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ORIGINAL ARTICLE

Levels of lead in blood and water in occupationally exposed and unexposed population of the Guntur district, Andhra Pradesh: baseline analysis of a prospective cohort study

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ABSTRACT

Background: Lead can be ingested, inhaled, or absorbed through the skin, leading to morbidity and mortality.
Aim: This study aimed to estimate and compare the prevalence of high blood lead levels (BLLs) among the adult population with and without occupational lead exposures.
Methods: A baseline survey of a prospective cohort study was conducted in 2022 among 180 adult males and females (20 – 60 years old) in the Guntur district, Andhra Pradesh. The study participants were divided accordingly into three groups: direct occupationally exposed (Group 1); indirect air pollution-exposed (Group 2); and indirect non-occupationally exposed (Group 3). The participants were interviewed using a structured data collection instrument. Blood and water lead levels were estimated using a graphite furnace atomic absorption spectrophotometer. We defined statistical significance as $P < 0.05$.
Result: Among the studied participants, 65.56% were less than 40 years of age and 74.44% were males. The BLLs ranged from 2.15 µg/dL to 19.03 µg/dL. The mean BLLs were 8.50 ± 2.36, 7.34 ± 3.02, and 5.65 ± 2.91 µg/dL for Groups 1, 2, and 3, respectively. The lead content in samples of 20 L-canned water in each group was more than 10 µg/L. On adjustment in multivariate analysis, the male gender and direct occupational exposure are significant risk factors for high BLLs (i.e., ≥5 µg/dL).
Conclusion: Both occupationally exposed and unexposed groups in the study had higher mean BLLs than recommended. The mean BLL in the occupationally exposed group was significantly higher compared to the general population. Higher lead content in drinking water may expose individuals to lead-related symptoms.
Relevance for Patients: High BLLs can have significant negative health effects on the human body. Lead is particularly harmful to the central nervous system and cardiovascular system.

1. Introduction

Lead occurs naturally in the Earth's crust and poses significant toxicity to humans when ingested, inhaled, or absorbed through the skin [1]. It persists in various environmental mediums, such as soil, air, drinking water, and homes, where it accumulates and does not degrade [1]. High levels of lead exposure can have adverse effects on adults, such as inducing coma, convulsions, and death [1]. Reports have identified six primary

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sources that significantly contribute to lead exposure: gasoline additives; food can solder; lead-based paints; ceramic glazes; drinking water systems; and cosmetic and folk remedies [2]. Other significant exposures include inadequately controlled industrial emissions from lead smelters and battery recycling plants, contaminating both the environment and people in the vicinity [2]. The highest level of environmental contamination is found to be associated with uncontrolled recycling operations, with the most highly exposed adults being those who work with lead [3].

In India and most developing countries, the main source of lead pollution was previously automobile exhaust. With the use of unleaded petrol, lead pollution due to automobile exhaust has drastically dropped [4]. Approximately 143,000 people die annually from lead poisoning, accounting for 0.6% of the global disease burden [5], and Southeast Asia accounts for over half of the global burden of lead-related illness. Greater blood lead levels (BLL) are linked to increased all-cause mortality in both men and women with cardiovascular diseases. Although the World Health Organization (WHO) has set a standard BLL of 5 μg/dL for adults [1], the Environmental Health Committee of the Council of State and Territorial Epidemiologists (CSTE) indicated that a blood lead reference value (BLRV) >3.5 μg/dL is considered high. BLRV is used to identify patients with the highest BLL in the population but is not indicative of a toxicity threshold [6]. Adult lead toxicity is typically considered at mean BLL ≥10 μg/dL, but there is evidence linking long-term risks to chronic lead exposure below 10 μg/dL [7]. Other studies indicate a correlation between higher BLLs and increased cardiovascular mortality in adults [8]. Lead is a strong inhibitor of δ-aminolevulinic acid dehydratase, affecting the spleen and hematopoietic system [9].

