Research Article

A Cross-sectional Assessment of the Potability of Water Quality from Available Water Sources in the Villages of the Palwa Field Practice Area, Ujjain

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Background: Approximately 64 percent of the Indian population resides in rural settings. They have access to varied water sources like well, rivers, ponds, handpumps, tubewells, which come with a cost of risk of diverse contamination. The present study explores this component in the studied villages.

Aim & Objective: To assess the water quality of the routinely used water source in 7 adopted villages under 'Community Adoption Program for Postgraduates (CAPP)' in the field practice area of RD Gardi Medical College, Ujjain, M.P.

Methodology: Under the signature 'Community Adoption Program for Postgraduates (CAPP)', seven villages in the rural field practice area of the Department of Community Medicine were selected by quota sampling. On-site testing of water samples for commissioned sources was carried out for pH, TDS, and temperature using a Deluxe water analysis kit (model 172). Additional samples were collected and transported under specific conditions for further chemical and microbiological analysis at institutional laboratories.

Result: 24 samples from viable water sources from 7 villages were collected for laboratory and microbiological analysis, of which 5 samples were from a well, 9 from a tubewell, 5 from a handpump, and 5 from a tap. Among these samples 24 (100%) exceeded the desirable limit for Total Hardness, 23 (96.15%) exceeded the desirable limit for TDS, 22 (88.4%) exceeded the desirable limit for alkalinity, 19 (80.7%) exceeded the desirable limit for Calcium Hardness, 10 (42.3%) exceeded the desirable limit for magnesium hardness, 8 (34.6%) exceeded the desirable limit for chloride. 24 samples sent for microbiological evaluation, of which 21 samples (87.5%) recorded growth on MacConkey Purple broth, and 12 samples (50%) recorded fecal coliform >10MPN/100 mL with Indole test and Brilliant Green Bile Broth (BGBB), and 8 samples (33.33%) reported the presence of *E. coli* >1. On inferential analysis, chloride levels demonstrated a statistically significant association ($p = 0.047$). A concentrated group of villages (in close proximity) reported significantly high physiochemical parameters with respect to TDS, Total Hardness, and Total Alkalinity. (ANOVA, $p<0.05$).

Conclusion: Results highlighted the need for continued quality checks of usable water sources from rural Indian setups, and necessary corrections of deranged parameters for better population health.

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Introduction

Water-related diseases are not confined to water-borne diseases, which are caused by consuming water that is contaminated water. Still several other conditions that are directly or indirectly related to the water people consume and use on a daily basis. The spectrum ranges from infectious diarrheal diseases to noninfectious dermal, cardiovascular, and renal conditions. Of all contaminants, the presence of microbial ones, indicating faecal contamination in drinking water, is grave.

In 2022, globally, at least 1.7 billion people used a drinking water source contaminated with faeces[1]. More than 2 billion people reside in countries facing high levels of water stress, while around 4 billion endure

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severe water shortages for at least one month each year (UN, 2019)[2].

To assess the quality of usable water, one needs to understand the definition of safe and wholesome water, that is, the water that is free from pathogens, harmful chemical substances, free from color and odor (pleasant to taste) and usable for domestic purposes. Water is said to be polluted or contaminated when it does not fulfill the above criteria[3]. To provide health care to the community safe and wholesome water supply is the key to it. There are certain diseases that are caused by consuming water with deranged physical parameters of water that need to be addressed, as well as water-related diseases. Like, elevated levels of calcium in water lead to an increase in the total hardness of water and long-term consumption of such water may lead to kidney stones, cardiovascular diseases, skin irritation and dryness. As the hard water makes it harder to wash off soap, it leaves residue on the skin. Hair damage as a result of dryness, irritation, and breakage of hair over time. Digestive discomfort in rare cases is also a cause of hard water. High TDS levels in water result from the presence of calcium, magnesium, sodium, chlorides, and sulphates. High levels of TDS in water lead to Kidney stones, kidney dysfunction that is caused by high levels of sodium, which strains the kidneys. Hypertension, by high sodium content. Excessive chloride in water leads to thyroid dysfunction over time and causes Hypothyroidism. Chronic ingestion of water with imbalanced pH levels may disrupt the body's acid-base balance, potentially affecting metabolic processes and overall cellular function. High pH water can dry out the skin and cause irritation, while very low pH water may lead to skin sensitivity and dermatitis.

