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Contaminated Turmeric Is a Potential Source of Lead Exposure for Children in Rural Bangladesh

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Background. During the conduct of a cohort study intended to study the associations between mixed metal exposures and child health outcomes, we found that 78% of 309 children aged 20–40 months evaluated in the Munshiganj District of Bangladesh had blood lead concentrations \( \geq 5 \) \( \mu \)g/dL and 27% had concentrations \( \geq 10 \) \( \mu \)g/dL. Hypothesis. Environmental sources such as spices (e.g., turmeric, which has already faced recalls in Bangladesh due to high lead levels) may be a potential route of lead exposure. Methods. We conducted visits to the homes of 28 children randomly selected from among high and low blood lead concentration groups. During the visits, we administered a structured questionnaire and obtained soil, dust, rice, and spice samples. We obtained water samples from community water sources, as well as environmental samples from neighborhood businesses. Results. Lead concentrations in many turmeric samples were elevated, with lead concentrations as high as 483 ppm. Analyses showed high bioaccessibility of lead. Conclusions. Contamination of turmeric powder is a potentially important source of lead exposure in this population.

1. Introduction

Lead poisoning remains a major public health problem, particularly for young children in developing countries. Several epidemiological investigations have shown a high prevalence of elevated blood lead concentrations among Bangladeshi children living in large urban and industrial centers [1–3]. Children in rural Bangladeshi communities may also be at risk of exposure to lead through the continued use of leaded gasoline in rural areas [2], poorly developed waste management systems, and cottage industries that are increasingly found in rural settings. The harmful effects of lead are exacerbated by poor nutrition and micronutrient deficiencies, also highly prevalent in rural Bangladesh. The purpose of this study was to evaluate potential sources of lead exposure among children in a rural community in Bangladesh who had been identified in an ongoing cohort study as having high blood lead concentrations.

2. Methods

2.1. Subject Selection. This research was conducted in Sirajdikhan, located in the Munshiganj District in Bangladesh, a primarily rural and agricultural area largely devoted to the cultivation of rice and potatoes. Sirajdikhan is located 29.3 km southwest of Dhaka city, with a total population
of 1.4 million and population density of 1,439 persons per
km [2]. The literacy rate is 56.4% among males and 55.7% among females. Approximately 12% of the district is con-
sidered urbanized (having an area around a central place
with improved communication, electricity, water supply,
sanitation, and nonagricultural occupations) [4]. Emerging
local industries include brick kilns, textile weaving/dyeing,
and carpentry/woodworking.

Participants were children who are currently enrolled in
an ongoing population-based prospective birth cohort study
designed to investigate the association between prenatal
arsenic exposure and neurodevelopment in children. Partici-
pants were recruited from areas in which Dhaka Community
Hospital (DCH) operates rural health clinics. After high
blood lead concentrations were identified during an ongoing
study, we selected 30 participants for environmental expo-
sure assessment. Participants were grouped into quartiles
according to blood lead concentrations, and 15 subjects
from both the highest and lowest quartiles were selected
for participation through random digit assignment. Twenty-
eight families agreed to participate in exposure assessment
activities.

Details of the recruitment strategy, eligibility criteria, and
sample collection from pregnant women and newborns have
been published previously [5, 6]. All children in the birth
cohort study were eligible for followup studies, and DCH-
trained health care workers invited their families to partic-
ipate. Informed consent was provided by the parents of all
participants before enrollment. Boston Children's Hospital's
Committee for Clinical Investigation ceded review of this
study to the Harvard School of Public Health (HSPH). This
study was approved by the Human Research Committees at
HSPH and DCH.

2.2. Blood Lead Measurements. Lead concentrations were
measured in blood samples collected from fingerstick blood
collected at 20 to 40 months of age, with a subset confirmed
with samples obtained via venipuncture. Fingerstick blood
lead concentrations were measured using portable LeadCare
II instruments (Magellan Diagnostics, Billerica, MA, USA)
that have a reportable range of 3.3–65 μg/dL. Before testing,
study staff washed the children’s hands to avoid lead con-
tamination from the skin. Each child’s finger was pricked
with a single-use lancet, and a 50 μL capillary tube was filled
after discarding the first droplet. Test results were available
within 10 minutes. Daily quality-assurance measures were
performed according to the user’s manual.

