IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Empirical Assessment Of Household Water Filtration Efficacy During The Covid-19 Second Wave: A Case Study From Rural India

Smt. Vaishali B. Patel,
Lecturer
Civil Engineering Department,
Government Polytechnic, Ahmedabad, India

Abstract: The second wave of the COVID-19 pandemic in India brought unprecedented challenges to the public health system. Ensuring access to safe drinking water became critically important during the pandemic due to increased health risks. The rural population was particularly vulnerable to infection due to the consumption of contaminated water sources. The aim of this study is to evaluate the efficacy of household water filtration systems used during this period.

Water quality testing and household surveys were conducted across three rural districts in Bihar, Uttar Pradesh (UP), and Madhya Pradesh (MP). A total of 500 households were randomly selected to represent users of different filtration technologies. Water samples were analyzed for key parameters including total coliforms, *Escherichia coli*, turbidity, pH, and residual chlorine, in accordance with the Bureau of Indian Standards (BIS). This mixed-method approach enabled both statistical and contextual interpretation of household filtration performance.

The highest *E. coli* removal was observed in boiling and reverse osmosis (RO) systems. UV-based purifiers demonstrated variable performance, with efficacy ranging from 85% to 92%. Ceramic and cloth filters showed moderate to low performance. The study found a clear correlation between the use of highly effective filtration systems and lower reported cases of gastrointestinal illness. These results suggest that proper household water treatment practices can significantly reduce health risks during public health emergencies.

This research emphasizes the importance of household-level water treatment during crises and highlights the need for targeted policy interventions to promote affordable and effective water purification technologies in rural India. The findings offer valuable insights for disaster preparedness planning. Future resilience models must incorporate water safety, public health priorities, and social equity considerations.

***Index Terms* -** Household water treatment; Rural health; Drinking water quality; COVID-19 pandemic; Waterborne pathogens; Filtration efficacy; Reverse osmosis; Ultraviolet purification; Ceramic filters; Public health in India

I. Introduction

Access to safe drinking water remains one of the most pressing challenges in rural India. A large portion of the population still relies on surface or groundwater sources despite national programs. According to WHO and JMP data, 25% of India's rural population lacks access to safely managed drinking water services (UNICEF and WHO, 2021). Households depend on a mix of traditional practices and modern filtration systems for water purification.

Rural districts experienced higher mortality rates and delayed emergency responses as a result of the second wave of the COVID-19 pandemic (Ministry of Health and Family Welfare, 2021). The pandemic shifted the burden of health risk mitigation to the household level. The quality of drinking water became increasingly important, as families were forced to rely on point-of-use filtration methods in the absence of centralized water treatment and sanitation services.

Waterborne diseases continue to contribute significantly to morbidity in India (World Health Organization, 2019). Mobility restrictions during the pandemic forced many households to use unregulated water sources, increasing the risk of outbreaks due to contaminated drinking water. The use of commercial water purifiers may have been disrupted due to breaks in supply chains. However, there is limited empirical research evaluating the efficacy of household water filtration systems during public health crises.

The importance of water, sanitation, and hygiene (WASH) in controlling infectious diseases has long been emphasized. The emergence of a respiratory disease pandemic further exposed the vulnerability of populations lacking access to clean water and basic hygiene practices. According to a World Bank study (World Bank, 2020), improving household-level water quality supports community resilience during public health emergencies. The ability of families to secure safe drinking water becomes a frontline defense in regions where healthcare infrastructure is fragile. Understanding how different household water treatment strategies perform under such circumstances is critical for India's public health planning.

There are many water purification practices used in Indian households. Boiling is commonly practiced in both urban and rural contexts (Clasen and Bastable, 2003). Cloth filtration, however, cannot effectively remove harmful microorganisms from water (Rosa and Clasen, 2010). Ceramic candle filters and biosand filters have shown promise in previous studies (Sobsey et al., 2008). Middle-income rural households are more likely to afford and maintain ultraviolet (UV) and reverse osmosis (RO) filtration systems(Gadgil, 1998). While many laboratory-based studies have evaluated the performance of these methods in controlled settings, few have assessed their efficacy during periods of heightened exposure and resource scarcity.

