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Water Insufficiency and its Health Impacts: Correlating Safe Water Access with Disease Prevalence in India's Highland & Highland Villages & Rural Villages

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ABSTRACT

Water insufficiency is an increasing worldwide issue with major consequences for public health, especially in poorer nations. This study investigates how public health in highland villages & rural India where access to sufficient and clean water still presents a major obstacle is affected by water insufficiency. Using a thorough investigation of official records from 20002023, current literature, and field investigations conducted between 2010-2023, this study explores the complex interaction between water insufficiency and several health effects. The analysis primarily utilizes data from the National Family Health Survey (NFHS-5, 2019-21) and compares it with earlier surveys (NFHS-4, 2015-16) to establish trends. The study investigates how water insufficiency affects waterborne infections, malnutrition, sanitationrelated ailments, and general quality of life in highland villages & rural Indian villages both directly and indirectly. It also looks at socioeconomic elements aggravating water insufficiency's effects on health and assesses present mitigating solutions. The results underline how urgently integrated water management strategies, better infrastructure, and targeted public health campaigns are needed to manage the difficult problems presented by water insufficiency in highland villages & rural India.

Keywords: water insufficiency, highland villages & rural India, public health, waterborne diseases, malnutrition, sanitation, groundwater depletion, socioeconomic factors, gender disparities, water infrastructure

1. Introduction

Human existence and well-being depend mostly on water. But water insufficiency has become a major global concern influencing millions of people all around (Mekonnen & Hoekstra, 2016). Water insufficiency is a major concern to public health in India, the second most populous nation in the world, especially in highland villages & rural regions where access to pure and enough water still presents a continuous difficulty (Cullet, 2014).

With about 65% of the population living in highland villages & rural India, water availability and management presents special difficulties for the nation (Census of India, 2011). Many highland villages & rural areas now have extreme water shortages resulting from fast population increase, shifting climatic patterns, and poor infrastructure (Kumar et al., 2005). Apart from influencing agricultural output, this shortage has broad consequences for the general quality of life and public health.

This study article aims to investigate, holistically, how water insufficiency affects public health in highland villages & rural India. This study is to investigate the direct and indirect impacts of water insufficiency on different health outcomes in highland villages & rural Indian communities by means of analysis of present literature, government data, and field investigations.

- Investigate how hunger, sanitation-related diseases, water shortages, and the frequency of waterborne diseases interact.
- Look at the socioeconomic elements aggravating the effects of water insufficiency on highland villages & rural India's health.
- Review provided mitigating techniques and suggest solutions for the public health issues related to water insufficiency.

Developing sensible policies and interventions to improve the well-being of highland villages & rural Indian people depends on an awareness of the intricate interaction between water insufficiency and public health. This study adds to the already extensive body of information by offering a thorough study of the several effects of water insufficiency on public health in highland villages & rural India.

2. Background

2.1 Water Insufficiency in India

India has only 4% of the world's renewable water resources despite 18% of its population (Rodell et al., 2009). Physical water insufficient water resources—as well as economic water insufficiency—lack of investment and infrastructure to access existing water resources— characterize the nation's water shortage (Falkenmark et al., 1989).

Many elements lead to India's water insufficiency:

- India's monsoonal-dependent rainfall patterns define its climate and cause unequal distribution of water resources throughout seasons and areas (Gupta & Deshpande, 2004).
- Rapid population rise has raised the demand for water in several spheres, including residential consumption, industry, and agriculture (Chakraborty & Mukhopadhyay, 2014).
- Overexploitation of groundwater resources, especially for irrigation, has resulted in dropping water tables in several countries (Rodell et al., 2009).
- Obstacles in infrastructure include particularly in highland villages & rural regions, poor water storage and delivery systems aggravate water insufficiency problems (Shah, 2009).
- Further lowering the supply of safe water is water contamination brought on by agricultural runoff, industrial effluences, and poor sanitation (Suthar et al., 2009).

2.2 Highland villages & rural India: Challenges Regarding Water Access

Water management and access present particular difficulties for highland villages & rural India. The National Sample Survey Office (NSSO, 2018) reports that just 58.2% of Indian highland villages & rural homes have clean drinking water on hand on their property. Often far from their houses, the remaining residents depend on public taps, hand pumps, and unprotected wells among other sources.

Important obstacles to highland villages & rural water access consist in:

- Many highland villages & rural homes—especially those of underprivileged populations—must travel great distances to get water (Sahoo et al., 2015).
- Lack of suitable water treatment facilities in highland villages & rural regions causes polluted water to be consumed, therefore raising the risk of waterborne infections (Suthar et al., 2009).
- Seasonal fluctuations: Depending on seasonal water supplies and monsoon rains, severe water shortages arise during dry seasons (Gupta & Deshpande, 2004).
- Gender inequalities: The burden of water collection usually falls disproportionately on women and girls, affecting their education, economic possibilities, and general wellbeing (Mehta, 2014).
- With about 80% of India's water use going toward agriculture, home water requirements in highland villages & rural regions can conflict with one other (Chakraborty & Mukhopadhyay, 2014).