The assessment of water quality and treatment before community supply is an important part of the health care of the community, which goes unnoticed. Rural areas have gained focus on water supply with the Jal Jeevan Mission and yet, the quality of drinking water needs to be improved. There is limited research on the water quality assessment of water sources in rural areas, so in this study, we tried to assess the quality of water from different sources in rural settings.

Material and Methods

Under the flagship Community Adoption Programme for Postgraduates (CAPP), the Department of Community Medicine, R.D. Gardi Medical College (RDGMC), Ujjain, has adopted seven villages within its designated field practice area. Each postgraduate student is assigned one village for a duration of three years, thereby ensuring continuity of engagement and longitudinal community exposure. The primary objective of this initiative is to systematically assess the public health situation of the adopted villages, identify gaps in service delivery, and implement feasible interventions aimed at overall health improvement and social development.

The seven villages were selected from a pool of sixty villages spread across three blocks of Ujjain district, which constitute the rural field practice area of RDGMC. The Rural Health and Training Centre (RHTC) at Palwa village serves as the central hub for supervision, logistical support, and coordination of all community-based activities. The villages were selected using the quota sampling method, ensuring adequate representation from each block and reflecting the heterogeneity of the rural population in terms of demographics, infrastructure, and health service availability.

Planned activities under the programme are aligned with the World Health Organization's Healthy Village Initiative and encompass a wide range of community-oriented public health measures. These include:

Need assessment surveys, conducted to identify priority health issues and determinants of ill-health; School health camps, organized to build rapport with the community while addressing child health concerns; Water quality testing, undertaken to assess the safety of commonly used drinking water sources; Health education and behavior change communication (IEC/BCC) activities, designed to promote awareness regarding sanitation, nutrition, and lifestyle modification; Participation in immunization sessions, in coordination with frontline health workers; and Organization of general health camps, with a focus on screening, preventive services, and referral of identified cases[4].

Water Quality Assessment in Adopted Villages

One of the key activities under CAPP is the assessment of drinking water quality in the adopted villages, given its direct implications for communicable and non-communicable diseases. A season-wise approach was undertaken to evaluate variations in water quality, with sampling planned for pre-monsoon and post-monsoon periods. The strategy focused on the most commonly used water sources in each village to ensure representativeness of exposure patterns.

The planning and organization of water testing were coordinated by the Water Chemistry Laboratory of the Department of Community Medicine. Water samples were collected by the corresponding author with the help of the health research department. Water samples were collected between March and August 2024 using sterile containers to prevent cross-contamination. For each source, 1 liter of water was collected for physicochemical analysis and 100 ml for microbiological analysis. The Deluxe Water Analysis Kit (Model 172) was used in the field to measure basic parameters such as pH, temperature, total dissolved solids (TDS), conductivity, and salinity. Additional portable instruments, including the ECO Tester hand-held digital pH, Hanna TDS meter, and standard air thermometer, were employed to ensure precision and cross-verification of results. The titration method was used to measure hardness, chloride, and alkalinity as per standard methods[5].

For the collection of water samples from handpump, tubewell and tap, we let the water run for at least 2 to 5 minutes to flush the system, then rinse the container with source water, followed by filling the container and capping it immediately. Following the sample collection the sampled water was transported back to the laboratory same day.

Sources of water sampled included wells, tubewells, handpumps, and piped taps, reflecting the diversity of drinking water infrastructure in rural areas. While the physicochemical parameters and inorganic constituents were analyzed in the institutional Water Chemistry Laboratory, microbiological examination (including detection of coliform contamination) was carried out in the Department of Microbiology.

The comparison of Water quality parameters across different water sources and across villages was done using the Kruskal-Wallis' test. The data obtained were further processed using ArcGIS version 10 software to create village-wise spatial maps of variation in water quality parameters, enabling visualization of risk areas and seasonal trends. Such analysis provided an evidence base for health education interventions, advocacy with local governance bodies, and recommendations for improving water safety in the adopted villages.