According to evidence on the long-term effects of low-level lead exposures and the prevalence of lower levels in the population, the United States (US) Department of Health and Human Services advises reducing BLLs among all individuals to <10 μg/dL [7,10,11]. It is widely recognized that the lead exposure standard set by the US Occupational Health and Safety Administration is outdated and does not provide adequate protection against lead poisoning [10,12]. This standard permits workers to continue working in lead-exposed environments with BLLs of up to 40 μg/dL.

Developed countries, such as the US, United Kingdom, and Germany, have implemented aggressive measures to address lead poisoning while developing countries present slower and more sporadic actions. Within the past decade, there have been numerous reports of lead poisoning in humans, particularly from developing countries faced with environmental and occupational lead exposure [4]. The present study was conducted to estimate and compare BLLs in the adult population with and without occupational lead exposure.

2. Methods

2.1. Study design

A baseline survey of the prospective cohort study was conducted in the Guntur district, Andhra Pradesh, India, which was approximately 30 km from the All India Institute of Medical Sciences (AIIMS), Mangalagiri. The study was conducted in 2022 among adult males and females from 20 to 60 years of age. The study participants were divided accordingly into three groups:

(i) Group 1: Direct occupationally exposed individuals, such as workers in lead battery manufacturing, construction workers, demolition workers, gas station attendants, lead smelters, smolderers, and painters.
(ii) Group 2: Indirect air pollution-exposed individuals, such as traffic police, police, truck drivers, bus drivers, auto drivers, and petrol bunk workers.
(iii) Group 3: Indirect non-occupationally exposed individuals, such as indoor officer workers, teachers, primary health-care workers, and housewives.

Individuals were eligible for participation in Groups 1 and 2 after working in the same occupation for at least 6 months or in Group 3 after residing in the area or working in the same occupation for the past 6 months. Individuals with symptoms suggestive of critical illness, diabetes mellitus, hypertension, recently underwent surgery, and those who denied consent were excluded from the study.

The sample size was calculated using the sample formula required per group:

$$n = \left(\sigma_1^2 + \sigma_2^2\right) \times \frac{[Z_{1-@/2} + Z_{1-\beta}]^2}{(M_1 - M_2)^2} \quad \text{(I)}$$

Where σ_1 denotes the standard deviation (*SD*) of the outcome variable in Group 1, σ_2 denotes the *SD* of the outcome variable in Group 2, $Z_{1-@/2}$ and $Z_{1-\beta}$ denote the probability of two types of errors at 1.96 and 1.282, respectively, and $M_1 - M_2$ denotes the mean difference between groups. The means of continuous variables were compared using a *t*-test. We utilized the findings from two previous studies as Groups 1 and 2 to determine the sample size. Group 1 included workers handling raw material in a battery factory in Nellore, Andhra Pradesh, with a mean ± 2*SD* BLL (μg/dL) of 26.2 ± 2.142 in 2016 – 2017 [3]. Group 2 included non-occupationally lead-exposed healthy school teachers from various public and government sectors, representing various nodal areas of Jodhpur with a mean ± 2*SD* BLL (μg/dL) of 6.89 ± 9.5 [13]. Utilizing a 95% confidence interval (CI) and 90% power, we calculated the required sample size to detect a 3.0 μg/dL difference in BLLs in any two groups to be 60. Hence, the total sample studied was 180, excluding nonresponse and attrition.

After ascertaining the eligibility of the participant, detailed information about the study was provided through the Participant Information Sheet and consent document. Both these documents were in Telugu, and any difficult words were explained with the assistance of a local interpreter. Data collection was conducted once written consent was accorded. The project was approved by the ethical committee of the AIIMS Institute (AIIMS/MG/IEC/2022-2023/135).

Investigators were trained in data collection, blood collection, and transportation. A pilot survey was conducted and corrective

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measures were taken. A structured data collection instrument, comprising information about sociodemographic details (e.g., age, smoking status, alcohol ingestion, and duration of occupational exposure) and clinical details, was developed. This instrument was pretested, suitably modified, and subsequently implemented. Basic sociodemographic information (e.g., family size, age, education, occupation, gender of members of the family, and occupational years) was collected to study the correlation of these factors to the risk of high BLL.

In this study, BLL was considered the outcome variable, while the exposure variables include the participants' occupation, age, education, smoking status, and alcohol intake, among others.

