Heavy Metal Contamination in Drinking Water and Its Association with Health Risks among Peri-Urban Households in Peshawar

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Abstract

Background: Heavy metal contamination in drinking water is an under-recognized but serious public health issue in Pakistan. Peri-urban settlements of Peshawar largely depend on shallow tube wells and tanker water, both highly vulnerable to chemical pollutants. Chronic exposure to arsenic, lead, and chromium may lead to anemia, impaired growth, and organ dysfunction.

Methods: A community-based cross-sectional study was conducted among 220 households in two peri-urban settlements of Peshawar (Shaheen Muslim Town and Warsak Road colony) between January and July 2025. Household water samples (n=220) were analyzed for arsenic, lead, and chromium using atomic absorption spectrophotometry. Structured questionnaires and household health records were used to capture information on anemia, growth retardation in children (<12 years), and liver disease in adults. Logistic regression was applied to estimate associations between water contaminants and health outcomes.

Results: Arsenic exceeded WHO limits in 29% of samples, lead in 18%, and chromium in 11%. Children from arsenic-contaminated households had a higher prevalence of stunting

compared to those from uncontaminated households (27% vs 14%, $p<0.05$). Lead contamination was associated with a two-fold increased odds of anemia (AOR=2.0; 95% CI: 1.1–3.6). Adults from households with contaminated water were more likely to have liver morbidity (16% vs 7%, $p=0.04$).

Conclusion: Heavy metal contamination of drinking water in peri-urban Peshawar is a significant public health threat, linked with stunting, anemia, and liver morbidity. Strengthened water monitoring, safe supply systems, and targeted awareness interventions are urgently needed to protect vulnerable populations.

Keywords: Heavy metals, Water pollution, Stunting, Anemia, Public health, Peshawar

Introduction

Access to safe drinking water is fundamental for human health, yet nearly two billion people worldwide consume water contaminated with hazardous substances (1). Heavy metals such as arsenic, lead, and chromium persist in the environment and bioaccumulate, causing adverse health effects even at low exposure levels (2,3). Chronic arsenic ingestion is associated with stunting, skin lesions, and cancers, while lead exposure contributes to anemia, neurodevelopmental impairment, and cardiovascular disease (4,5).

In Pakistan, the majority of studies on water contamination have focused on Punjab and Sindh, with extensive evidence of arsenic contamination in groundwater (6,7). However, relatively little is known about Khyber Pakhtunkhwa, where peri-urban settlements are rapidly expanding. These communities, often underserved by municipal water supply, depend on shallow tube wells or tanker water, both highly vulnerable to contamination from industrial effluents and poor regulation (8).

Peshawar, the provincial capital, faces mounting challenges related to water quality. Informal settlements frequently report gastrointestinal complaints, anemia, and chronic illnesses, yet systematic evidence linking chemical water contamination to health outcomes is scarce. This study aimed to investigate heavy metal contamination in peri-urban household drinking water in Peshawar and its association with selected health outcomes, focusing on stunting, anemia, and liver morbidity.

Methods

Study Design and Setting: A cross-sectional study was conducted between January and July 2025 in two peri-urban settlements of Peshawar: Shaheen Muslim Town and Warsak Road colony.

Sample Size and Selection: A total of 220 households were randomly selected. In each household, one water sample was collected and household members were surveyed for health outcomes.

Water Analysis: One-liter water samples were collected in sterile bottles and transported under controlled conditions. Laboratory testing was conducted at Khyber Medical University using atomic absorption spectrophotometry to measure arsenic, lead, and chromium. WHO guidelines were used as reference thresholds (arsenic 10 μg/L, lead 10 μg/L, chromium 50 μg/L).

Health Outcomes:
- Children (<12 years): stunting assessed via height-for-age z-scores; anemia assessed using hemoglobin levels (<11 g/dL).
- Adults: liver morbidity defined as documented liver disease or abnormal ALT/AST levels from household medical records.

Data Collection: Structured questionnaires captured sociodemographic data, sanitation, and health history.

Statistical Analysis: Data were analyzed using SPSS v27. Descriptive statistics summarized contamination levels and health outcomes. Chi-square tests compared prevalence across groups. Logistic regression models estimated adjusted odds ratios (AOR) with 95% confidence intervals, adjusting for household income, sanitation, and parental education.