Result

A total of 24 samples from viable and the most used sources from 7 villages were collected for analysis. Out of which 5 samples were taken from a well, 9 from a tubewell, 5 from a handpump, 5 from a tap. 4 samples were taken from Salamata, Shakkarkhedi, and Samanera, each, 3 from Tukral, Jhalara, Khedachitawaliya and Lambikhedi each (Table 1).

The Water Chemistry Laboratory of the Department of Community Medicine at the institute tested several parameters of drinking water, namely total hardness, calcium hardness, magnesium hardness, conductivity, salinity, total alkalinity, and chloride. The mean values and ranges across all sources were: pH 7.43 (7.4–8.6), TDS 992.73 mg/L (316–1710), salinity 1.23 ppt (0.4–2.8), alkalinity 357.23 mg/L (60–680), chloride 237.26 mg/L (104–719), conductivity 1.56 mS (0.98–2.58), total hardness 574.92 mg/L (160–1000), calcium hardness 373.38 mg/L (109.2–767), and magnesium hardness 212.72 mg/L (30.3–378.5) (Table 2).

For interpretation, the results were compared with the Bureau of Indian Standards (IS:10500:2012) for drinking water[6]. According to these guidelines, each parameter has a desirable limit and a permissible limit. The desirable limit refers to the concentration level below which water is considered safe, palatable, and without health risk. The permissible limit is the maximum allowable concentration in situations where no alternate source of water is available; beyond this, water is likely to cause health concerns or become unfit for consumption. In this study, parameters such as TDS (mean 992.73 mg/L), total hardness (mean 574.92 mg/L), and calcium hardness (mean 373.38 mg/L) frequently exceeded the the desirable limits (500 mg/L for TDS and 200 mg/L for hardness) but mostly remained within the permissible limits (2000 mg/L for TDS and 600 mg/L for hardness). Chloride levels (mean 237.26 mg/L) were close to the desirable limit of 250 mg/L, though still within the permissible limit of 1000 mg/L.

Out of 24 samples sent for microbiology in the preliminary report, 21 samples recorded growth on McConkey purple broth. On further confirmatory test with indole & Brilliant Green Bile Broth (BGBB) recorded 12 samples with faecal coliform of >10 MPN/100 mL, and 8 samples recorded *E. coli* >1 count, suggesting the sampled water as unsatisfactory for drinking purposes. (Table 3)

On comparison of physiochemical parameters with microbiological contamination, 21 samples were found contaminated with presumptive coliform compared whereas physiochemical parameters were found statistically insignificant (Table 4).

Table 5 compares physicochemical parameters of water samples with respect to faecal contamination status following a confirmatory test with indole. Where chloride levels demonstrated a statistically significant association ($p = 0.04$), high chloride was more common in uncontaminated samples (9) compared to contaminated samples (5). In contrast, normal chloride was more frequent in contaminated water (8 vs. 2). This indicates that water with lower chloride levels was more likely to harbour faecal contamination. In contrast, higher chloride

Table 1: Village-wise distribution of water samples collected from different water sources n = 24

S No	*Source*	*Salamata*	*Shakkarkhedi*	*Samanera*	*Tukral*	*Jhalara*	*Kheda chitawalya*	*Lambikhedi*	*Total*
1	Well	1	0	1	0	1	0	2	5 (20.8%)
2	Tubewell	2	3	1	2	0	1	0	9 (37.6%)
3	Handpump	1	0	1	0	1	1	1	5 (20.8%)
4	Tap	0	1	1	1	1	1	0	5 (20.8%)
5	Total	4	4	4	3	3	3	3	24

Table 2: Mean & Range of all sources of different parameters

Parameter	*Mean*	*Range*	*Desirable limit*	*Permissible Limit*
pH	7.43	7.4-8.6	6.5-8.5	NR
TDS	992.73	316-1710	500	2000
Salinity*	1.23	0.4-2.8	-	-
Alkalinity	357.23	60-680	200	600
Chloride	237.26	104-719	250	1000
Conductivity**	1.56	0.98-2.58	-	-
Total Hardness	574.92	160-1000	200	600
Calcium Hardness	373.38	109.2-767	200	600
Magnesium Hardness	212.72	30.3-378.5	200	600

Salinity* - No direct desirable or permissible limit is prescribed for salinity in BIS or WHO standards.
Conductivity** - BIS (IS:10500:2012) and WHO guidelines do not specify a desirable or permissible limit for electrical conductivity.

seemed to be associated with better microbiological safety in this dataset (Table 5).