2.2. Blood sample collection

Blood samples (3 mL) were collected under sterile conditions using BD Vacutainer® Eclipse™ blood collection needles (368608; BD, USA) into BD Vacutainer® EDTA tubes (367861; BD, USA) containing EDTA K2 anticoagulant for BLL measurements. The blood samples were transported to the AIIMS Mangalagiri Biochemistry Laboratory, while maintaining a cold chain (i.e., in cold boxes with temperature monitors). At the laboratory, the samples were processed accordingly. In a 100 mL volumetric flask, 5 mL of 10% Triton X-100, 2 mL of NH_4PO_4, and four drops of 70% HNO_3 were mixed and diluted to volume with deionized water to form the matrix modifier. To prepare a multipoint calibration curve, 0.1, 5, 10, 30, and 60 μg/dL working standard lead-containing solutions were prepared in 1% HNO_3. The final standard solutions were prepared by mixing 100 μL of each of the working standard solutions with 900 μL of matrix modifier in autosampler vessels to produce 0.1, 0.5, 1, 3, and 6 μg/dL, respectively. These standard solutions were set aside until the bubbles dissipated. The samples were then prepared by mixing 100 μL of whole blood (with anticoagulant) with a 900 μL matrix modifier. BLLs were estimated using a graphite furnace atomic absorption spectrophotometer. The trace element blood collection tubes used here refer to BD Vacutainer® specialty tubes (368381; BD, USA). The BLL measurement method has been validated with an estimated detection limit of <1 μg/dL and requires only a small sample size. The measurement method also has a multi-element capacity with little interference.

Information about the study was shared with the communities through field health workers, schools, Anganwadi, and social media. Any eligible participants (for either one of the three groups) visiting the AIIMS hospital or the Centre for Rural Health AIIMS Nutakki were enrolled using purposively sampling. Furthermore, independent camps were conducted at peripheral centers. The investigator introduced himself/herself to the participant before the start of the interview. Individuals were given patient information sheets. Thereafter, the research team explained the study, its objectives, procedure, and the rights of the participants. If the individuals agreed to participate in the study after going through the information sheet, written consent was obtained. A unique code was assigned to each participant. The participants were interviewed according to the interview schedule, and blood sampling was conducted after the interview. The laboratory technicians were kept blinded, and all blood testing reports were shared with the participants.

The four water sources were evaluated in each group of participants. The first sample was the first water from the tap in any randomly selected participants' houses within the study area. The second water sample was from a 20-L packed plastic can of water available in the vicinity of the above house. The third water sample was from the water purifier in any of the randomly selected participants' houses. The fourth water sample was from the tap at the nearest health-care facility, school, or office from the selected participants' house.

2.3. Data analysis

Data were entered in Microsoft Excel and analyzed by using IBM SPSS Statistics Base version 28.0. Lead exposures at baseline were categorized into three groups. The continuous variables in the study (i.e., BLLs) were summarized as mean ± *SD*. Normality was assessed using the Kolmogorov–Smirnov test. The categorical variables, including age, gender, and occupational exposure, were presented as frequency or percentage.

Bivariate analysis of categorical parameters, i.e., comparison of BLLs, was performed using the Chi-square (χ^2) test. The mean BLLs of the three groups were compared using analysis of variance with *post hoc* analysis. Multivariate logistic regression was performed to distinguish the exposure variables according to BLL < or ≥5 μg/dL. Statistical significance was defined as $P < 0.05$.

3. Results

Approximately 65.56% of participants were less than 40 years old, with a mean age of 35.65 ± 9.21 years; 74.44% of participants were males; 68.33% of participants were are at least 10th class (i.e., more educated); 47.22% of participants belonged to the upper middle socioeconomic status (Table 1). The median (interquartile range [IQR]) of family and individual incomes were INR 20000 (15000) and INR 15000 (8500), respectively.

Table 2 reports that 17.78% of participants were smokers and 3.8% used smokeless tobacco. Overall, 37.78% of participants reported that their house was within a 1 km radius of the highway or traffic zone. Approximately 50.56% of participants were using 20-L canned water for drinking.