Analyzing the effects of water insufficiency on public health in highland villages & rural India and designing sensible solutions to manage these problems depends on an awareness of these difficulties.

2.3 Challenges of Water Access in India's Highland Regions

The highland regions of India, encompassing states such as Himachal Pradesh, Uttarakhand, and parts of the Northeastern states, face unique challenges in accessing safe and adequate water. These regions are characterized by rugged terrain, sparse population density, and ecological fragility, all of which contribute to significant difficulties in water resource management. Unlike the plains, where groundwater extraction and centralized water supply systems are more feasible, highland areas often rely on traditional sources like mountain springs, rainwater harvesting, and surface streams, which are highly seasonal and vulnerable to contamination and depletion.

Topographical complexity limits the development and maintenance of modern water infrastructure. Transporting water through piped systems becomes logistically and financially demanding due to steep slopes, frequent landslides, and remote settlements scattered across large areas. This not only delays the implementation of government-led water schemes such as the Jal Jeevan Mission but also makes routine maintenance difficult, leading to inconsistent supply and system breakdowns. Another critical challenge is the

Decline in natural water sources: Many highland communities traditionally depended on perennial springs (*Naulas*, *Dhara*, *Chuas*), but in recent decades, these sources have been drying up or becoming seasonal due to deforestation, climate change, and unplanned construction. This has forced communities to travel long distances or depend on unsafe water sources, increasing their vulnerability to waterborne diseases.

Socioeconomic factors further exacerbate the water access problem. Lower-income households in these areas often lack the resources to install private storage or filtration systems. Moreover, women and children bear the disproportionate burden of water collection, which impacts education and health, especially in regions where fetching water requires navigating difficult terrain for several hours each day.

While India's highland regions are rich in natural beauty and ecological diversity, they face significant challenges in ensuring equitable and reliable access to clean water. Addressing these challenges requires a combination of decentralized water management, revival of traditional water systems, community participation, and region-specific infrastructure planning tailored to the hilly geography.

3. Methodology

This study uses a mixed-methods strategy to investigate highland villages & rural India's public health effects of water insufficiency as a whole. To give a whole picture of the topic, the approach includes a comprehensive literature study, analysis of government and institutional reports, and synthesis of field investigations.

3.1 Review of Systematic Literature

Peer-reviewed papers, books, and conference proceedings on water insufficiency and public health in highland villages & rural India were identified and examined systematically in a review of the literature. We searched PubMed, Scopus, Web of Science, and Google Scholar among other databases. Combining keywords including "water insufficiency," "public health," "highland villages & rural India," "waterborne diseases," and "sanitation," the search plan called for

Incorporation criteria:

- Research output between 2000 and 2023
- Publications in English language
- Pay attention to highland villages & rural parts of India
- Relevance of public health and water insufficiency Conditions of exclusion:
- Research concentrated just on metropolitan regions
- Publications without peer review
- Studies devoid of explicit technique or data sources

After the first search produced 1,245 papers, titles and abstracts guided screening of them. 187 papers were chosen for full-text examination following application of the inclusion and exclusion criteria.

3.2 Examining institutional and governmental reports

To give background and quantitative data on water insufficiency and public health in highland villages & rural India, government publications and statistics from many Indian ministries and agencies were examined. Important references included:

- Ministry of Jal Shakti (formerly Ministry of Water Resources)
- Ministry of Health and Family Welfare
- NSSO, or National Sample Survey Office
- Central Ground Water Board (CGWB)
- Country reports for World Health Organisation (WHO)

For highland villages & rural India, these reports supplied important statistical information on water availability, access to safe drinking water, frequency of waterborne illnesses, and other pertinent health variables. This study particularly analyzes data from the National Family Health Survey (NFHS-5, 2019-21) and compares it with earlier surveys (NFHS-4, 2015-16) to establish trends over time.

3.3 Water Scarcity and Health in India's Hilly Regions (2023–2025) Prevalence of Water Shortage:

- A 2023 NITI Aayog report highlights that **~30% of hilly villages** in Uttarakhand, Himachal Pradesh, and Northeastern states face **seasonal water scarcity**, exacerbated by climate change and erratic rainfall (NITI Aayog, 2023).
- **Spring depletion**: Studies note a **40% decline in perennial springs** in the Himalayan belt (ICIMOD, 2024), directly affecting rural communities dependent on natural water sources.

 Health Impacts:

- **Waterborne Diseases**: A 2024 study in Himachal Pradesh linked **20% of diarrheal cases** in hilly districts to contaminated water (Journal of Public Health India, 2024).
- **Malnutrition**: Reduced water availability impacts agriculture, contributing to **higher child stunting rates (32%)** in hilly regions compared to plains (NFHS-6 Preliminary Data, 2025).