The comparison of physicochemical parameters across different water sources revealed numerical differences, though none were statistically significant. For total hardness, the highest mean rank was observed in handpumps (15.00), followed by taps (14.20) and tubewells (12.67), with wells showing the lowest rank (8.00; p = 0.40). Calcium hardness was greatest in tap water (16.60), slightly lower in handpumps (14.80), and lowest in wells (6.90; p = 0.14), suggesting a trend toward higher calcium content in tap sources. In the case of magnesium hardness, tubewells recorded the highest mean rank (13.44), while taps had the lowest (10.20; p = 0.71). Chloride levels were also highest in tap water (17.00) and lowest in wells (8.20; p = 0.25). With respect to alkalinity, handpump sources showed the highest rank (16.20), whereas tubewells had the lowest (11.39; p = 0.62). Although these variations did not reach statistical significance, wells consistently exhibited lower values across several parameters, indicating relatively reduced mineral content, while taps and handpumps tended to present higher values for calcium, chloride, and alkalinity. These findings, while inconclusive due to the small sample size (n = 24), provide useful trends that may warrant further investigation with larger datasets or seasonal assessments (Table 6).

The inter-village comparison demonstrated significant differences for certain parameters. Total hardness showed statistically significant variation (p = 0.02), with the highest values recorded in Khedachitawlaya (19.17) and Samanera (18.63), and the lowest in Shakkarkhedi (4.75). Alkalinity also approached statistical significance (p = 0.05), being highest in Samanera (19.75) and lowest in Shakkarkhedi (4.38). Other parameters, including calcium hardness (p = 0.17), magnesium hardness (p = 0.549), and chloride (p = 0.21), did not differ significantly between villages. These findings highlight village-specific water quality profiles shaped by hydrogeological and environmental factors. From a health perspective, higher hardness levels may predispose residents of certain villages to urolithiasis and scaling problems, while very low hardness and alkalinity may increase risks of pipeline corrosion and reduced buffering capacity in villages such as Shakkarkhedi (Table 7).

Among the seven adopted villages, statistically significant variation (p = 0.026) was observed in total hardness, while alkalinity showed a borderline

Table No. 3 – Microbiological contamination of samples

S No	*Village*	*Source*	*Faecal Coliform (MPN/100 mL)*	*E. Coli*	*Quality of drinking water*
1	Shakkarkhedi	Tubewell	920	920	Unsatisfactory
2		Tubewell	350	<2	Unsatisfactory
3		Tubewell	540	4	Unsatisfactory
4		Tap	>1800	1600	Unsatisfactory
5	Samanera	Handpump	79	<2	Unsatisfactory
6		Well	>1800	240	Unsatisfactory
7		Tubewell	23	<2	Unsatisfactory
8		Tap	0	0	Satisfactory
9	Jhalara	Handpump	0	0	Satisfactory
10		Well	0	0	Satisfactory
11		Tap	0	0	Satisfactory
12	Tukral	Tubewell	0	0	Satisfactory
13		Tap	0	0	Satisfactory
14		Tubewell	2	0	Satisfactory
15	Khedachitawalya	Tubewell	0	0	Satisfactory
16		Handpump	0	0	Satisfactory
17		Tap	0	0	Satisfactory
18	Lambikhedi	Well	>1800	63	Unsatisfactory
19		Well	>1800	63	Unsatisfactory
20		Handpump	0	0	Satisfactory
21	Salamata	Handpump	920	<2	Unsatisfactory
22		Well	540	<2	Unsatisfactory
23		Tubewell	>1800	13	Unsatisfactory
24		Tubewell	4	2	Unsatisfactory