Blood samples obtained via venipuncture were collected
in trace metal-free tubes for measurement of arsenic, man-
ganese, and lead concentrations, the aims of the primary
cohort study. Samples were analyzed for lead at the trace
metals laboratory at HSPH in Boston, Massachusetts. Blood
samples were first weighed (~1g) and digested for 24 hours
in 2 mL of concentrated nitric acid. These samples were
then treated with 1 mL of 30% hydrogen peroxide per 1 g of
blood and left overnight. Samples were subsequently diluted
to 10 mL with deionized water. Lead concentrations were
measured using a dynamic reaction cell-inductively coupled
plasma mass spectrometer (DRC-ICP-MS, DRC II, Perkin
Elmer). Analyses were performed using an external calibra-
tion method using lutetium as an internal standard to account
for instrument drift. Continual calibration standards and the
use of a standard reference solution (NIST 1643e: Metals
in Water) were used to monitor precision and accuracy of
the analysis. The final sample concentration used in the
results was an average of 5 replicate measurements for each
individual samples.

Quality control included analysis, procedural blanks,
duplicate samples, spiked samples, and analysis of a certified
reference material (NIST 955b: bovine blood for lead) to
monitor for contamination, accuracy, and recovery rates.
Recovery rates for lead in quality control and spiked samples
were 81%–108%, and precision was measured as % relative
standard deviation (SD), with a result of less than 3% for lead.
The average limit of detection (LOD) was 0.2 μg/dL.

2.3. Questionnaires. Trained study staff administered ques-
tionnaires that collected medical histories and demographic
information. This questionnaire included detailed questions
about potential sources of lead exposure including paint,
distance to roads and shops, battery recycling, parents’
occupations, and children’s hand-to-mouth activity.

2.4. Environmental Sample Collection. Site visits were con-
ducted at each participant’s home, and trained staff collected
soil, drinking water, turmeric, and rice samples in trace
metal-free 50 mL plastic centrifuge tubes. Three battery
recycling/recharging plants were visited, and soil samples
were collected from a region of soil closest in proximity to
the shop. Soil samples were extracted from an approximately
4” × 4” × 1” area of soil and collected using a plastic
trowel. During the ongoing sample collection, samples were
stored at room temperature in DCH. Rice, turmeric, and soil
samples were sealed with Parafilm and packaged in Coleman
coolers for shipment to HSPH. Water samples were analyzed
at laboratories at the Bangladesh University of Engineering
and Technology (BUET) and Dhaka University.

Soil samples were dried and filtered through a 200 μm
sieve to simulate the size of inadvertent particle ingestion.
Four grams of soil, turmeric, or rice was transferred into
X-ray fluorescence (XRF) analytical cups after thorough
homogenization to determine the concentration of total lead
in the samples by X-Ray fluorescence (Nilton XL3T, Billerica,
MA). Rice samples were ground into a fine powder using
a trace metal-free spice grinder. The limit of detection by
XRF is approximately 10 ppm. Water samples were tested
using atomic absorption spectroscopy (AAS) at laboratories
at Dhaka University and the Bangladesh University of Engi-
neering and Technology. The limit of detection by AAS was
0.01 mg/L.

2.5. Bioaccessibility Analysis. Lead bioaccessibility in tur-
meric samples was estimated using the simple bioavailability
extraction test (SBET), an in vitro gastric fluid extraction
that simulates metal dissolution in the stomach. The SBET
was performed following procedures previously established
by the US Environmental Protection Agency (EPA) [7, 8].
Following the SBET analysis, lead concentrations were measured using inductively coupled plasma mass spectrometry (ICPMS) to determine the fraction of total lead that was bioaccessible in simulated gastric fluid.

2.6. Statistical Analyses. We calculated descriptive statistics for both blood lead measures and selected subject characteristics. We dichotomized blood lead concentrations at different reference levels corresponding to current US and World Health Organization guidelines (i.e., ≥5 μg/dL and ≥10 μg/dL). The government of Bangladesh currently does not have recommended blood lead guidelines for children. Associations between demographic variables and blood concentrations were conducted using Fisher’s exact tests. For environmental samples, we calculated descriptive statistics. All analyses were performed in SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).

3. Results

In this analysis, we used data from 309 children who provided fingerstick blood samples as of May 1, 2013. Venous blood samples were available for 176 (57%) of these children at the same visit. This sample represents 74% of the planned enrollment from this site for the birth cohort study. Table 1 presents the demographic characteristics of children and families.