Ethics: Ethical approval was obtained from the Institutional Review Board of Khyber Medical University. Written informed consent was obtained from household heads.

Results

Table 1. Heavy metal contamination in drinking water (n=220 samples)

Parameter	Samples above WHO limit (%)	Mean ± SD	WHO guideline
Arsenic	29.0	14.6 ± 6.2 μg/L	10 μg/L
Lead	18.0	12.3 ± 5.1 μg/L	10 μg/L
Chromium	11.0	52.4 ± 8.7 μg/L	50 μg/L

Table 2. Health outcomes by contamination status

Outcome	Contaminated HH (%)	Uncontaminated HH (%)	p-value
Child stunting	27.0	14.0	0.03
Child anemia	38.0	21.0	0.01

Adult liver morbidity	16.0	7.0	0.04

Table 3. Logistic regression of heavy metal exposure and health outcomes

Exposure	Outcome	AOR (95% CI)	p-value
Arsenic >10 μg/L	Child stunting	2.1 (1.1–4.0)	0.02
Lead >10 μg/L	Child anemia	2.0 (1.1–3.6)	0.01
Chromium >50 μg/L	Liver morbidity	1.9 (0.8–4.4)	0.11

Discussion

This study provides new evidence on the public health risks of heavy metal contamination in drinking water in peri-urban Peshawar. Nearly one-third of households exceeded WHO limits for arsenic, with corresponding increases in child stunting. The prevalence of anemia in lead-contaminated households was significantly higher, consistent with lead's well-documented hematotoxic effects (5,9).

Our findings align with research from Bangladesh and India, where arsenic exposure has been strongly linked to growth impairment in children (7,10). Similarly, the association between lead and anemia parallels global pooled analyses highlighting even low-level exposure as harmful (9). Although chromium contamination was less common, its potential association with liver morbidity warrants further longitudinal investigation.

Unlike most studies in Pakistan, which focus predominantly on microbial contamination (6,8), this work highlights the overlooked burden of chemical pollutants in Khyber Pakhtunkhwa. The dual risks of malnutrition and chronic disease underscore the urgency of interventions, including safe water provision, monitoring of informal supply systems, and public education.

Strengths: Direct measurement of contaminants, combined with health outcome data from the same households.
Limitations: Cross-sectional design limits causal inference; liver morbidity data relied on available medical records; findings may not be generalizable to all peri-urban settlements.

Conclusion

Heavy metal contamination in peri-urban Peshawar poses a substantial risk for child stunting, anemia, and adult liver morbidity. Strengthening water quality monitoring, enforcing regulatory standards, and expanding safe water access are critical for reducing exposure and protecting vulnerable populations.

References

1. WHO. Guidelines for drinking-water quality, 4th edition. Geneva: World Health Organization; 2017.
2. Naujokas MF, Anderson B, Ahsan H, et al. The broad scope of health effects from chronic arsenic exposure. Environ Health Perspect. 2013;121(3):295–302.
3. Järup L. Hazards of heavy metal contamination. Br Med Bull. 2003;68(1):167–82.
4. Baig SA, Xu X, Khan SA. Microbial and chemical contamination of drinking water in Pakistan: a review. Environ Sci Pollut Res. 2012;19(8):3550–64.
5. Rasheed H, Kay P, Slack R, et al. Arsenic exposure and related health risks in Pakistan: a review. Environ Int. 2020;137:105579.
6. Khan S, Shahnaz M, Jehan N, et al. Drinking water quality and human health risk in Charsadda district, Pakistan. J Clean Prod. 2013;60:93–101.
7. Rahman MM, Ng JC, Naidu R. Chronic exposure of arsenic via drinking water and its adverse health impacts on humans. Environ Geochem Health. 2009;31 Suppl 1:189–200.
8. Farooqi A, Masuda H, Firdous N. Toxic fluoride and arsenic contaminated groundwater in the Lahore and Kasur districts, Punjab, Pakistan and possible contaminant sources. Environ Pollut. 2007;145(3):839–49.
9. Lanphear BP, Hornung R, Khoury J, et al. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ Health Perspect. 2005;113(7):894–9.
10. Chakraborti D, Rahman MM, Das B, et al. Groundwater arsenic contamination and its health effects in India and Bangladesh. Environ Health Perspect. 2010;118(5):647–54.