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Assessing the Long-Term Effectiveness of Sustainable Rural Water Treatment Technologies in Mitigating Arsenic Contamination of Groundwater in Afghanistan

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Abstract

Arsenic contamination in groundwater is a pressing global concern, impacting more than fifty million individuals across seventy-plus countries. Various sources contribute to this contamination, including human activities, geological processes, and natural biological factors. Afghanistan, where groundwater serves as the primary drinking water source, faces a critical need for sustainable arsenic removal solutions. Currently, 78% of the population relies on household tub wells for safe drinking water, highlighting the urgency of addressing arsenic contamination. Recent studies have revealed alarming arsenic levels, with approximately 61% of water samples exceeding World Health Organization standards.This study aims to assess and compare existing arsenic removal technologies to determine their suitability for Afghan households. Three commonly used methods—Sono Sand Filter, Kanchan Arsenic Removal, and Arsenic Bio Sand Filter—will be evaluated based on their efficacy and practicality. Preliminary findings indicate that the Arsenic Bio Sand Filter exhibits the highest efficiency, achieving a removal rate of 95%. Furthermore, this method offers additional benefits such as reducing pathogens, bacteria, iron, and turbidity levels.

The ultimate goal of this research is to provide insights to policymakers and stakeholders, enabling them to develop effective mitigation strategies. By addressing arsenic-related health risks, these strategies can contribute to improving public health outcomes in Afghanistan.

Keywords: Arsenic, Contamination, Household, Groundwater

1. Introduction

Groundwater contamination with arsenic is a global issue affecting millions worldwide. Studies estimate that over 150 million people in more than 70 countries face health risks from arsenic in drinking water [1,2]. This includes countries like Bangladesh and India, where tens of millions are at risk case of high range of arsenic in drinking water [3,4]. Afghanistan faces a similar challenge. Groundwater serves as a primary source of drinking water for 78% of the population, accessed mainly through household wells [5,6]. Recent studies reveal concerning levels of arsenic contamination, with over 60% of samples exceeding the World Health Organization (WHO) guideline for safe drinking water. The source of this contamination appears to be natural and geological, impacting various regions across the country [7]. This widespread arsenic contamination poses a significant threat to public health. Studies link exposure to arsenic in drinking water with various health problems, including cancers and skin diseases [8,9]. Given the reliance on groundwater and the severity of the contamination, there's a critical need for sustainable water filtration technologies specifically designed for arsenic removal in Afghanistan [2,10]. This research aims to address the issue of arsenic contamination in Afghanistan's groundwater by reviewing global arsenic pollution trends, assessing current household water treatment technologies in developing countries, and identifying the most suitable arsenic removal method for Afghanistan's specific needs.

2. Methodology

The methodology employed in this study commenced with an extensive review of arsenic contamination issues spanning Asia, America, Africa, Europe, and specifically Afghanistan. This review involved an in-depth examination of arsenic treatment technologies commonly employed in developing nations, with a particular emphasis on identifying methodologies suitable for implementation within the Afghan context. Data analysis was conducted utilizing a combination of qualitative and quantitative techniques, drawing from both primary and secondary sources. Primary data collection methods included administering questionnaires, conducting interviews, making observations, and collecting samples. Meanwhile, secondary data sources comprised a range of published and unpublished reports, journal articles, guidelines, and policy documents. The collected data underwent analysis using various software tools, including Excel, SPSS, and X-connect, to derive meaningful insights. Standard methodologies recommended by reputable organizations such as the American Public Health Association (APHA), American Water Works Association (AWWA), and the Water Environment Federation (WEF) were adhered to throughout the analysis process.

Furthermore, Atomic Absorption Spectroscopy (AAS) was employed for the analysis of samples obtained from well water. These samples were tested in the ENPHO laboratory to detect arsenic concentrations both before and after filtration, ensuring accurate assessment of the efficacy of the employed arsenic removal technologies.