Table 4: Comparison of physiochemical parameters with presumptive coliform

		Presumptive Coliform		*Total (n=24)*	*p-value*
		Absent (%)	*Present (%)*		
TDS	High	3 (13.04)	20 (86.96)	23	0.69
	Normal	0 (0.00)	1 (100)	1	
Calcium Hardness	High	3 (15)	17 (85)	20	0.40
	Normal	0 (0.00)	4 (100)	24	
Magnesium Hardness	High	0 (0.00)	10 (100)	10	0.11
	Normal	3 (21.43)	11 (78.57)	14	
Chloride	High	1 (12.50)	7 (87.50)	8	1.0
	Normal	2 (12.50)	14 (87.50)	16	
Alkalinity	High	3 (13.64)	19 (86.36)	22	0.57
	Normal	0 (0.00)	2 (100)	2	
Total		03 (12.5)	21 (87.5)	24	

Table 5: Comparison of chemical parameters of water samples with respect to faecal contamination

		Quality of drinking water		*Total*	*p-value*
		Satisfactory	*Unsatisfactory*		
TDS (ppm)	High	11	12	23	
	Normal	0	1	1	1.00
Total		11	13	24	
Calcium Hardness (mg/l)	High	11	9	20	
	Normal	0	4	4	
Total		11	13	24	.09
Magnessium Hardness (mg/l)	High	5	6	11	
	Normal	6	7	13	1.00
Total		11	13	24	
Chloride (mg/l)	High	9	5	14	
	Normal	2	8	10	.04
Total		11	13	24	

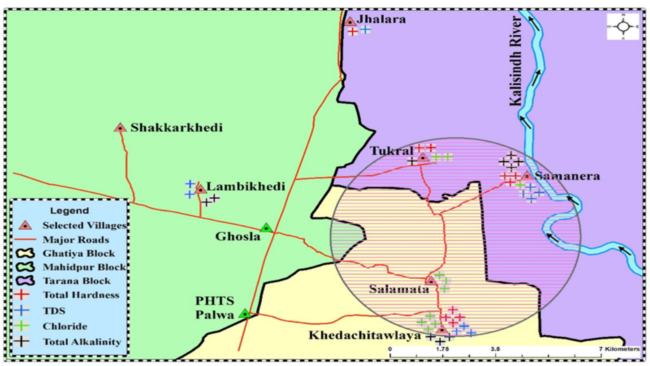

Fig. 1: Geographic distribution of high-risk villages concerning physicochemical parameters of groundwater using ArcGIS.

difference ($p = 0.051$), indicating village-level disparities in groundwater quality. As shown in Table 6, Khedachitawlaya and Samanera emerged as high-risk villages, with Khedachitawlaya recording the highest mean levels of total hardness and chloride, and Samanera showing the highest mean levels of TDS and total alkalinity. In contrast, Shakkarkhedi consistently recorded the lowest values for hardness and alkalinity, suggesting relatively softer water with reduced buffering capacity. The geographic clustering of these high-risk villages is illustrated in Figure 2, which depicts their spatial distribution using ArcGIS (ArcMap version 10), highlighting a distinct concentration of elevated physicochemical parameters in certain pockets of the study area.

Discussion

This study assessed the drinking water quality of seven adopted villages in Central India, combining

Table 6: Comparison of water quality parameters across different sources using the Kruskal-Wallis test

Source		*N*	*Mean rank*	*p*
Total hardness (mg/l)	Handpump	5	15.00	
	Tap	5	14.20	
	Tubewell	9	12.67	0.40
	Well	5	8.00	
	Total	24		
Calcium Hardness (mg/l)	Handpump	5	14.80	
	Tap	5	16.60	
	Tubewell	9	12.06	0.14
	Well	5	6.90	
	Total	24		
Magnesium Hardness (mg/l)	Handpump	5	14.60	
	Tap	5	10.20	
	Tubewell	9	13.44	0.71
	Well	5	11.00	
	Total	24		
Chloride (mg/l)	Handpump	5	11.20	
	Tap	5	17.00	
	Tubewell	9	13.11	0.25
	Well	5	8.20	
	Total	24		
Alkalinity (mg/l)	Handpump	5	16.20	
	Tap	5	11.50	
	Tubewell	9	11.39	0.62
	Well	5	11.80	
	Total	24		