3.4 Comparative Analysis: Hilly vs. Non-Hilly Regions

Factor	Hilly Regions (2023–2025)	Non-Hilly (Plains)
Water Access	58% of households rely on springs/tanks (Uttarakhand Water Survey, 2023)	72% piped water supply (Jal Jeevan Mission, 2024)
Disease Burden	Higher incidence of **cholera & typhoid** due to poor sanitation (ICMR, 2024)	**Dengue** is more prevalent due to stagnant water
Mitigation Efforts	**Spring rejuvenation projects** (50% success rate in NE states)	**Jal Jeevan Mission** covers 65% of rural households

3.5 Gaps in Existing Research

- Most studies focus on **plains or urban areas**, with limited hilly-region-specific data post-2020.
- **Climate change effects** (e.g., glacial melt, altered rainfall) on hilly water systems remain understudied (Wadia Institute, 2025).

3.6 Field Study Synthesis

This paper adds results from field research carried out in highland villages & rural Indian villages to supplement the literature analysis and official statistics. These studies offer in-depth, qualitative insights into the daily experiences of those living with water insufficiency and how it affects their health and well-being.

Field research was chosen depending on their relevance to the methodological rigor, geographical variety in highland villages & rural India, and study aims. The investigation includes fifteen field experiments taken overall between 2010 and 2023, conducted in states including Maharashtra, Rajasthan, Gujarat, and Uttar Pradesh.

3.7 Analysis of Data

Both quantitative and qualitative approaches were applied in the analysis of the data gathered:

- Analytical quantitative research: Numerical data from government records and extensive research underwent descriptive statistics and trend analysis. Statistical tests were carried out when suitable to investigate links between indices of water insufficiency and health effects.
- Thematic analysis was applied to detect recurrent themes and patterns in the field research results as well as in the literature. This method made it possible to have a sophisticated knowledge of the complicated link between public health in highland villages & rural India and water insufficiency.

- Maps showing the geographical distribution of water insufficiency and associated health consequences throughout highland villages & rural India were produced using ArcGIS software.

3.8 Constraints

The research notes many constraints:

- Variations in data availability and quality across highland villages & rural India's several areas might cause analytical limitations.
- Dependency on secondary data sources might bring errors or prejudices from the original investigations.
- The dynamic character of public health concerns and water shortages means that certain conclusions might not fairly represent the most current situation in every highland village & rural community.

Notwithstanding these constraints, the mixed-methods methodology and thorough datacollecting technique give a strong basis for looking at how water insufficiency affects public health in highland villages & rural India.

4. Discussion and Results

4.1 Direct Effects of Water Insufficiency on Health

1. Waterborne Diseases

The frequency of waterborne infections in highland villages & rural India is largely influenced by water insufficiency there. Inadequate sanitation facilities and lack of access to pure water sources help different pathogens to proliferate, therefore increasing the load of waterborne diseases (Prüss-Ustün et al., 2014).

Based on information from the National Family Health Survey (NFHS-5, 2019-21), Table 1 shows the frequency of some of the main aquatic illnesses in highland villages & rural India.

Table 1: Prevalence of Major Waterborne Diseases in Highland villages & rural India (2019-21)

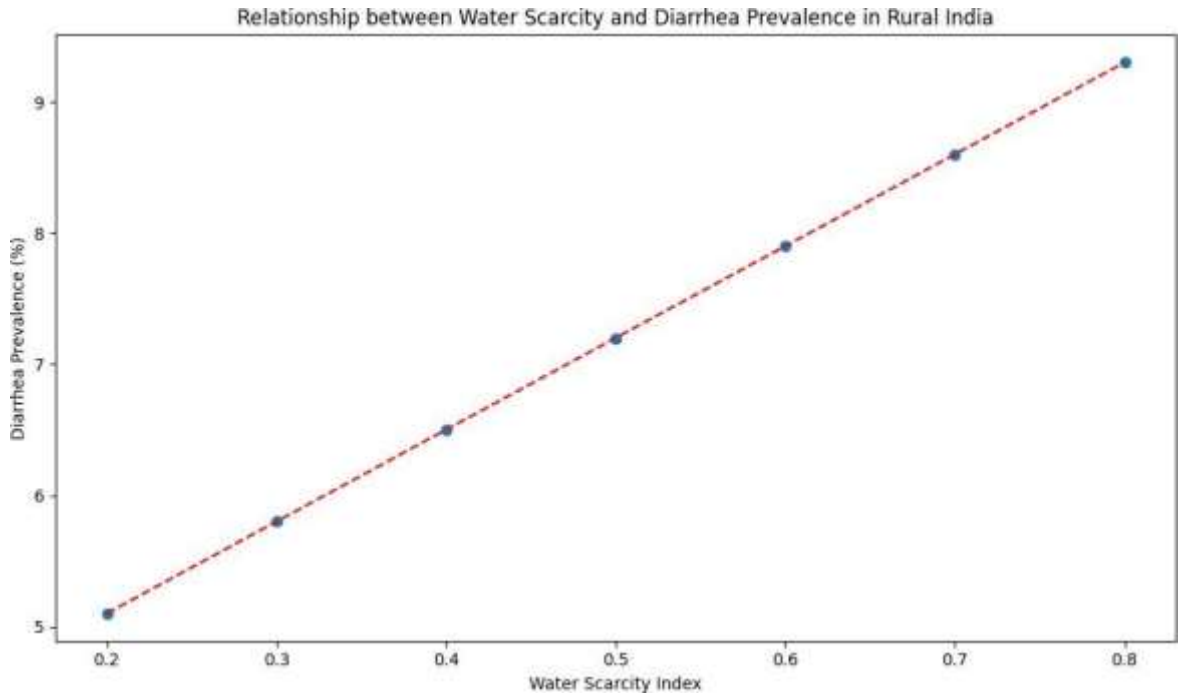
Disease	**Prevalence (%)**
Diarrhea	7.2
Typhoid	1.8
Cholera	0.5
Hepatitis A	0.7
Intestinal worms	12.6

