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Arsenic Contamination in Groundwater: A Comprehensive Study of Hand Pump Water Quality in Punjab

S. Ramesh*

Annamalai University, Annamalainagar

Arsenic contamination in drinking water is a significant public health concern, particularly in regions where groundwater is the primary source of water supply. This study investigates the levels of arsenic in hand pump water samples collected from the districts of Bathinda, Faridkot, and Moga in Punjab, India. By analyzing 120 samples across various villages, this research aims to quantify arsenic concentrations, assess compliance with WHO guidelines, and evaluate the potential health risks posed to local populations. The findings reveal alarming variations in arsenic levels, with several samples exceeding the permissible limits, underscoring the urgent need for effective monitoring and remediation strategies to ensure safe drinking water for affected communities.

1. Introduction

Arsenic is a naturally occurring element that can contaminate groundwater, primarily through geological processes and anthropogenic activities. This paper explores the extent of arsenic pollution in Punjab, focusing on the districts of Bathinda, Faridkot, and Moga, where reliance on hand pumps for drinking water is prevalent.

1.1 Background

Arsenic is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC). Chronic exposure to arsenic through drinking water can lead to severe health issues, including skin lesions, internal cancers, and developmental effects in children. The WHO has established a guideline limit of 0.01 mg/L (10 ppb) for arsenic in drinking water, which many regions, including parts of India, frequently exceed.

1.2 Objectives

The primary objectives of this study are:

- To quantify arsenic concentrations in hand pump water samples from selected districts in Punjab.
- To assess the compliance of these concentrations with WHO and USEPA guidelines.
- To evaluate the potential health risks associated with arsenic exposure for local populations.

2. Methodology

This section outlines the systematic approach taken for sample collection, analysis, and data interpretation.

2.1 Study Area

The study was conducted in three districts of Punjab: Bathinda, Faridkot, and Moga. Each district was selected based on previous reports of arsenic contamination and reliance on groundwater for drinking purposes.

2.2 Sample Collection

A total of 120 hand pump water samples were collected from various villages within the three districts. The sampling process involved:

- Random selection of hand pumps to ensure a representative distribution.
- Collection of water samples in sterilized containers to prevent contamination.
- Documentation of geographical coordinates and environmental conditions at each sampling site.

*Annamalai University, Annamalainagar.
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2.3 Analytical Techniques

The collected samples were analyzed for arsenic concentrations using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). The analytical process included:

- Preparation of samples through filtration and dilution.
- Calibration of the ICP-AES with standard arsenic solutions.
- Running samples in duplicate to ensure accuracy and reliability of results.

2.4 Data Analysis

Statistical analysis was performed using software tools to determine mean arsenic concentrations, standard deviations, and compliance rates with WHO guidelines. Geographic Information System (GIS) mapping was utilized to visualize arsenic distribution across the study area.

3. Results

The results section presents the findings of the arsenic concentration analysis, organized by district and village.

Discussion

1. Health Implications

The presence of arsenic in drinking water poses significant health risks, particularly in Bathinda, where 30% of samples exceeded the WHO limit. Chronic exposure can lead to serious health issues, including skin lesions, internal cancers, and developmental problems in children.

2. Environmental Factors

The geological composition of Punjab, combined with agricultural practices and groundwater extraction, contributes to arsenic leaching into drinking water sources. The study highlights the need for further investigation into the sources of contamination and the effectiveness of current water management practices.

3. Socioeconomic Impact

Arsenic contamination not only affects health but also has broader socioeconomic implications. Communities relying on contaminated water for irrigation may face reduced agricultural productivity, leading to economic strain and increased health care costs.

4. Recommendations

- **Regular Monitoring**: Implement routine testing of groundwater sources to ensure compliance with safety standards.
- **Public Awareness**: Educate communities about the risks of arsenic exposure and the importance of using safe drinking water.
- **Remediation Strategies**: Develop and promote water purification technologies to reduce arsenic levels in drinking water.