3. Results and Discussion

The examination of water samples collected from Bhairahawa village unveiled notable arsenic contamination, exceeding both the World Health Organization (WHO) guideline values and the Nepal Drinking Water Quality Standards (NDWQS). Table 1 below displays the findings derived from analyses conducted at the Environmental Public Health Organization (ENPHO) laboratory, showcasing divergent arsenic concentrations in both untreated and treated water samples:.

No- Sample	sample refers	Parameters	Concentration in Raw water	Efficiency Removal	Unit	Water Source and Types of Filters
1126	RW	As	0.07	Very good	mg/L	Well water (groundwater)
1127	FW	As	0.05		mg/L	Kanchan Filter
1128	RW	As	0.83	Not good	mg/L	Well water (groundwater)
1129	FW	As	0.23		mg/L	Sono Arsenic Filter
1130	RW	As	0.39	Excellent	mg/L	Well water (groundwater)
1131	FW	As	0.005		mg/L	Arsenic Bio Sand Filter

Table 1: Analysis Report and Water Test Results from the ENPHO Lab

These results underscore the severity of arsenic contamination in the village's water sources and emphasize the necessity for effective mitigation measures to safeguard public health. This study presents the results of an analysis conducted at the Environmental Public Health Organization (ENPHO) Lab using the Atomic Absorption Spectroscopy (AAS) method. The focus of the analysis was to assess the levels of arsenic contamination in groundwater samples collected from various sources across Nepal. The samples were divided into two categories: raw water (RW) and filtered water (FW), allowing for the evaluation of different filtration methods in reducing arsenic concentrations.

The analysis revealed varying levels of arsenic in the raw water samples, ranging from 0.07 mg/L to 0.83 mg/L. Subsequent filtration using Kanchan, Sono Arsenic, and Arsenic Bio Sand Filters resulted in significant reductions in arsenic concentrations in the filtered water samples. Specifically, the Kanchan Filter reduced arsenic levels to 0.05 mg/L, while the Sono Arsenic Filter achieved a concentration of 0.23 mg/L. Notably, the Arsenic Bio Sand Filter demonstrated the highest efficacy, yielding an arsenic concentration of 0.005 mg/L.

These findings highlight the importance of employing effective filtration methods for mitigating arsenic contamination in groundwater. The Arsenic Bio Sand Filter, in particular, emerges as a promising solution for addressing arsenic contamination effectively. Further research and implementation of such filtration technologies are crucial for ensuring access to safe drinking water in regions affected by arsenic contamination.

Water quality parameters	Range of concentration in raw water	% of Raw water Exceeding the NDWQS	Removal efficiency by ABSF (%)	References
AS (PPb)	91.57	80 – 54	83	(Uddin et al , 2007)
Fecal coliform (cfu/100 mg)	72.86	90	97	(Tahura et al ,1998)
Iron (mg/L)	0 -5	79	100	(Luqman et al , 2013)
Hardness (mg/L)	19-664	1	7	(Ahksorn & Visoottiviseth, 2004)
pH	6- 7.5	40	----------	(Hossain et al ,2016)
Phosphate (mg/L)	0 – 2	80	75	(Geroni et al , 2002)