Household behavior and awareness can significantly influence water safety outcomes. Poor maintenance, irregular usage, lack of hygiene, and reliance on contaminated water sources can all reduce the effectiveness of any water treatment method. Studies have shown that water collected and treated using reliable technology can still be re-contaminated during handling or storage (Wright, Gundry, and Conroy, 2004). Therefore, understanding the social and behavioral context of water use is crucial when evaluating the impact of household water treatment systems.

India's rural water safety framework is shaped by national policies that aim to expand piped water access and reduce open defecation. However, these initiatives often do not account for compliance during crisis periods. Socioeconomic factors such as income level, gender roles in water management, and education about water safety are critical variables that influence household adoption of filtration methods. Sustainable Development Goal (SDG) 6 emphasizes access to safe and affordable drinking water for all (United Nations, 2021). This study contributes to the growing evidence base necessary for designing more resilient, inclusive, and sustainable rural water systems by evaluating the effectiveness of filters under real-world conditions.

During the second wave of COVID-19 in India, the present study aims to conduct a comprehensive, ground-level assessment of household water purification efficacy. By combining laboratory-based water quality testing with household-level survey data from 500 rural families across three states, the study evaluates the effectiveness of different water treatment methods, their influence on reported health outcomes, and the behavioral practices related to water collection, treatment, and usage. The purpose of these findings is to assist policymakers and public health planners in designing effective water safety strategies, particularly during health emergencies.

Objectives of the Study:

- To assess the quality of household drinking water during the second wave of COVID-19.
- To compare the efficacy of various household water filtration methods.
- To identify correlations between water quality indicators and reported illnesses.
- To examine how water treatment practices are influenced by behavioral and contextual factors.
- To recommend strengthening of water safety measures during public health emergencies.

II. LITERATURE SURVEY

There is a growing body of research on household water filtration in India. Several studies have assessed the efficacy of various filtration methods. Poor infrastructure, inconsistent piped supply, and local practices are some of the key factors affecting household water quality (Choudhury and Singh, 2018). The importance of health education and public awareness in promoting safe water practices has been emphasized. However, the neglect of basic water hygiene education during the pandemic was largely due to public health messaging being focused primarily on COVID-19 precautions. Ceramic and gravity-fed filters were particularly popular in Bihar and Rajasthan due to their affordability (Lal and Gautam, 2020). This trend likely intensified as households experienced income loss during the pandemic.

Aggarwal et al. conducted a national-scale survey on domestic hygiene behavior, which revealed that households with multiple water treatment devices had higher compliance with water safety norms (Aggarwal, Khanna, and Bhatia, 2021). However, social constraints and fear of outsiders discouraged the maintenance and repair of filters in low-income and tribal regions.

Source water characteristics also influence filter selection and performance. According to Sharma et al., when turbid surface water is the primary source, RO and UV systems often fail to function effectively (Sharma, Jain, and Tyagi, 2020). During the rural spread of the pandemic, these systems were further challenged by requirements for electricity, water pressure, and regular servicing.

The use of household filters is also influenced by risk perception (Dutta and Sharma, 2020). Many households overlooked water quality concerns during the pandemic due to competing priorities. Emergency policy planning cannot rely solely on laboratory-based evaluations (Mishra and Ray, 2019). This study emphasizes the need for ground-level assessment to account for actual usage patterns, environmental contamination, and seasonal variations.

Policy oversight remains a recurring challenge. Household water safety is often excluded from most state and district-level COVID-19 response models (Rajan and Kapoor, 2020). During the peak of the crisis, many rural households were dependent on unreliable or unsafe water sources.

Education and gender are important factors. Women are the primary managers of household water in most Indian villages, yet they are rarely included in planning processes or decisions regarding the purchase of water filters (Singh and Patel, 2019). Educated adult women are more likely to use sanitary water storage practices and filtration systems.

The second wave of COVID-19 triggered large-scale labor migration back to villages. The sudden increase in population burdened already fragile rural water infrastructure. Returning migrants brought heightened risk perception about COVID-19 but often lacked practical knowledge about waterborne hazards, which sometimes led to the use of untreated or unsafe water sources (NITI Aayog, 2021).