Table 3 reports that 36.7% of participants were painters and 30.0% were construction workers in Group 1; 50.0% were traffic police and 33.3% were auto drivers in Group 2; and 41.7% were primary health-care workers (accredited social health activist [ASHA] and Anganwadi) and 40.0% were office workers in Group 3. The median (IQR) working hours in a typical day was 8 (2) h. The median (IQR) number of years in the present occupation of study participants was 10 (11.7) years.

Figure 1 displays the violin plot of the distribution of participants for BLLs and the group studied. Overall, 56 (93.3%) participants in Group 1, 46 (76.6%) participants in Group 2, and 28 (46.6%) participants in Group 3 had BLLs >5 μg/dL of blood. The BLL ranged from 2.15 μg/dL to 19.03 μg/dL.

Table 1. Distribution of study participants by their sociodemographic factors (n=180)

Sociodemographic factor	Number of participants, n (%)				χ^2	P
	Cat 1	Cat 2	Cat 3	Total		
Age (years)					33.12	<0.001*
<40	27 (45.0)	35 (58.3)	56 (93.3)	118 (65.56)		
≥40	33 (55.0)	25 (41.7)	4 (6.7)	62 (34.44)		
Gender					108.16	<0.001*
Female	0 (0.0)	2 (3.3)	44 (73.3)	46 (25.56)		
Male	60 (100.0)	58 (96.7)	16 (26.7)	134 (74.44)		
Education (class)					17.09	<0.001*
<10	29 (48.3)	20 (33.3)	8 (13.3)	57 (31.67)		
≥10	31 (51.7)	40 (66.7)	52 (86.7)	123 (68.33)		
Migrant					5.92	0.05
Yes	8 (13.3)	19 (31.7)	16 (26.7)	43 (23.89)		
Living with family					0.7	0.7
Yes	56 (93.3)	57 (95.0)	58 (96.7)	171 (95.00)		
Socioeconomic status						
Upper	4 (6.7)	24 (40.0)	17 (28.3)	45 (25.00)	23.21	0.001*
Upper middle	31 (51.7)	23 (38.3)	31 (51.7)	85 (47.22)		
Lower middle	20 (33.3)	12 (20.0)	11 (18.3)	43 (23.89)		
Lower	5 (8.3)	1 (1.7)	1 (1.7)	7 (3.89)		

Note: Socioeconomic status is determined using the BG Prasad scale; *$p < 0.05$ denotes statistical significance.
Abbreviation: Cat: Category.

Table 2. Distribution of study participants by their behavior and residential factors (n=180)

Behavior/residential factor	Number of participants, n (%)				χ^2	P
	Cat 1	Cat 2	Cat 3	Total		
Smoking					21.51	<0.001*
Yes	13 (21.7)	19 (31.7)	0 (0.0)	32 (17.78)		
Smokeless chewable tobacco					14.56	0.001*
Yes	7 (11.7)	0 (0.0)	0 (0.0)	7 (3.89)		
Alcohol use					34.71	<0.001*
Yes	22 (36.7)	27 (45.0)	0 (0.0)	49 (27.22)		
Residence within 1 km of highway/traffic zone					17.92	0.001*
Maybe	14 (23.3)	16 (26.7)	18 (30.0)	48 (26.67)		
No	33 (55.0)	13 (21.7)	18 (30.0)	64 (35.56)		
Yes	13 (21.7)	31 (51.7)	24 (40.0)	68 (37.78)		
Drinking water					20.42	0.002*
Household filtered/RO water	1 (1.7)	8 (13.3)	16 (26.7)	25 (13.89)		
20 L-canned water	39 (65.0)	30 (50.0)	22 (36.7)	91 (50.56)		
Municipality	17 (28.3)	18 (30.0)	15 (25.0)	50 (27.78)		
Others	3 (5.0)	4 (6.7)	7 (11.7)	14 (7.78)		
Personal protective					12.33	0.015*
No/not applicable	45 (75.0)	47 (78.3)	40 (69.0)	132 (73.33)		
Sometimes	8 (13.3)	0 (0.0)	3 (5.2)	11 (6.11)		
Yes	7 (11.7)	13 (21.7)	15 (25.9)	35 (19.44)		

Note: *$P < 0.05$ denotes statistical significance.
Abbreviation: Cat: Category; RO: Reverse osmosis.