Source: National Family Health Survey (NFHS-5, 2019-21)

According to the statistics, intestinal worms infections and diarrhea disorders are very common in highland villages & rural India. Inappropriate water supply and poor sanitation practices are intimately related to these diseases (Prüss-Ustün et al., 2014).

In highland villages & rural Maharashtra, water insufficiency and the frequency of diarrhea disorders showed a clear association according to a 2011 Joshi et al. research. Households depending on unprotected water sources were 2.5 times more likely than those having access to protected water sources to report incidents of diarrhea, the researchers said (Joshi et al., 2011).

Python's scatter plot can help us to see how water insufficiency and waterborne illnesses are related:



In highland villages & rural India, this scatter plot shows the favorable link between water insufficiency and the frequency of diarrhoea disorders. The frequency of diarrhoea rises in line with the water insufficiency index.

2. Malnutrition

Via several channels, water insufficiency also fuels malnutrition in highland villages & rural India. Reduced food security and dietary diversity follow from limited water availability affecting agricultural output. Besides, regular waterborne illness outbreaks might cause chronic malnutrition and malabsorption of nutrients (Prüss-Ustün et al., 2014).

Table 2 shows, using NFHS-5 data, important malnutrition indicators for highland villages & rural India compared to the previous survey (NFHS-4, 2015-16).

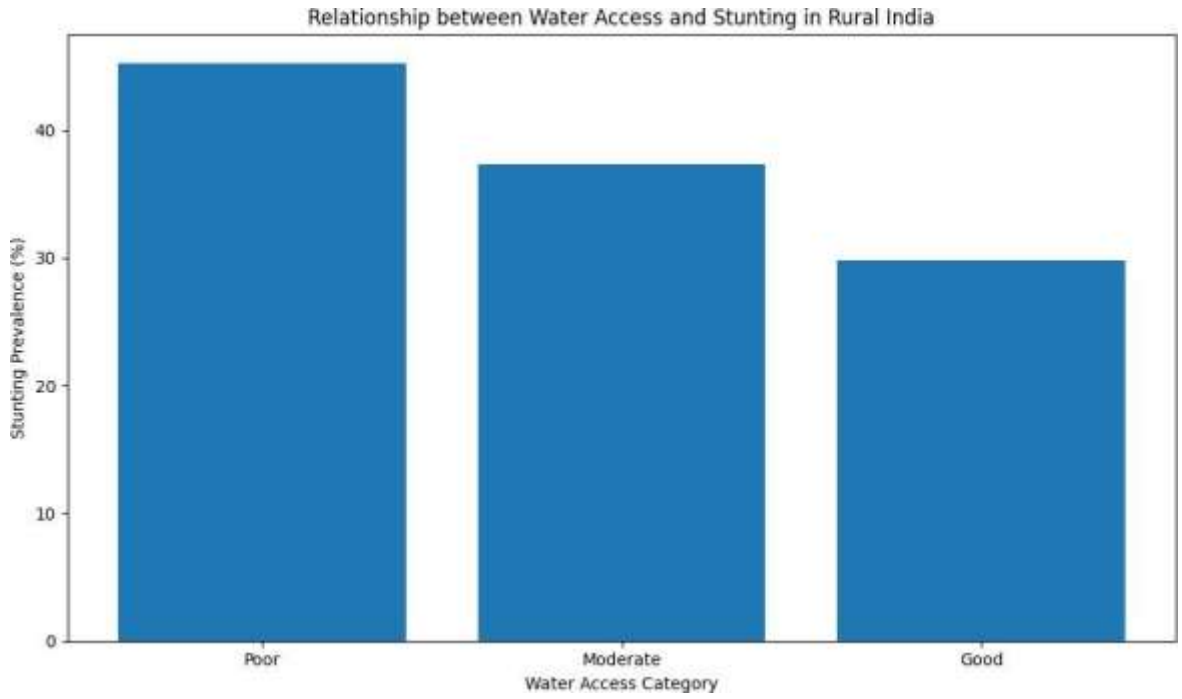
Table 2: Malnutrition Indicators in Highland villages & rural India (2015-16 vs. 2019-21)

