead paint, while other neighborhoods had as many as 2/3 of the sites with excessive lead in the paint[10]. As more sites in Bhutan are tested, the likelihood of finding excessive amounts of lead in paint will increase.

It was surprising no excessive lead in wall paints were found at any site in this study. Wall paint, especially paints which are older, have a higher chance of containing lead. Dust from lead paint is an important source of lead contamination wherever lead paint has been used. Although lead in paint is currently regulated in India, a 2015 National Report on lead in enamel household paint in India found 46% of tested paint had excessive amount of lead[11]. In a Jakarta, Indonesia study, 26.3% of preschools had at least one painted wall with excessive amounts of lead[10]. As Bhutan imports most of its paint from India and other neighboring countries, it is likely that lead-containing paint will still be found as additional XRF studies are conducted.

The most concerning finding in this study is that all the playground sites and 14.4% of all the tests conducted on the playground equipment had excessive amounts of lead in the paint. Lead-based paints on playground equipment and other wooden structures in parks have been found in different countries around the world. A study from England of playground equipment found 42% of paint samples had excessive amounts of lead[12]. A study

from Israel found 90% of paint tested on playground equipment and benches to have excessive amounts of lead[13].

The colors most often found on the playground equipment to have high amounts of lead were yellow, green and orange. Other studies have also found the colors yellow, orange, and green to have the highest levels of lead in paints tested[12,14,15].

LIMITATIONS

Being the first known XRF study in Bhutan, the items chosen to analyze were determined from international studies. This approach potentially missed some sources of lead which are unique to Bhutan. Also, as Covid-19 restrictions limited travel, the finding from this study are not representative for Bhutan.

RECOMMENDATIONS

As lead research in Bhutan is in its infancy, larger combined blood lead level and XRF studies are necessary to further understand the prevalence of lead poisoning in children and to identify sources of lead in those children's environments. Additional XRF studies of playgrounds and other areas infants and children visit are also necessary. Once additional data is available, environmental, and governmental policies will need to be developed or strengthened as well as public health initiatives started to reduce lead exposure.

CONCLUSIONS

Although this study was the first of its kind and limited in scope, one potentially important source of lead in children's environment has been identified. As the extent of lead poisoning previously identified in infants and children was extensive, additional XRF studies will be required to identify other potential sources of lead in Bhutan.

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AUTHORS CONTRIBUTION

Following authors have made substantial contributions to the manuscript as under:

DP: Concept, design, data collection and analysis, manuscript writing and review.

UW: Design, data collection and analysis, manuscript writing and review

NG: Design, data collection and analysis, manuscript writing and review

KW: Design, data collection and analysis, manuscript writing and review

CW: Design, data collection, manuscript review

PE: Concept, design, data collection and analysis, manuscript writing and review

Author agree to be accountable for all respects of the work in ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

None

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