The mean blood levels of lead were 8.50 ± 2.36, 7.34 ± 3.02, and 5.65 ± 2.91 μg/dL for Groups 1, 2, and 3, respectively. The BLLs among the three groups of participants were statistically significant ($P < 0.001$). The mean BLL was highest in Group 1, followed by Groups 2 and 3. There was also a statistically significant difference in the mean BLLs of Group 1 vs. Group 2 (P = 0.03), Group 2 vs. Group 3 (P = 0.007), and Group 1 vs. Group 3 ($P < 0.001$).

Table 4 reports the lead content in water samples among the three studied groups. The lead content in samples of 20 L-canned

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water in each group was more than 10 μg/L. In Group 2, the lead levels were 29.34 μg/L in a sample of household filter water and 18.06 μg/L in a sample of facility-based water. In Group 3, the lead levels were 16.43 μg/L in a sample of municipality water.

Bivariate analysis revealed that age ≥40 years, male gender, direct occupational exposure, education <10th class, lower socioeconomic status, use of alcohol, and drinking from 20 L-canned water are significant risk factors for high BLLs, i.e., ≥5 μg/dL. On adjustment in multivariate logistic regression, male gender and direct occupational exposure are significant risk factors for high BLLs, i.e., ≥5 μg/dL (Table 5).

Table 3. Distribution of participants in the three groups by occupation

Occupation	Number of participants, *n* (%)			
	Group 1	Group 2	Group 3	Total
Carpenter, or welding worker	15 (25.00)			15 (8.30)
Car mechanics	5 (8.30)			5 (2.80)
Painters	22 (36.70)			22 (12.20)
Construction worker	18 (30.00)			18 (10.00)
Petrol bunkers		8 (13.33)		8 (4.44)
Auto drivers		20 (33.30)		20 (11.10)
Traffic police		30 (50.00)		30 (16.70)
Driver		2 (3.30)		2 (1.10)
Office workers			24 (40.00)	28 (15.60)
ASHA and Anganwadi worker			25 (41.70)	25 (13.90)
Teachers			5 (8.30)	5 (2.80)
Student			2 (3.30)	2 (1.10)
Manual labor			2 (3.30)	2 (1.10)
Housewife			1 (1.70)	1 (60.00)
Private job			1 (1.70)	1 (1.70)
Total	60 (100.00)	60 (100.00)	60 (100.00)	180 (100.00)

Abbreviation: ASHA: Accredited social health activist.

Table 4. Lead content in water samples among the three studied groups (*n*=12)

Sample type	Water lead content (μg/L)		
	Group 1	Group 2	Group 3
20 L-canned water	16.38	12.23	65.11
Household filter water	7.28	29.34	7.56
Facility-based water	4.79	18.06	7.71
Municipality water	7.1	7.5	16.43

4. Discussion

The present study was conducted to estimate and compare BLLs among the adult population with and without occupational lead exposure. The present study was the first of its kind for its community-based BLL estimation among three different exposed groups in Andhra Pradesh, India, namely direct occupational exposure, indirect air pollution exposure, and indirect non-occupational exposure to lead. This study found that the majority of participants had high BLLs. The WHO has established a reference value of 5 μg/dL BLL as the threshold at which public health action is recommended [14]. In the present study, mean BLLs in all three groups were higher than the reference value. In India, the Bureau of Indian Standards set a maximum permissible limit of 10 μg/L for lead in drinking water [15]. The lead content in all four samples of 20 L-canned water and one reverse osmosis (RO) plant was more than permissible.

Occupational lead exposure may occur in various labor-based fields, such as construction, painting, smelting, and others. Therefore, the BLL of these workers is much higher than in the general population. In the air, lead particles can be inhaled by individuals and enter their bloodstream. The WHO has established a guideline value for lead in outdoor air of 0.5 μg/m³ [16]. Despite the use of unleaded fuels in some parts of India, lead levels in outdoor air still exceed this guideline [17].