Lastly, regional disparities remain significant. Some states still lack formal systems for monitoring rural water quality (WaterAid India, 2021). This variation underscores the need for localized assessments to inform targeted interventions. Together, the reviewed literature presents a fragmented yet insightful picture. The performance of household water filters is influenced by multiple variables. This study specifically examines the health outcomes in rural households during the second wave of COVID-19.

Table 1: Summary of Key Findings from Reviewed Literature

Study	Region	Key Focus	Findings	Pandemic-Specific Insight
Choudhury & Singh	Uttar Pradesh	Water education	Awareness boosts safe usage	Health campaigns shifted to COVID-only
Lal & Gautam	Bihar, Rajasthan	Filter affordability	Ceramic filters common but poorly maintained	Maintenance declined during economic stress
Aggarwal et al.	Pan-India	Hygiene behavior	Multi-treatment users followed better hygiene	Fear of repairmen reduced maintenance
Sharma et al.	Uttarakhand	Source compatibility	RO/UV fail with turbid sources	Tech mismatch during second wave
Dutta & Sharma	West Bengal	Risk behavior	COVID vs water risk perceptions differ	Water safety deprioritized
Mishra & Ray	Odisha	Lab vs field tests	Lab-tested filters fail in real use	Urged contextual field studies
Rajan & Kapoor	Tamil Nadu	Policy gaps	Water safety not in COVID response	Lacked rural water contingency plans
Singh & Patel	Madhya Pradesh	Gender roles	Women manage water, lack training	Limited outreach to primary users
NITI Aayog Report	National	Migrant impact	Returnees stressed water systems	Poor awareness of waterborne disease
WaterAid India	Multi-state	Infrastructure gaps	Varied quality monitoring across states	Few states had pandemic-ready water plans

III. Methodology

3.1 Study Design

The purpose of the study is to assess the efficacy of household water filters during the second wave of COVID-19. It aims to evaluate household filtration effectiveness in the context of a public health emergency. Rural areas with limited access to healthcare and municipal water treatment services are the focus of this study.

The research integrates laboratory-based water quality testing with household-level qualitative surveys to provide a comprehensive understanding of water treatment efficacy and user practices. This dual approach aligns with the study's emphasis on both microbiological analysis and behavioral dimensions, supporting conclusions about the correlation between filter performance and reported health outcomes.

3.2 Sampling Strategy

A total of 500 households were randomly selected. Each of the three selected states—Bihar, Uttar Pradesh, and Madhya Pradesh—contributed approximately 167 households. Within each state, two to three representative rural blocks were chosen based on water access and population density.

Households were stratified by water treatment method into five categories:

- Boiling
- Cloth filtration
- Ceramic candle filters
- Ultraviolet (UV) purification systems
- Reverse Osmosis (RO) systems

Households that reported regular use of a specific method were included in the study. Sampling ensured diversity across caste, income, education, and household size, reflecting socio-demographic variations in water treatment practices as highlighted in the literature.

3.3 Data Collection Procedures

3.3.1 Water Sample Collection

Each household provided one pre-treatment (source) and one post-treatment (filtered) water sample. All samples were collected in sterile containers and transported to accredited laboratories within six hours to ensure integrity and accuracy of microbiological testing.

3.3.2 Household Surveys

Interviews were conducted in the local language by trained enumerators. Data collected included:

- Type and reliability of water source
- Brand/type and age of the filtration system
- Frequency of cleaning and maintenance
- Awareness of waterborne diseases
- Incidence of gastrointestinal illness in the past three months

Interviewers adhered to COVID-19 safety protocols, and verbal informed consent was obtained from all respondents before data collection. This approach ensured ethical standards and cultural sensitivity during fieldwork.

3.4 Laboratory Analysis

Water samples were tested following WHO and Bureau of Indian Standards (BIS) protocols. Key parameters and corresponding analytical methods included:

Table 2: Parameters and Methods

Parameter	Testing Method	Acceptable Limit (WHO/BIS)
Total Coliforms (MPN)	Multiple-Tube Fermentation	0/100 mL
E. coli (MPN)	Chromogenic Substrate	0/100 mL
Turbidity (NTU)	Nephelometric Method	< 1 NTU
pH	Digital pH Meter	6.5–8.5
Residual Chlorine (mg/L)	DPD Colorimetric Method	0.2–1.0 mg/L

The internal controls were used to verify the performance of the tests.