Table 2: Overall Water Quality Test Results and Removal Efficiency by ABSF

The table.2 presents an assessment of water quality parameters and removal efficiency by the Arsenic Bio Sand Filter (ABSF), based on data collected from various sources in an undisclosed region. The analysis covers a range of parameters including arsenic concentration, fecal coliform levels, iron content, water hardness, pH, and phosphate concentration. Results indicate that arsenic levels in raw water samples ranged from 54 to 91.57 parts per billion (PPb), with 80% of samples exceeding the National Drinking Water Quality Standards (NDWQS) [11,12]. The Arsenic Bio Sand Filter (ABSF) exhibited a notable removal efficiency of 83% for arsenic contamination, indicating its effectiveness in addressing this specific water quality issue. However, despite this success, challenges persist regarding other crucial parameters. Fecal coliform levels were found to be high, with an average measurement of 72.86 colony-forming units per 100 milligrams (cfu/100 mg). Alarmingly, 90% of samples exceeded the National Drinking Water Quality Standards (NDWQS), indicating potential risks to public health. Iron concentrations displayed significant variability, ranging from 0 to 5 milligrams per liter (mg/L). A substantial portion, accounting for 79% of samples, exceeded the NDWQS, underscoring the presence of iron contamination in the water sources. Water hardness levels also varied widely, ranging from 19 to 664 mg/L. While only a small percentage (1%) exceeded the NDWQS, the range suggests diverse mineral content, which could impact water quality and usability. pH levels ranged from 6 to 7.5, with 40% of samples exceeding NDWQS thresholds. Fluctuations in pH can affect water chemistry and influence its suitability for various applications, including drinking and irrigation. Phosphate concentrations ranged from 0 to 2 mg/L, with 80% of samples exceeding NDWQS limits. Elevated phosphate levels can lead to eutrophication and negatively impact aquatic ecosystems [13-16]. Further research is warranted to optimize water treatment methods and ensure safe drinking water access for all.

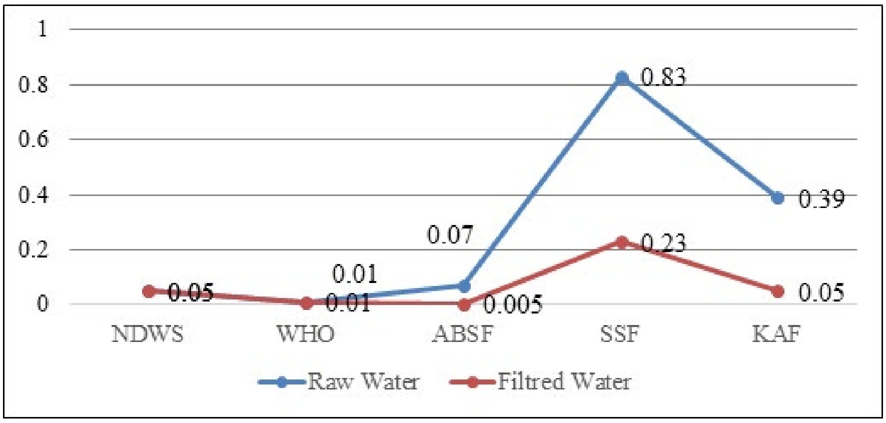

Figure 1: A Comparison Between Raw and Filtered Water Samples Against the Guideline Values Established by the WHO

Additionally, a study conducted by aimed to assess the magnitude of arsenic contamination across several provinces, with a specific focus on areas such as Ghazni, Panjshir, and Logar. Through the analysis of 1756 water samples, the study revealed alarming levels of arsenic exceeding the guidelines set by the World Health Organization (WHO). Particularly concerning was Ghazni province, which recorded the highest contamination rate at 61% [17].

4. Conclusion

In conclusion, addressing the widespread issue of elevated arsenic contamination in groundwater requires prioritizing the sustainability of water treatment technologies for arsenic removal. Anthropogenic activities such as agriculture, industry, and sewage significantly contribute to arsenic levels in drinking water sources. A study conducted in Ghazni and Midanwardek provinces of Afghanistan highlighted alarming rates of arsenic contamination in groundwater, with approximately 61% of samples surpassing the WHO standard of 0.01 mg/L. Oxidation methods, which involve controlled oxidation with air followed by filtration, show promise for arsenic treatment. A notable distinction among arsenic removal methods lies in the iron-based absorption mechanism, particularly evident in the Arsenic Bio Sand Filter compared to conventional sand filters. Through evaluation based on a ranking system, the Arsenic Bio Sand Filter emerged as the most efficient and suitable method for household arsenic removal, recommended for implementation in Afghanistan.

Furthermore, sustainable household arsenic removal systems have been found to be effective in significantly reducing arsenic levels, while also removing bacteria, sediments, and iron. The design of these systems, tailored for individual households, has demonstrated impressive arsenic removal rates, typically reaching 95%, alongside substantial reductions in bacteria and other contaminants.

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