Table 7: Comparison of water quality parameters across villages using Kruskal-Wallis' test

Village		*N*	*Mean Rank*	*p*
Total hardness (mg/l)	Jhalara	3	14.00	0.02
	Khedachitawlaya	3	19.17	
	Lambikhedi	3	8.00	
	Salamata	4	8.25	
	Samanera	4	18.63	
	Shakkarkhedi	4	4.75	
	Tukral	3	16.67	
	Total	24		
Calcium Hardness (mg/l)	Jhalara	3	13.00	0.17
	Khedachitawlaya	3	19.67	
	Lambikhedi	3	7.33	
	Salamata	4	9.38	
	Samanera	4	17.50	
	Shakkarkhedi	4	8.25	
	Tukral	3	13.17	
	Total	24		
Magnessium Hardness (mg/l)	Jhalara	3	13.33	0.54
	Khedachitawlaya	3	17.00	
	Lambikhedi	3	12.67	
	Salamata	4	7.00	
	Samanera	4	14.00	
	Shakkarkhedi	4	10.00	
	Tukral	3	15.67	
	Total	24		
Chloride (mg/l)	Jhalara	3	12.00	0.21
	Khedachitawlaya	3	18.33	
	Lambikhedi	3	7.33	
	Salamata	4	9.00	
	Samanera	4	14.75	
	Shakkarkhedi	4	9.00	
	Tukral	3	18.67	
	Total	24		
Alkalinity (mg/l)	Jhalara	3	11.33	0.05
	Khedachitawlaya	3	17.00	
	Lambikhedi	3	16.00	
	Salamata	4	9.13	
	Samanera	4	19.75	
	Shakkarkhedi	4	4.38	
	Tukral	3	11.33	
	Total	24		

physicochemical and microbiological analysis. The chemical assessment showed that although most parameters were within permissible limits, several, including TDS, total hardness, and calcium hardness, frequently exceeded desirable standards. Chloride levels were close to the desirable threshold. These findings suggest that while water is chemically acceptable, it often falls short of optimal quality for long-term consumption.

Microbiological results revealed a more pressing issue. Out of 24 samples, 21 (87.5%) were contaminated, with one-third containing E. coli, rendering the majority unsatisfactory for drinking. This aligns with earlier WHO/UNICEF reports, which emphasize that microbial contamination, rather than chemical exceedances, is the major public health concern in rural water supplies[1,2].

Detection of coliforms in higher concentrations was used as an index of the presence of enteropathogens in water because they are members of Enterobacteriaceae that are found in human and animal intestines and thus also present in large numbers in sewage. Among them, only *E. coli* is a reliable indicator that is not found in other sources[7].

When chemical parameters were compared between contaminated and uncontaminated samples, no significant associations were found for TDS, magnesium hardness, or calcium hardness. Interestingly, chloride demonstrated a statistically significant association ($p = 0.047$), with higher concentrations more common in uncontaminated samples. While earlier studies often report elevated chloride alongside fecal contamination due to sewage intrusion, the inverse relationship here may reflect residual chlorine in treated or piped sources, highlighting the need for free chlorine measurement in future monitoring[8,9].

Comparison across different water sources (handpumps, taps, tubewells, wells) showed no significant differences, although wells generally recorded lower mineral content and taps/handpumps showed higher values. At the village level, however, statistically significant variation was observed for total hardness ($p = 0.026$), with Khedachitawlaya and Samanera showing higher values and Shakkarkhedi lower levels. Alkalinity also approached significance ($p = 0.051$), with contrasting extremes between Samanera and Shakkarkhedi. These findings highlight the role of hydrogeological conditions and local practices in shaping village-specific water profiles.

From a public health perspective, high hardness in some villages may predispose residents to renal calculi and scaling in household water systems, while very low hardness and alkalinity increase risks of corrosion and reduced buffering against acids. The widespread fecal contamination represents the most immediate threat, contributing to diarrheal diseases and related morbidities, especially in children. Within the framework of the Community Adoption Programme, these results underscore the need for targeted interventions such as household-level treatment (boiling, filtration, chlorination), community education on safe storage, and infrastructure improvements through Panchayati Raj Institutions.