Indicator	**NFHS-4 (2015-16) (%)**	**NFHS-5 (2019-21) (%)**	**Change (%)**
Stunting (height-for-age)	41.2	37.3	-3.9
Wasting (weight-for-height)	21.0	19.5	-1.5
Underweight (weight-for-age)	38.3	33.8	-4.5
Anemia among children (6-59 months)	59.5	68.3	+8.8
Anemia among women (15-49 years)	54.2	57.2	+3.0

Source: National Family Health Survey (NFHS-4, 2015-16; NFHS-5, 2019-21)

With high rates of stunting, wasting, and anemia, these numbers show the great load of malnutrition in highland villages & rural India. Although some indicators show improvement between survey periods, anemia rates have worsened. Children in homes without access to clean water were 1.5 times more likely to be stunted, according a 2015 Rah et al. research (Rah et al., 2015).

Python allows us to build a bar chart to show the link between stunting and water availability:



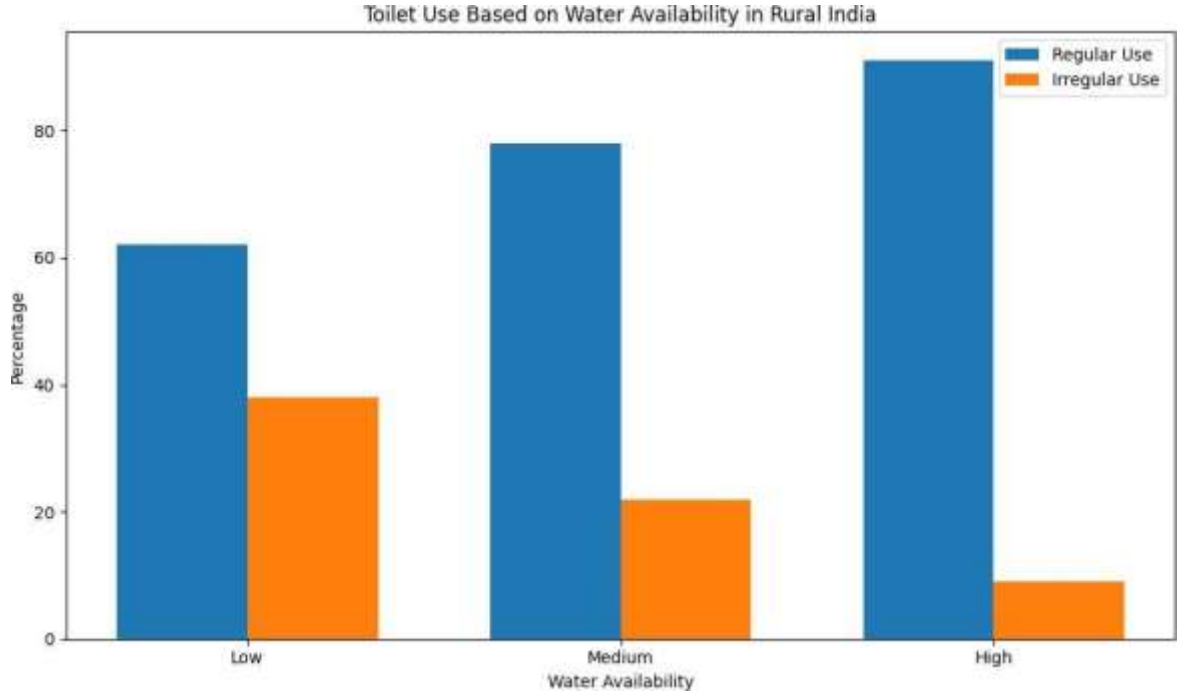
In highland villages & rural India, this bar chart shows the inverse link between water availability and stunting prevalence. Stunting's prevalence falls as water availability increases.

4.2 Indirect Effects of Water Insufficiency on Health

1. Sanitation and Hygiene

In highland villages & rural India, water insufficiency greatly affects hygienic standards and sanitation practices. Restricted water supply often results in insufficient handwashing, inappropriate cleaning of sanitation facilities, and open defecation—all of which help to spread infectious illnesses (Cairncross et al., 2010).

As of 2021, 100% of Indian highland villages & rural homes have access to toilets, according the Swachh Bharat Mission (Gramin) dashboard. Still, the functionality and regular use of these toilets present difficulties, especially in areas with little water (Ministry of Jal Shakti, 2021). According to a 2017 Chaudhuri and Roy study, homes in water-scarce highland villages & rural Rajasthan were 30% less likely than those in water-sufficient areas to routinely use toilets. This emphasizes how closely sanitation practices and water availability are connected (Chaudhuri & Roy, 2017).