The overall median fingerstick blood lead concentration at approximately the age of 2.5 years was 8.1 μg/dL (range: <LOD-443.0 μg/dL). The mean venous blood lead concentration was 8.0 μg/dL (range 2.0–36.3 μg/dL). There was good correlation between venous blood lead concentrations and fingerstick blood lead concentrations (the Spearman correlation coefficient 0.82, P < 0.001). In our sample, 78% of the children tested had fingerstick blood concentrations at or above the current CDC reference level of 5 μg/dL and 27% of the children tested had fingerstick blood lead concentrations at or above the previous CDC action level of 10 μg/dL. Similar distributions were seen among venous blood samples, with 84% of the children having venous blood lead concentrations above 5 μg/dL and 26% having concentrations above 10 μg/dL (Table 2). Sex, parental education level (low education level defined as primary education or less), and BMI were not associated with elevated blood lead concentrations (results not shown).

Lead concentrations varied among our turmeric samples, with a mean of ~80 μg/g and a range of <LOD to 483 μg/g. The average bioaccessibility of lead in turmeric was 42.9%. These results are summarized in Figure 1. Soil samples did not show high concentrations of lead (median = 16.3 μg/g and maximum = 33.6 μg/g). Total chromium concentrations were also measured by XRF to test for the presence of PbCrO₄ and were not elevated. Only 3 turmeric samples had chromium concentrations above the limit of detection (42 μg/g, maximum = 235 μg/g). No water sample had a lead concentration above the limit of detection. Additionally, no rice sample had a lead concentration above the level of detection. Soil samples from three battery recycling shops showed that the soil inside the shop’s walls had elevated lead (mean = 1632 ppm), but outside of the shops the soil lead concentrations were not significantly elevated (mean = 28 ppm).
Almost 80% of children aged 20 to 40 months tested in Munshiganj had blood lead concentrations at or above 5 μg/dL, the reference level currently set by the US Centers for Disease Control and Prevention (CDC), and 26% of the children tested had blood lead concentrations at or above the previous CDC action level of 10 μg/dL. The original intention of the study was to investigate arsenic and manganese toxicity, and blood lead concentration was measured as a potentially important covariate; these high blood lead concentrations were not anticipated.

In our study, turmeric samples had high concentrations of lead, with high levels of bioaccessibility, suggesting that contamination of food spices may be an important source of lead exposure in this setting. The elevated levels of lead in these turmeric samples (mean, ∼80 μg/g; range, <LOD to 483 μg/g) in conjunction with an average bioaccessibility of lead in turmeric of 42.9% further support the hypothesis that turmeric is an important source of lead exposure for this cohort.

Previous reports of elevated blood lead concentrations in Bangladeshi children have focused on large cities and industrial areas [1–3]. Sirajdikhan, by contrast, is a primarily rural area, providing evidence that lead poisoning in Bangladesh is not limited to urban centers.

Previous research has identified lead-contaminated foodstuffs originating from Bangladesh and India, further supporting our turmeric findings. A recent study by Saha and Zaman [9] demonstrates the potential for contamination of foodstuffs such as fish and vegetables to occur in urban Bangladesh settings. In September 2013, the US Food and Drug Administration (FDA) announced voluntary recall by distributors of Pran brand turmeric powder, a Bangladeshi company, due to elevated levels of lead [10]. Additional studies identified the presence of contaminated spices originating from India and Bangladesh in markets in Boston, MA [11–13]. This study builds upon these reports by identifying turmeric as a potential direct exposure route within a vulnerable community.

While this research identifies the presence of lead-contaminated turmeric, the method of contamination is unknown. Uptake of lead from soil into the turmeric is a possible, but unlikely, source of contamination, as previous studies estimate the maximum uptake of lead into the root of the plant to be approximately 10% [14]. Additionally, it is possible that the addition of lead chromate to these samples (to increase the weight and bright color) may be the source of lead contamination. However, we did not find high chromium levels in our turmeric samples, as would be expected with the addition of lead chromate. Further testing and closer inspection of the growing and manufacturing process is needed.

We were not able to assess the amount of turmeric ingested by children, and this is a further limitation of this study. We did not find a strong correlation between turmeric lead concentrations and blood lead concentrations, though we note that the turmeric samples were obtained months after the blood concentrations were measured. We therefore report that the high levels of lead in turmeric are a potential risk to the community.

### 5. Conclusion

There is an urgent need to identify the source of lead exposure in rural communities in Bangladesh. Turmeric, a spice commonly used in Bangladesh cooking, is a potential source of lead exposure. Further testing is needed to confirm these sources. Once identified, preventative measures can be taken.

### Ethical Approval

This study was approved by the Human Research Committees at the Harvard School of Public Health (HSPH) and Dhaka Community Hospital (DCH).

### Conflict of Interests

The authors report no conflict of interests.

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