In the present study, the not occupationally exposed group mainly consisted of primary health-care workers and office-based workers. While not being exposed to occupational lead or air pollution zones, the mean BLL in this group was also more than 5 μg/dL. One of the primary reasons for the high BLL in this group could be the use of 20 L-canned water for drinking purposes. The finding suggests that the purification techniques for these water plants are suboptimal. RO plants should be equipped with updated technology for testing heavy metals. Although lead can enter the water supply from a variety

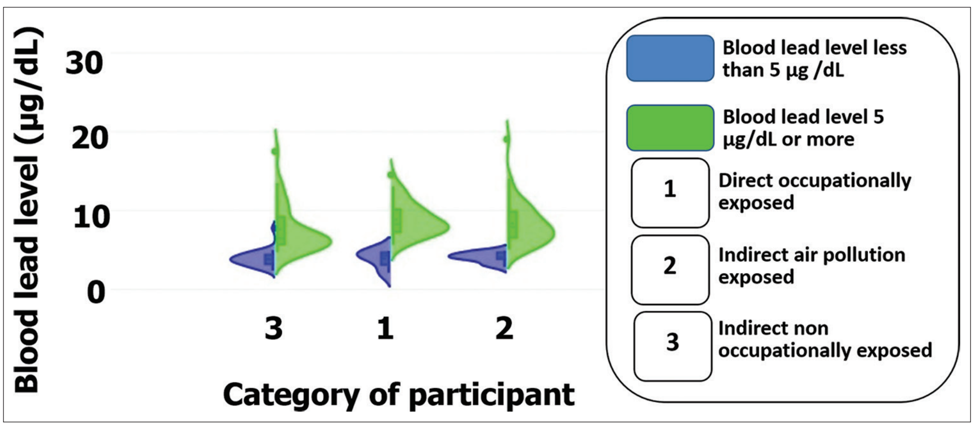

Figure 1. Distribution of study participants by blood lead levels.

Table 5. Logistic regression analysis of risk factors of blood lead level (BLL) ≥ 5 μg/dL

Risk factor	Number of participants, n (%)			Bivariate logistic regression		Multivariate logistic regression	
	BLL <5 μg/dL	BLL ≥5 μg/dL	Total	COR (95% CI)	*P*	AOR (95% CI)	*P*
Age (years)							
<40^	39 (33.1)	79 (66.9)	118 (65.6)	0.43 (0.21 – 0.93)	0.029*	1.03 (0.38 – 2.76)	0.947
≥40	11 (17.7)	51 (82.3)	62 (34.4)				
Gender							
Female^	25 (54.3)	21 (45.7)	46 (25.6)	0.19 (0.9 – 0.39)	< 0.001*	0.32 (0.12 – 0.85)	0.023*
Male	25 (18.7)	109 (81.3)	134 (74.4)				
Occupation (exposure)							
Direct^	4 (6.7)	56 (93.3)	60 (33.3)	8.70 (2.96 – 26.6)	< 0.001*	4.15 (1.06 – 16.26)	0.04*
Indirect	46 (38.3)	74 (61.7)	120 (66.7)				
Education (class)							
<10^	10 (17.5)	47 (82.5)	57 (31.7)	2.26 (1.04 – 4.94)	0.037*	1.18 (0.45 – 3.08)	0.735
≥10	40 (32.5)	83 (67.5)	123 (68.3)				
Socioeconomic status							
Upper or upper middle^	25 (55.6)	20 (44.4)	45 (25.0)	0.35 (0.17 – 0.73)	0.004*	0.47 (0.19 – 1.16)	0.102
Middle or lower-middle	105 (77.8)	30 (22.2)	135 (75.0)				
Smoking							
Yes^	5 (15.6)	27 (84.4)	32 (17.8)	2.35 (0.85 – 6.52)	0.09	0.85 (0.21 – 3.35)	0.823
No	45 (30.4)	103 (69.6)	148 (82.2)				
Smokeless chewable tobacco							
Yes^	1 (14.3)	6 (85.7)	7 (3.9)	2.37 (0.27 – 20.21)	0.41	N/A	N/A
No	49 (28.3)	124 (71.7)	173 (96.1)				
Alcohol							
Yes^	6 (12.2)	43 (87.8)	49 (27.2)	3.62 (1.43 – 9.16)	0.004*	2.27 (0.67 – 7.62)	0.184
No	44 (33.6)	87 (66.4)	131 (72.8)				
Highway within a 1 km radius of residence							
Yes^	53 (77.9)	15 (22.1)	68 (37.8)	1.61 (0.79 – 3.23)	1.78	N/A	N/A
No	77 (68.8)	35 (31.2)	112 (62.2)				
Drinking water							
20 L-canned water^	16 (17.6)	75 (82.4)	91 (50.6)	2.89 (1.45 – 5.76)	0.002*	2.16 (0.98 – 4.73)	0.05
Others	34 (38.2)	55 (61.8)	89 (49.4)				