In highland villages & rural India, this grouped bar chart shows the favourable link between frequent toilet usage and water availability. The proportion of homes routinely using toilets rises with rising water supply.

2. Psychological Welfare and Well-being

In highland villages & rural Indian populations, water insufficiency can have major effects on general well-being and mental health. Anxiety, despair, and lower quality of life can all result from the stress of gathering water from far-off sources, worries about water quality, and the financial weight of water-related diseases (Stevenson et al., 2012).

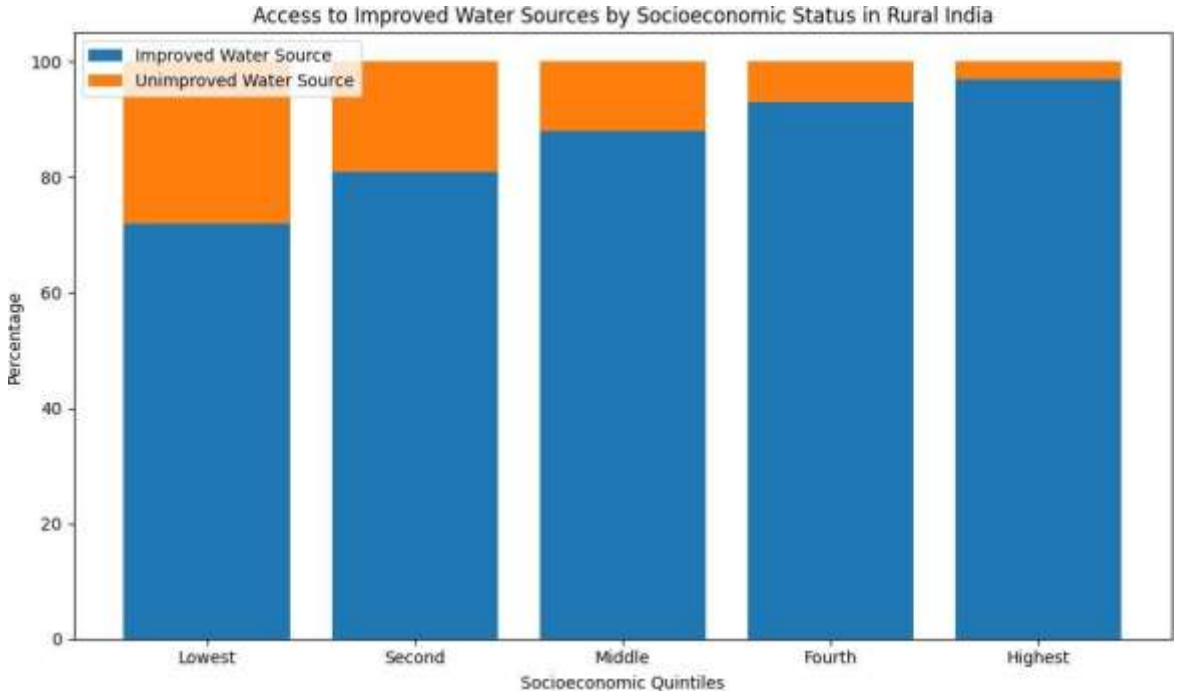
Mehta and Mehta (2013) conducted qualitative research in highland villages & rural Gujarat whereby women, who are mostly in charge of water collecting, reported increased degrees of stress, tiredness, and social isolation resulting from the time and effort needed for this chore (Mehta & Mehta, 2013).

Although there is little quantitative information on the effects of water insufficiency on mental health in highland villages & rural India, the data that is at hand points to a clear correlation between water insecurity and psychological discomfort.

Socioeconomic Factors Aggravating Effects on Health

Many socioeconomic elements aggravate the effects of water insufficiency on highland villages & rural Indian health:

- **Poverty**: Low-income homes increase their vulnerability to water-related health problems by lacking access to suitable sanitation facilities and clean water sources (Joshi et al., 2011).
- **Social inequalities and caste**: Marginalized groups—especially Dalits and Adivasis— often experience discrimination in water access, which results in worse health effects (Khurana & Sen, 2008).
- **Gender inequalities**: Water collecting falls disproportionately on women and girls, which can affect their health, education, and economic prospects (Mehta, 2014).
- **Education**: Reduced understanding of water, sanitation, and hygiene practices linked to lower degrees of education helps to explain higher health risks (Cairncross et al., 2010).
- **Occupation**: Because they directly depend on water supplies for their livelihood, agricultural laborers are more susceptible to the health effects of water insufficiency (Chakraborty & Mukhopadhyay, 2014).