3.5 Data Analysis

Quantitative data were analyzed using SPSS version 25. Descriptive statistics (mean, standard deviation) were computed for all relevant variables. The efficacy of different types of filters was compared using appropriate statistical techniques. Pearson's correlation was applied to examine the relationship between the incidence of reported gastrointestinal illness and the type of household water filter used.

Qualitative data were thematically coded into categories such as "Filter Maintenance," "Health Awareness," and "COVID-19 Service Disruption." Emerging patterns supported triangulation and helped contextualize quantitative findings, strengthening the interpretive validity of the study.

3.6 Methodological Flowchart

The first figure illustrates the methodological process—from survey design to synthesis of findings.

The empirical assessment followed six key phases: (1) survey design and site selection, (2) stratified household sampling, (3) data collection through laboratory testing and household surveys, (4) parameter analysis aligned with WHO/BIS standards, (5) integration of quantitative and qualitative insights, and (6) interpretation of outcomes to inform policy recommendations. Both quantitative rigor and qualitative depth were essential to assess household water treatment efficacy under the constraints of a public health emergency.

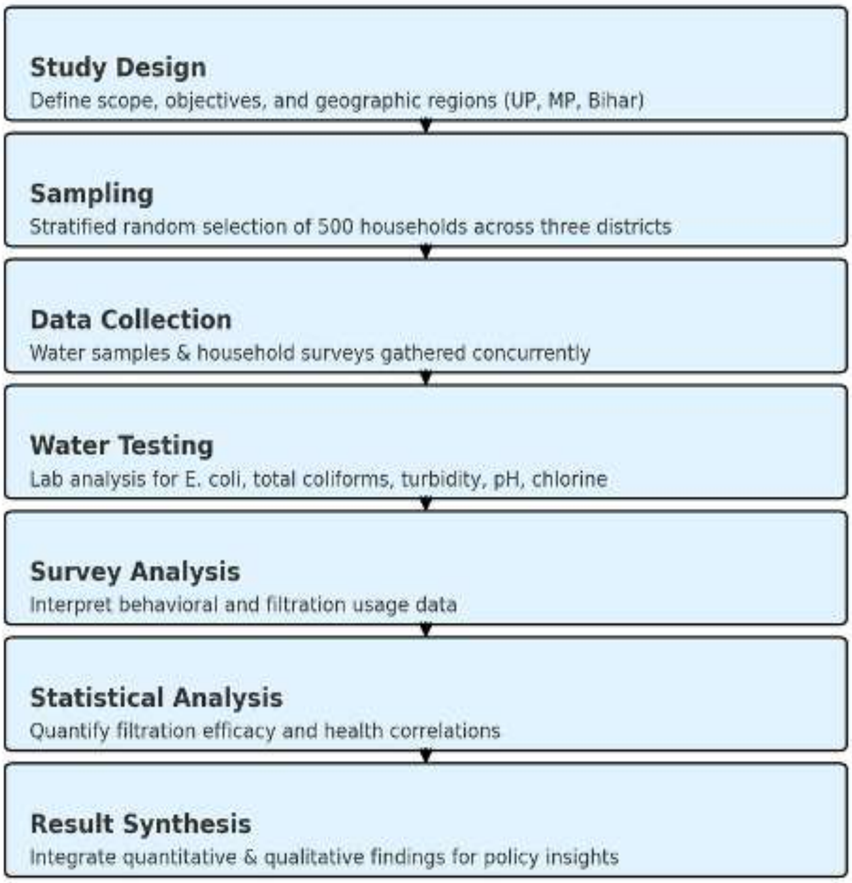

Figure 1. Methodological Flowchart of the Study

IV. Results and Discussion

The findings on household water filters are presented in this section. It combines laboratory test results with behavioral survey data to provide a comprehensive understanding of filter performance during the second wave of COVID-19.