These tables and discussion points provide a clear overview of the findings and implications of the study on arsenic contamination in Punjab's groundwater.

3.1 Arsenic Levels in Bathinda

In Bathinda, arsenic concentrations ranged from 0.008 to 0.153 mg/L, with a mean value of 0.0569 mg/L. Notably, 30% of the samples exceeded the WHO guideline limit. Specific results are detailed in Table 1, which lists arsenic levels by village.

Table 1: Arsenic Concentrations in Bathinda District

Village Name	Arsenic Concentration (mg/L)	Compliance with WHO Limit (0.01 mg/L)
Ghugiana	0.0020	Compliant
Malwaha	0.0840	Non-compliant
Lande Ke Machaki	0.0060	Compliant
Khurd Sukhladi	0.0580	Non-compliant
Bhinder Kalan	0.0000	Compliant
Kothe Rajpura	0.0030	Compliant
Mean	**0.0569**	
Range	**0.008 - 0.153**	

3.2 Arsenic Levels in Faridkot

Faridkot exhibited a range of arsenic levels from 0 to 0.153 mg/L, with a mean concentration of 0.0156 mg/L. Approximately 15% of samples were found to exceed the permissible limit. Detailed results are presented in Table 2.

Table 2: Arsenic Concentrations in Faridkot District

Village Name	Arsenic Concentration (mg/L)	Compliance with WHO Limit (0.01 mg/L)
Daulatpur Niwan	0.0000	Compliant
Qila Nan	0.0078	Compliant
Sadasingh Wala	0.0136	Non-compliant
Kahnsingh Wala	0.0014	Compliant
Mean	**0.0156**	
Range	**0 - 0.153**	

3.3 Arsenic Levels in Moga

The analysis of Moga's water samples indicated concentrations ranging from 0 to 0.0137 mg/L, with a mean value of 0.0021 mg/L. None of the samples exceeded the WHO limit, but the presence of arsenic still raises concerns for long-term exposure.

Table 3: Arsenic Concentrations in Moga District

Village Name	Arsenic Concentration (mg/L)	Compliance with WHO Limit (0.01 mg/L)
Salena	0.0000	Compliant
Sher Singh Wala	0.0082	Compliant
Bhawan Kaur Singh	0.0028	Compliant
Mean	**0.0021**	
Range	**0 - 0.0137**	

Table 4: Summary of Arsenic Levels Across Districts

District	Mean Arsenic Concentration (mg/L)	Percentage of Non-compliant Samples
Bathinda	0.0569	30%
Faridkot	0.0156	15%
Moga	0.0021	0%

These tables and discussion points provide a clear overview of the findings and implications of the study on arsenic contamination in Punjab's groundwater.

3.4 Comparative Analysis

A comparative analysis of arsenic levels across the three districts is illustrated in Figure 1, highlighting the significant disparities in water quality and the need for targeted interventions.

4. Discussion

This section interprets the results, discussing the implications of arsenic contamination for public health and the environment.

4.1 Health Implications

The potential health risks associated with long-term exposure to arsenic in drinking water are examined. Chronic exposure can lead to various health issues, including:

- Skin lesions and keratosis.
- Increased risk of internal cancers, particularly bladder and lung cancer.
- Developmental effects in children, including cognitive impairments.

4.2 Environmental Factors

Factors contributing to arsenic contamination, such as geological formations, agricultural practices, and industrial activities, are analyzed. The study discusses how the natural geology of Punjab, combined with excessive groundwater extraction, exacerbates arsenic leaching into drinking water sources.

4.3 Socioeconomic Impact

The socioeconomic implications of arsenic contamination are also considered, particularly how it affects agricultural productivity and public health expenditures in affected communities.

5. Conclusion

The study concludes with a summary of findings and recommendations for future research and policy actions aimed at mitigating arsenic contamination in Punjab's groundwater. Key recommendations include:

- Regular monitoring of water quality in hand pumps.
- Public awareness campaigns about the risks of arsenic exposure.

Implementation of water purification technologies in affected areas.

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