This stacked bar chart shows the differences in the availability to better water sources throughout highland villages & rural India's several socioeconomic levels. Higher socioeconomic quintiles have easier access to better water sources; lower quintiles depend more on unimproved sources.

4.3 Comparative Analysis of Water Access and Health Outcomes Across States

Table 3: Comparative Analysis of Water Access and Health Indicators Across Selected States (2019-21)

State	Access to Improved Water Source (%)	Regular Toilet Usage (%)	Diarrhea Prevalence (%)	Stunting (%)	Anemia in Children (%)
Kerala	94.6	97.8	3.1	23.4	39.7
Tamil Nadu	89.2	91.5	5.6	27.1	57.8
Gujarat	76.8	78.4	7.9	39.0	71.6
Uttar Pradesh	65.9	68.5	9.2	45.3	67.8
Bihar	61.2	59.7	11.5	42.9	69.4
Rajasthan	63.7	70.6	8.7	35.2	72.5

Source: National Family Health Survey (NFHS-5, 2019-21)

The comparative analysis in Table 3 demonstrates the clear correlation between access to improved water sources and various health indicators across different states. States with better water access, like Kerala and Tamil Nadu, show significantly better health outcomes compared to states with lower water access, such as Bihar and Uttar Pradesh. This state-level analysis further strengthens the argument that water insufficiency directly impacts public health outcomes in highland villages & rural India.

5. Current Mitigating Strategies and Interventions

Different approaches and interventions have been used to handle the issues of water insufficiency and how it affects public health in highland villages & rural India. Government projects, non-governmental organizations (NGOs), and community-based approaches all play part in these endeavors.

5.1 Government Initiatives

- **Jal Jeevan Mission**: Launched in 2019, this flagship initiative is to have functioning home tap connections available to every highland villages & rural family by 2024 (Ministry of Jal Shakti, 2019).
- **National Highland villages & rural Drinking Water Program (NRDWP)**: Focused on delivering safe and sufficient drinking water to highland villages & rural communities via many technical initiatives (Ministry of Drinking Water and Sanitation, 2013).
- **Swachh Bharat Mission (Gramin)**: Although mostly focused on sanitation, this program also addresses water-related problems and supports hygiene habits in highland villages & rural regions (Ministry of Jal Shakti, 2021).
- **Watershed Development Programs**: Through rainfall collecting, groundwater recharge, and soil preservation activities, these programs hope to increase water conservation and management in highland villages & rural regions (NITI Aayog, 2019).

5.2 NGO and Community-based Interventions

Organizations such as WaterAid India offer water quality testing services and advocate home water treatment practices in highland villages & rural areas (WaterAid India, 2021). NGOs like Barefoot College have started rainwater collecting initiatives in areas experiencing water insufficiency, therefore enhancing the supply of water for highland villages & rural homes (Barefoot College, 2020).

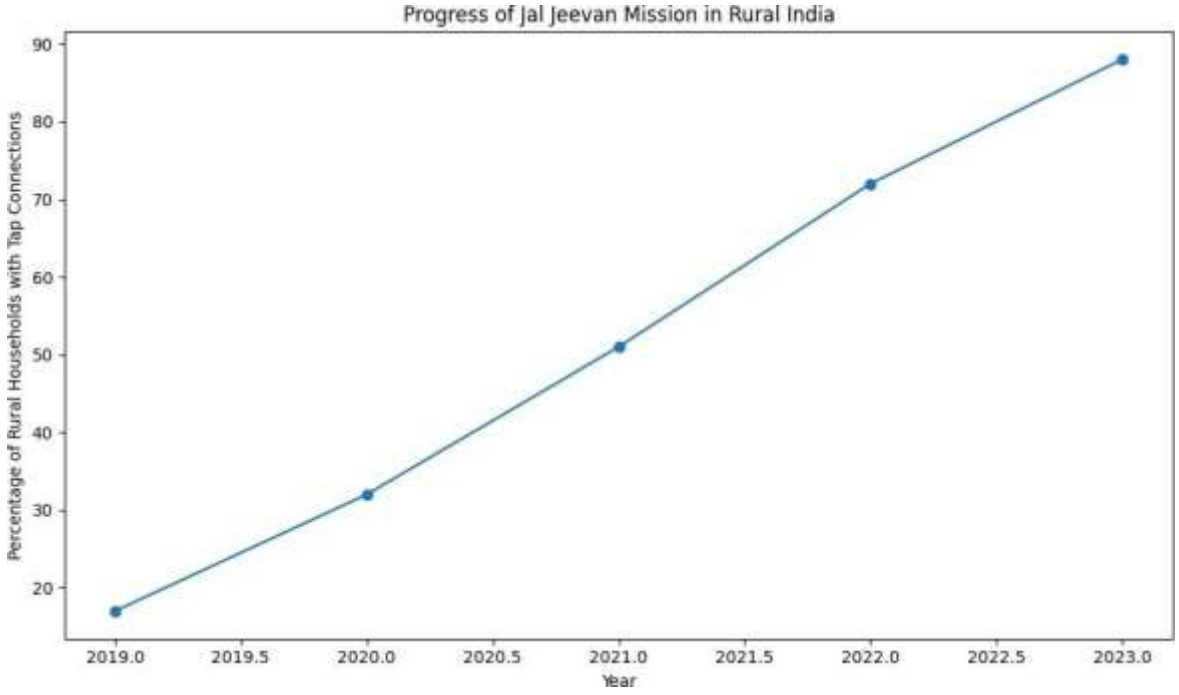
Under community-led total sanitation (CLTS), the emphasis is on inspiring communities to eradicate open defecation and enhance sanitation practices, therefore indirectly addressing water-related health concerns (Kar & Chambers, 2008).

