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 poses a significant global risk, affecting over fifty million people across more than seventy countries. Sources of contamination include anthropogenic, geogenic, and biogenic factors. In Afghanistan, where groundwater serves as a primary drinking water source, the need for sustainable arsenic removal technologies is paramount. Presently, 78% of the population relies on groundwater accessed through household tub wells for safe drinking water. Recent studies indicate alarming levels of arsenic contamination, with around 61% of water samples exceeding World Health Organization standards. This research aims to evaluate and compare existing arsenic removal technologies, focusing on their suitability for households in Afghanistan. Three popular methods, including Sono Sand Filter, Kanchan Arsenic Removal, and Arsenic Bio Sand Filter, will be assessed based on their effectiveness and feasibility. Preliminary findings suggest Arsenic Bio Sand Filter as the most efficient method, with a removal effectiveness of 95% and additional benefits in pathogen, bacteria, iron, and turbidity reduction. Ultimately, this study seeks to inform policymakers and stakeholders to develop mitigation strategies, thereby reducing arsenic-related health risks and improving public health outcomes in Afghanistan.

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 (WHO, 2001 and U.S,2002,). This includes countries like Bangladesh and India, where tens of millions are at risk case of high range of arsenic in drinking water (Ahuja, 2015 and Ahmed,2001). Afghanistan faces a similar challenge. Groundwater serves as a primary source of drinking water for 78% of the population, accessed mainly through household wells (Safi et al, 2016 and Katsoyiannis et al ,2014). Recent studies reveal concerning levels of arsenic contamination, with over 60% of samples exceeding the World Health Organization (WHO) guideline for safe drinking water (Asante and Ntow,2009). The source of this contamination appears to be natural and geological, impacting various regions across the country (Ahksorn and Visoottiviseth, 2004). 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 (Thakur et al, 2010 and Van et al, 2009). 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 (U.S & EPA 2002, Shaw et al 2010). 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 involved a comprehensive review of arsenic contamination issues across Asia, America, Africa, Europe, and specifically in Afghanistan. This review encompassed
an examination of arsenic treatment technologies utilized in developing nations, with a focus on identifying the most appropriate methods for implementation in Afghanistan. Data analysis utilized both qualitative and quantitative techniques, drawing from primary and secondary sources. Primary data collection methods included questionnaires, interviews, observations, and sampling, while secondary data sources comprised published and unpublished reports, journal articles, guidelines, and policy documents. Data analysis was conducted using Excel, SPSS, and X-connect software. Standard methods recommended by the American Public Health Association (APHA), American Water Works Association (AWWA), and the Water Environment Federation (WEF) were employed, with Atomic Absorption Spectroscopy (AAS) utilized for analyzing samples collected from well water in the ENPHO laboratory to detect arsenic concentrations before and after filtration.

3- Results and Discussion

The analysis of water samples from Bhairahawa village revealed significant arsenic contamination, surpassing WHO guideline values and Nepal Drinking Water Quality Standards (NDWQS). Table 1 presents the results obtained from the Environmental Public Health Organization (ENPHO) laboratory, indicating varying arsenic concentrations in raw and filtered water samples.

Table 1 Analysis report and water test results from the ENPHO Lab

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

This study presents the findings of an analysis conducted at the ENPHO Lab by AAS method, focusing on the assessment of arsenic contamination levels in groundwater samples from various sources in Nepal. The samples were categorized as either raw water (RW) or filtered water (FW) to observe the effectiveness of different filtration methods in reducing arsenic concentrations. Results indicated varying arsenic levels in RW samples, ranging from 0.07 mg/L to 0.83 mg/L. Following filtration using Kanchan, Sono Arsenic, and Arsenic Bio Sand Filters, the arsenic concentrations in FW samples decreased significantly. 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 exhibited the highest efficacy, yielding an arsenic concentration of 0.005 mg/L. These findings underscore the importance of utilizing effective filtration methods, with the Arsenic Bio Sand Filter emerging as a promising solution for mitigating arsenic contamination in groundwater.

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

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

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) (Udmale et al, 2016 and Ngai & Walewijk, 2003). The ABSF demonstrated an impressive removal efficiency of 83% for arsenic. Fecal coliform levels were found to be 72.86 colony-forming units per 100 milligrams (cfu/100 mg), with 90% of samples exceeding NDWQS. Iron concentrations ranged from 0 to 5 milligrams per liter (mg/L), with 79% exceeding NDWQS, while water hardness ranged from 19 to 664 mg/L, with only 1% exceeding NDWQS. The pH levels ranged from 6 to 7.5, with 40% of samples exceeding NDWQS. Phosphate concentrations ranged from 0 to 2 mg/L, with 80% exceeding NDWQS. These findings highlight the effectiveness of the ABSF in reducing arsenic contamination, albeit challenges persist with other water quality parameters (Rahman et al, 2009, Munir and Rasul, 2001, Sthiannopkao et al, 2008, Saxena, 2012 and ). Further research is warranted to optimize water treatment methods and ensure safe drinking water access for all.

Furthermore, in another study by (UNICEF, 2012) assesses the extent of arsenic contamination across various provinces, focusing on areas such as Ghazni, Panjshir, and Logar. Analysis of 1756 water samples reveals alarming levels of arsenic exceeding WHO guidelines, with Ghazni registering the
highest contamination rate at 61%. The natural geological origin of arsenic pollution exacerbates the problem, leading to both acute and chronic health effects, including cancer and various organ diseases. The study underscores the urgent need for comprehensive interventions to mitigate arsenic contamination and ensure access to safe drinking water in affected regions, particularly in high-risk areas like Ghazni province.

4- Conclusion

In conclusion, the sustainability of water treatment technologies for arsenic removal is paramount in addressing the widespread issue of elevated arsenic contamination in groundwater. Anthropogenic activities, including agriculture, industry, and sewage, contribute significantly to arsenic levels in drinking water sources. A study conducted in Ghazni and Midanwardekh provinces of Afghanistan revealed 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 difference between 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 were found to be effective in significantly reducing arsenic levels, along with removing bacteria, sediments, and iron. The design of these systems, tailored for individual households, demonstrated impressive arsenic removal rates, typically reaching 95%, alongside substantial reductions in bacteria and other contaminants. Overall, the findings underscore the importance of implementing sustainable arsenic removal technologies to ensure access to safe drinking water and mitigate the adverse health effects associated with arsenic contamination.

Declarations

Author Contribution

A.W.A. and A.P.A. conceived and designed the study (A.W.A., A.P.A.). A.W.A. conducted fieldwork and collected data (A.W.A.). A.W.A. and A.P.A. analyzed and interpreted the data (A.W.A., A.P.A.). A.W.A. drafted the manuscript (A.W.A.). A.P.A. provided critical revisions and editing (A.P.A.). All authors reviewed and approved the final version of the manuscript (A.W.A., A.P.A.).

References


**Figures**

![Figure 1](image-url)
Compares raw and filtered water samples to WHO guideline values