In a water quality and health risk assessment in groundwater study conducted by S. Dogara in 2022 found that of 25 sampling sites with various sources like handpump, borewell, 60% of water samples were under the poor category of WQI. Groundwater of the study area was found to be contaminated with copper (Cu), iron (Fe), lead (Pb), and chromium (Cr), while low contamination of zinc (Zn) and arsenic (As) was found according to the heavy metal evaluation index (HEI). High contamination of chromium (HPI= 9740.8) and lead (HPI=188) was recorded as per HPI. Study recommends regular monitoring of the groundwater of the study area as well as treatment before using this water for drinking purposes[10]. S. Ali et al. in 2024 evaluated the groundwater quality in the district of Agra, from 50 water samples that were collected. The results showed water quality index mostly ranged between 105 and 185; hence, the study area fell in the category of unsuitable for drinking purposes. Therefore, it was inferred that the groundwater of the contaminated areas must be treated and made potable before consumption[11]. A correlational study conducted by LN Gupta et al. in 2022 of surface and ground water on physiochemical parameters, the results of the correlation study showed that calcium and TH are strongly correlated, followed by TH with CF. Ca2+, TH, CF, TA, TDS, SO42" and iron show a high correlation. The variation between surface and groundwater sources was not significant, indicating that no major point or non-point source joined the surface or subsurface resources. The results of the correlation study suggest that water quality can be managed by controlling TH and TDS concentrations through conventional and non-conventional removal processes before processing for agricultural and domestic consumption[12].

The study is not without limitations. The small sample size limited statistical power, and the cross-sectional design did not account for seasonal variation in water quality. Residual chlorine was not measured, restricting interpretation of the chloride–contamination association. Nonetheless, the strength of this study lies in its integrated approach, combining chemical and microbiological assessment across multiple villages to provide actionable insights.

Conclusion

In conclusion, the findings demonstrate that while chemical parameters are largely within safe limits, microbial contamination is widespread and remains the dominant health hazard. Significant inter-village differences in total hardness and alkalinity, along with the unexpected association between chloride and microbiological safety, call for further investigation with larger, seasonal datasets. Strengthening monitoring systems, promoting household water treatment, and ensuring sustainable infrastructure are critical steps toward improving drinking water safety in rural communities.

This study provides a comprehensive assessment of drinking water quality in seven adopted villages of Central India, combining physicochemical and microbiological analysis. While most chemical parameters remained within the permissible limits of BIS standards, several—including TDS, total hardness, and calcium hardness—frequently exceeded desirable levels, indicating concerns regarding palatability and long-term acceptability. More importantly, microbiological analysis revealed that the majority of water samples (87.5%) were contaminated, with one-third showing *E. coli* positivity, underscoring that microbial safety remains the most critical challenge for drinking water in the study area.

Statistical analysis highlighted significant inter-village variation in total hardness ($p = 0.026$) and borderline variation in alkalinity ($p = 0.051$), suggesting that hydrogeological conditions and local practices contribute to village-specific water profiles. The unexpected protective association of chloride with microbiological safety indicates the possible influence of treated or piped supplies, warranting further investigation with measurement of residual chlorine.

Overall, the findings emphasize that improving microbial safety should be prioritized over chemical quality, though both remain important for long-term health protection. Village-specific strategies under the Community Adoption Programme, including household-level treatment, safe storage practices, regular disinfection, and infrastructure strengthening through Panchayati Raj Institutions, are essential. Future studies with larger sample sizes and seasonal monitoring are recommended to better understand chemical–microbial interactions and to design sustainable interventions. Although the water samples exceeded the desirable limits and showed unfavorable results, the water can still be used for drinking purposes. For the fecal contamination of water, village representatives were informed, and IEC activities, along with the seasonal pattern of water quality assessment, will be planned in the near future.

Ethical Approval

The ethical approval has been given by the Institutional Ethics Committee of R.D. Gardi Medical College, Ujjain, with reference no. 01/2025

Conflict of Interest

None.

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