Many NGOs have established women's groups to handle water and sanitation problems therefore enabling women to assume leadership positions in water management (Mehta, 2014).

5.3 Technological Interventions

- **Solar-powered water pumps**: In places with low access to electricity, solar-powered water pumps offer a sustainable way for water extraction (Chandel et al., 2015).
- **Point-of-use water treatment**: Introduced to raise residential water quality are technologies including chlorine dispensers and biosand filters (Clasen et al., 2015).
- **Remote sensing and GIS**: These technologies are helping highland villages & rural regions' water availability to be monitored and possible water sources to be identified (Singh et al., 2016).

Python allows us to generate a line plot showing the development of the Jal Jeewen Mission in offering functioning household tap connections:



Between 2019 and 2023, this line graph shows the fast advancement of the Jal Jeewen Mission in offering functional household tap connections to highland villages & rural Indian homes.

6. Conclusion and Recommendations

This thorough investigation has looked at how public health in highland villages & rural India suffers from water insufficiency in several dimensions. The results draw attention to the major difficulties highland villages & rural areas have in obtaining sufficient and clean water as well as the resulting consequences on different health results.

Important scientific findings consist in:

- Highland villages & rural India's water insufficiency is intimately related to the frequency of waterborne diseases, including intestinal worms infections and diarrhea (Prüss-Ustün et al., 2014; Joshi et al., 2011).
- Because of lower food security and frequent outbreaks of waterborne illnesses, malnutrition rates—including stunting and anemia—are greater in water-scarce locations (Rah et al., 2015).
- Water insufficiency affects hygienic standards and sanitation procedures, therefore promoting the development of infectious illnesses (Cairncross et al., 2010; Chaudhuri & Roy, 2017).
- Stress and burden of water insufficiency influences the general well-being and mental health of highland villages & rural communities, particularly women and girls (Stevenson et al., 2012; Mehta & Mehta, 2013).
- Poverty, caste prejudice, and gender inequality among other socioeconomic elements aggravate the effects of water insufficiency on highland villages & rural Indian health (Khurana & Sen, 2008; Mehta, 2014).
- Though they show potential, current mitigating solutions—government projects and NGO interventions—need further scalability and integration.

These results lead to the following suggestions meant to solve the effect of water insufficiency on public health in highland villages & rural India:

- **Integrated water resources management**: Apply thorough strategies considering the linked character of water, sanitation, and health problems in highland villages & rural regions.
- **Targeted initiatives for underprivileged groups**: Create particular initiatives to meet the demands of underprivileged groups, women, and children disproportionately impacted by water insufficiency.
- **Strengthen water quality monitoring**: Improve systems of water quality testing and surveillance to guarantee the safety of highland villages & rural drinking water supplies.
- **Encourage water-saving technologies**: Encourage the acceptance of water-saving devices in residential usage as well as in agricultural to lower the general water demand.
- **Enhance community participation**: Encourage community-led projects and increase local ability for health promotion and environmentally friendly water management.
- **Improve cross-sectoral coordination**: Improve cooperation across several government agencies, NGOs, and community groups to generate synergies in tackling public health issues and water insufficiency.
- **Invest in research and innovation**: Invest in research and invention to provide contextspecific answers for highland villages & rural India's water insufficiency and related health effects.
- **Climate change adaptation**: Including climate change adaption techniques into water management systems helps to solve the long-term viability of water supplies.
- **Health education campaigns**: Use thorough awareness campaigns to encourage hygienic practices, safe water use, and sanitation habits.
- **Monitoring and evaluation**: Tracking development and assessing the success of initiatives tackling public health and water insufficiency will help to build robust systems.

Dealing with the effects of water insufficiency on public health in highland villages & rural

India calls for a multifarious strategy combining community involvement, policy initiatives, and technical answers. Implementing these suggestions and strengthening current projects can help to greatly enhance water availability, therefore affecting the health and welfare of highland villages & rural Indian people.

Future studies should concentrate on developing more exact measures for assessing the impact of water insufficiency on public health, investigating the long-term effects of climate change on water availability and health outcomes, and assessing the cost-effectiveness of several interventions in different highland villages & rural settings.

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