Note: *$P<0.05$ denotes statistical significance; variables with $P>0.2$ were not included in multivariate analysis (denoted by N/A); ^denotes the reference value.
Abbreviations: AOR: Adjusted odds ratio; CI: Confidence interval; COR: Crude odds ratio; N/A: Not available.

of sources, including old lead pipes, plumbing fixtures, lead solder used in plumbing, and lead-containing valves or fittings, the municipality water supply was found to have lead within permissible limits.

The present study results were comparable to those of recent studies: a meta-analysis of 31 studies involving the Indian population, i.e., 5472 people across nine states, reported a mean BLL of 7.52 μg/dL (95% CI: 5.28 – 9.76) in non-occupationally exposed adults [18]; a cross-sectional study of 32 male painters in Iran in 2021 reported a mean BLL of 8.1 ± 4.93 μg/dL [19]; a cross-sectional study among 254 workers aged 20 – 60 years old, at a battery factory in Nellore, Andhra Pradesh, in 2016 – 17 reported a mean BLL of 25.26 ± 2.1 μg/dL[3]; and a study from Turkey in 2001 among 99 traffic policemen reported a mean BLL of 9.4 ± 1.6 μg/L and 8.7 ± 1.7 μg/L for policemen working outdoors and indoors, respectively [20]. Our results were also lower compared to a study from China [21]. This could be due to workers in these industries being exposed to higher lead through inhalation of dust or fumes, ingestion of contaminated food or water, or in direct contact with lead-containing materials compared to the general population.

The present study reported mean BLLs higher than the recommended value in all three studied groups. Among these, the direct occupationally exposed group had the highest mean BLL, while lay people from the community had the lowest mean BLL. Occupation exposure and high water lead content are probably the causative factors for higher BLLs in this population. High BLLs can have significant negative health effects on the human body. Lead is particularly harmful to the central nervous system and cardiovascular system and can accumulate in the kidneys over time, leading to kidney damage. Lead can also interfere with the development and maintenance of healthy bones. However, there were some limitations of this study. While participants reported various symptoms, such as joint pains, headaches, abdominal pain, and muscle pain/fatigue, establishing a direct causal relationship with BLL alone is challenging per se. Detailed clinical and biological investigations are required to rule out other possible causes of these symptoms. In addition, the number of water samples collected was limited, and the study did not measure lead content in air samples. These limitations may affect the scope of the study to establish a clear causal relationship between the different factors and high BLLs among the study population.

5. Conclusion

Both occupationally exposed and unexposed groups in the study had higher mean BLL than recommended. The mean BLL in the occupationally exposed group was significantly higher compared to the general population. Higher lead content in drinking water exposes individuals to lead-related symptoms. Future estimations must be informed by larger and population-wide BLL research. Governments and public health organizations can mitigate lead exposure from water contamination by implementing measures such as mandatory labeling and periodic monitoring for 20 L-canned water available in local markets for drinking purposes.

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Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval and Consent to Participate

The project was approved by the ethical committee of the AIIMS Institute [AIIMS/MG/IEC/2022-2023/135]. Informed written consent was obtained from the participants for releasing their data without any personnel identifier before enrollment in the study.

Consent for Publication

Informed written consent was obtained from the participants for releasing their data without any personnel identifier before enrollment in the study.

Availability of Data

Data are available from the corresponding author upon reasonable request.

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