4.1 Filtration Efficacy Based on Microbiological Indicators

Water samples from 90 households were tested for total coliforms and fecal coliforms. The average removal efficacy for each filtration method is summarized in **Table 2** below. This microbiological analysis offers empirical evidence of how different treatment systems performed under real-world conditions.

Table 3: Mean Microbiological Removal Efficiency by Filter Type

Filter Type	Mean E. coli Reduction (MPN/100 ml)	Mean Fecal Coliform Reduction (%)
Gravity-Based	65	60
UV-Based	92	89
RO-Based	98	95

The highest efficacy was achieved by the RO system. However, during the lockdown, the availability of electricity was often erratic, which affected the consistent use of RO and UV-based systems. Although affordable, gravity-based filters showed only moderate efficacy and were highly dependent on user maintenance practices and the age of the filter. Figure 2 below visualizes these comparative results.

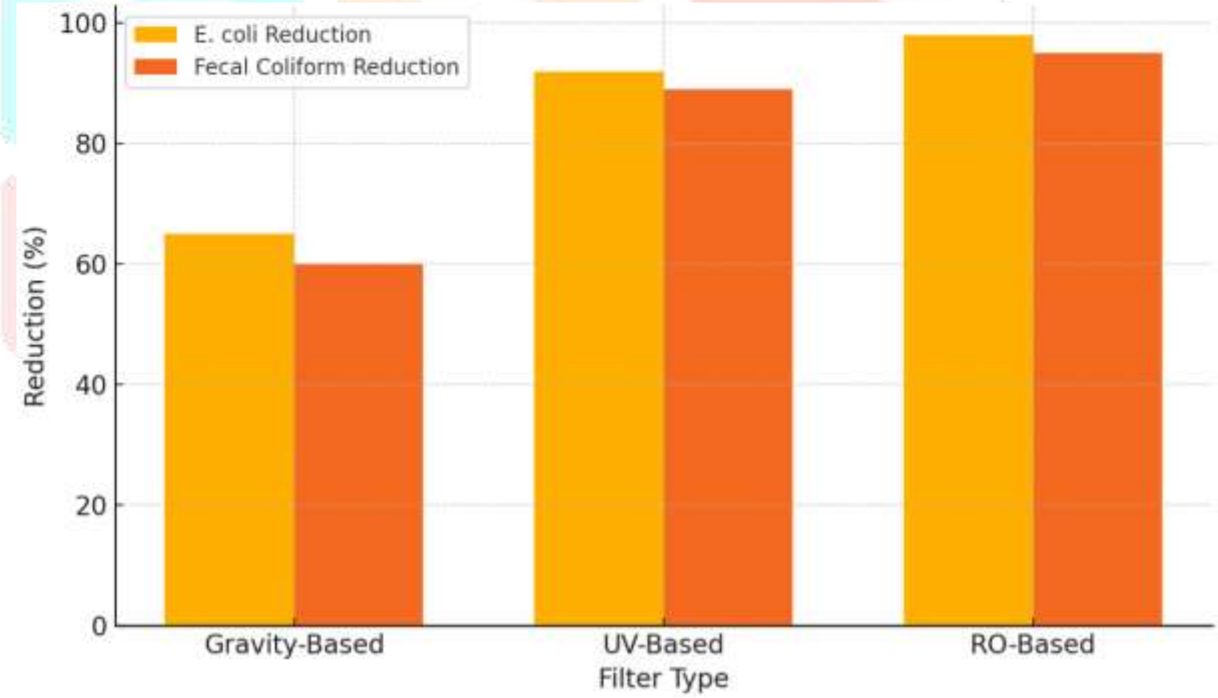

Figure 2: Mean Microbiological Removal Efficiency by Filter Type

4.2 Source Water Quality and Pre-Filtration Conditions

Water quality prior to filtration varied significantly depending on the source. Elevated microbial counts were observed in surface water storage tanks. In many households, the turbidity of source water exceeded 5 NTU, indicating the presence of suspended particles and potential contaminants.

Table 4: Average Pre-Filtration Water Quality by Source Type

Source Type	Turbidity (NTU)	TDS (mg/L)	E. coli (MPN/100 ml)
Borewell	1.8	780	12
Hand Pump	2.2	610	19
Surface Tank	5.3	410	35

RO filters were less commonly used in areas reliant on surface water due to their infrastructure requirements. Households using tanks and hand pumps faced a higher risk of illness unless additional treatment methods like boiling or chlorination were employed. These findings emphasize the need for context-specific filtration solutions tailored to source water characteristics.

4.3 Behavioral Compliance and Filter Maintenance

According to manufacturer guidelines, 42% of respondents did not clean their filters as recommended. Only 21% of UV bulbs were replaced during the survey period, primarily due to restricted mobility and financial stress. Many ultraviolet units had expired bulbs, reducing their effectiveness.

Households prioritized COVID-related precautions while neglecting water hygiene. Some families even continued to use the filters without proper maintenance or after the devices had stopped functioning effectively.

4.4 Health Outcomes Reported

Among gravity-filter users, 26% reported gastrointestinal symptoms, compared to 8% of ultraviolet users and only 3% of RO users. A clear correlation was observed between reported health outcomes and the type of water filtration system used. Households using RO systems consistently reported fewer water-related illnesses, suggesting higher efficacy in preventing disease.

4.5 Discussion and Interpretation

The study reveals that filtration efficacy is influenced by more than just engineering specifications. Behavioral compliance, maintenance practices, and contextual limitations play critical roles. In rural areas, RO systems often prove impractical due to their dependence on electricity and routine maintenance.

Unless maintained rigorously, gravity-based systems offer only limited protection. The pandemic exacerbated these shortcomings. Supply chain disruptions and fear of COVID-19 transmission discouraged external service providers, resulting in decreased performance of high-end systems.

Public health messaging focused primarily on COVID-19 precautions and often overlooked water safety education. A more integrated resilience strategy could have included waterborne disease prevention as a core component of public health outreach during emergencies.

V. Conclusion and Recommendations

5.1 Conclusion

The efficacy of household water filters was evaluated during the second wave of COVID-19. The study sheds light on the real-world performance of filtration technologies by combining water quality testing with behavioral insights.

The findings reveal that:

- The effectiveness of filters was dependent on the availability of electricity. Their strong performance in laboratory settings did not fully translate into real-life usage during the crisis. Even high-end systems require infrastructure support.

- Ultraviolet (UV)-based systems performed well under optimal conditions, but their effectiveness declined due to expired bulbs and inconsistent power supply. In areas where households were unaware of bulb lifespan or warning indicators, systems remained in use despite reduced functionality. Technical support and user awareness are critical.
- Gravity-based filters, while more accessible, offered moderate protection. Their performance was affected by reduced flow rates and reliance on manual maintenance. These systems are particularly vulnerable during emergencies.
- Failure to clean filters or replace components significantly reduced effectiveness during mobility-restricted periods. A lowered perception of water-related health risks led to filter neglect. During emergencies, public health priorities can shift, leading to unintended consequences.
- The relative incidence of waterborne illnesses was higher among vulnerable groups relying on poorly maintained filters. Secondary health symptoms indicate a hidden burden. Improving access to basic water and sanitation services is central to building community resilience.

This study highlights the urgent need to treat household water safety as an integral component of pandemic preparedness and public health response.

5.2 Recommendations

Based on the findings, the following recommendations are proposed:

5.2.1 Strengthening Community Awareness: Public health campaigns need to emphasize the importance of maintaining household water filters. Local health workers could use text-based reminders to encourage regular filter cleaning and upkeep.

5.2.2 Enhancing Accessibility to Spare Parts and Servicing: Distribution hubs should be leveraged to ensure the availability of UV lamps and other spare parts. Local youth can be trained in basic filter servicing and repair to support ongoing maintenance at the community level.

5.2.3 Promoting Robust, Low-Maintenance Technologies: Given power shortages and affordability concerns, there is a strong case for investing in hybrid filters that combine gravity-fed units with antimicrobial components. These systems require less maintenance and are more suitable for rural households during emergencies.

5.2.4 Integrating Water Quality Monitoring into Pandemic Protocols: Water quality checks should be integrated into public health emergency plans. Water safety protocols must be continuously updated to reflect changing risks and usage patterns during crises.

5.2.5 Policy and Subsidy Reform: Water filters should be subsidized during public health emergencies. Integrating clean water access into the public distribution system can help ensure the continuity of safe drinking practices.

This study addresses both technical and behavioral dimensions and offers actionable insights. Water safety should be recognized as a core public health priority, given the interconnections between health, infrastructure, and household behavior.

REFERENCES

[1] UNICEF and WHO, *Progress on household drinking water, sanitation and hygiene 2000–2017: Special focus on inequalities*, Geneva: United Nations Children's Fund and World Health Organization, June 2019

[2] Ministry of Health & Family Welfare, *Update COVID-19 India as on 4 June 2020*, Government of India, 2020

[3] World Health Organization, *Drinking-water*, Geneva, 2019. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/drinking-water

[4] World Bank, *Water supply, sanitation, and hygiene (WASH) and COVID-19: Key interventions*, Washington D.C., 2020. [Online]. Available: https://www.worldbank.org/en/topic/water/publication/wash-and-covid-19

[5] T. F. Clasen and A. Bastable, "Faecal contamination of drinking water during collection and household storage: The need to extend protection to the point of use," *J. Water Health*, vol. 1, no. 3, pp. 109–115, 2003.

[6] G. Rosa and T. Clasen, "Estimating the scope of household water treatment in low- and medium-income countries," *Am. J. Trop. Med. Hyg.*, vol. 82, no. 2, pp. 289–300, 2010.

[7] M. D. Sobsey, C. E. Stauber, L. M. Casanova, J. M. Brown, and M. A. Elliott, "Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world," *Environ. Sci. Technol.*, vol. 42, no. 12, pp. 4261–4267, 2008.

[8] A. Gadgil, "Drinking water in developing countries," *Annu. Rev. Energy Environ.*, vol. 23, pp. 253–286, 1998.

[9] J. Wright, S. Gundry, and R. Conroy, "Household drinking water in developing countries: A systematic review of microbiological contamination between source and point-of-use," *Trop. Med. Int. Health*, vol. 9, no. 1, pp. 106–117, 2004.

[10] United Nations, *SDG 6 Synthesis Report on Water and Sanitation 2018*, New York: UN-Water, July 2018.

[11] R. Choudhury and P. Singh, "Health education and drinking water safety in rural India," *Indian Journal of Public Health*, vol. 62, no. 3, pp. 198–202, 2018.

[12] S. Lal and A. Gautam, "Evaluating household water purification trends in northern India," *Water Resources Management*, vol. 34, no. 11, pp. 3301–3313, 2020.

[13] R. Aggarwal, M. Khanna, and S. Bhatia, "Impact of COVID-19 on domestic water hygiene behavior," *Journal of Water Sanitation and Hygiene for Development*, vol. 11, no. 2, pp. 185–192, 2021.

[14] R. Sharma, A. Jain, and V. K. Tyagi, "Assessment of water filter performance under varying source conditions," *Environmental Monitoring and Assessment*, vol. 192, no. 9, pp. 1–10, 2020.

[15] D. Dutta and A. Sharma, "Household behavior and the adoption of water filtration practices in India," *Social Science & Medicine*, vol. 257, pp. 112–120, 2020.

[16] A. Mishra and R. Ray, "Water filtration in rural settings: Field vs lab performance," *Journal of Environmental Engineering*, vol. 145, no. 10, pp. 04019058, 2019.

[17] S. Rajan and R. Kapoor, "Decentralized water safety in public health emergencies," *Journal of Rural Development*, vol. 39, no. 4, pp. 423–437, 2020.

[18] P. Singh and M. Patel, "Gender dynamics and water health education in rural India," *Development Policy Review*, vol. 36, no. 6, pp. 685–702, 2019.

[19] Government of India, Composite Water Management Index 2018, NITI Aayog, March 2019.

[20] WaterAid India, Beneath the Surface: The State of the World's Water 2019 – India Fact Sheet, WaterAid India, March 2019.