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Evaluation of drinking water quality and its influence on residents' health at BIT Mesra, Patna campus, Bihar

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Abstract

Groundwater, a vital resource stored within the earth's subsurface, serves numerous purposes, including domestic, industrial, commercial, cultural, recreational, and ecological. However, the increasing water demand, coupled with factors such as population growth, inadequate rainfall, groundwater scarcity, contamination, and finite resources, necessitates effective groundwater management. In the context of B.I.T Mesra, Patna Campus, Bihar, India, this study aims to assess the groundwater status. Untreated/raw and treated water samples were collected and analyzed for physicochemical parameters, including pH, Electrical Conductivity, Turbidity, Total Dissolved Solids, Total Suspended Solids, Hardness, and Alkalinity. Comparisons were made with Indian drinking standards and WHO guidelines. Results indicate that only total hardness and alkalinity levels exceed permissible limits, while other parameters meet the prescribed standards. A survey was conducted among residents to evaluate their awareness concerning water quality and associated health issues. This research underscores the importance of continuous monitoring and management strategies to ensure the sustainable use of groundwater resources in the study area.

Keywords: Drinking water, Quality, Awareness, Health issues, Water treatment.

1.Introduction

The significance of water in human life and activities cannot be overstated. Studies have indicated that a substantial portion of both urban (approximately 36%) and rural (around 65%) Indian populations lack access to safe drinking water (WHO, 2006). Groundwater serves as a crucial resource for domestic, industrial, and agricultural purposes globally. However, urbanization and industrialization have contributed to the degradation of groundwater quality, affecting its suitability for drinking, agricultural, and other essential uses, as outlined by various water quality standards (IS 10500, 2012; WHO, 2006).

Especially in rural areas where alternative water sources like dams, rivers, or canals are limited, groundwater exploration becomes essential. The increasing demand for freshwater due to population growth, unplanned urbanization, industrialization, and intensive agricultural practices has placed significant pressure on groundwater resources (Joarder et al., 2008). Groundwater not only fulfills over 80% of rural and 50% of urban domestic needs but also supports around 40% of India's agricultural output (Joshi & Seth, 2008).

However, excessive exploitation of groundwater, coupled with poor management practices, has led to declining water levels and contamination in many areas ((Kaur & Kumar, 2024). Pollution from sewage, industrial effluents, and agricultural runoff has altered the physiochemical properties of water, leading to numerous investigations (Mahananda et al., 2010). The WHO estimates that approximately 80% of human diseases are water related. Once contaminated, groundwater quality is challenging to restore, necessitating proactive measures for protection (Maniyar, 1990). Instances of waterborne diseases resulting from contaminated groundwater have been documented, posing significant health risks (Aremu et al., 2011; Elizabeth & Naik, 2005).

Understanding water chemistry is fundamental to comprehending the multidimensional aspects of aquatic environmental chemistry, including its sources, composition, reactions, and transport. The quality of water directly affects human welfare, particularly health, making water quality monitoring a critical aspect of management (Richards et al., 2021, 2022; Sehar et al., 2011). Several studies across different regions of Patna, Bihar, India highlight various aspects of groundwater quality and its implications. These studies utilize methodologies such as GIS to track groundwater quality and irrigation suitability, revealing significant findings regarding salinity levels, fluoride concentrations, and other contaminants (R. Kumar et al., 2022, 2023; Nandan, 2012; Talalaj, 2014; Zafar et al., 2022). The quality of drinking water is a critical determinant of public health and well-being. At the BIT Mesra, Patna campus in Bihar, concerns have arisen regarding the safety and quality of groundwater, which serves as the primary source of drinking water for residents. Despite adherence to established standards for various water quality parameters, issues such as water hardness, alkalinity, and potential contamination from industrial and agricultural activities persist. These factors not only compromise water safety but also pose significant health risks to the campus community.

This study aims to evaluate the suitability of groundwater for drinking purposes at BITP Campus, Patna, emphasizing the connection between groundwater quality and human health. It also advocates for interdisciplinary research to address water security and health risks in densely populated urban areas, aiming to fill knowledge gaps and propose solutions to safeguard groundwater resources.

2. Materials and methods

Study area

The study area i.e., Birla Institute of Technology Mesra, Off-Campus (Patna) (BITP) is shown in Fig. 1. It is situated at 25.5956° N latitude and, 85.0860° E longitude respectively. There are four hostels with a combined capacity of approximately 2,000 residents. The source of water within the campus is groundwater only.

Fig. 1: Location map of BITP (*Source*: Google Maps)

Water sampling

The raw or untreated water samples and treated water samples were collected in low-density polyethylene (LDPE) sampling bottles. Labeling of samples was used to prevent any misidentification of water samples. Details such as sample no., location details, date of sampling, etc. were used for labeling the sample. If more than one bottle of water sample was collected from any place, the sample was designated as n=1,2,3,4…., etc.

Physicochemical analysis

With the help of Indian Standards (parts of IS 3025) and APHA 2017, various physicochemical analyses have been carried out for the collected water samples. To evaluate the water quality, 7 physicochemical parameters i.e., Colour, pH, Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Total Hardness (TH), and Total alkalinity (TA) are selected respectively. All the physicochemical analysis is carried out in the Environmental Engineering laboratory of the Civil Engineering Department of Birla Institute of Technology Mesra, Off-Campus (Patna) The methods adopted for measuring each water quality and the instruments are summarized in Table 1.

Table 1: Methods and instrument details used for the physicochemical analysis of the water sample.

S No.	Parameter Tested	Instrument Used	Method Adopted	Indian Standard	Standard Methods (APHA, 2017)
1	Colour	-	Physical Examination	IS 3035 Part 4:1983	
2	pH	Digital pH Meter (LMPH10)	Electrometric method	IS 3035 Part 11:1983	4500-H^+B
3	EC	Digital Conductivity Meter (LMCM20)	Electrometric method	IS 3035 Part 14:1984	2510B
4	Turbidity	Digital Nephelometer	Colorimetric Method	IS 3035 Part 10:1984	2130B
5	TDS	Digital Conductivity Meter (LMCM20)	Gravimetric Method	IS 3035 Part 16:1984	2540C
6	TH	-	EDTA Titrimetric Method	IS 3035 Part 21:2009	2340C
7	TA	Digital pH Meter (LMPH10)	Titration Method	IS 3035 Part 23:1986	2320B

Survey for Water quality and health

A survey was conducted to assess the water quality and health issues among the residents of the BITP campus. The survey contains questions about occupation, age, water use, facilities, awareness of waterborne diseases and technologies like rainwater harvesting, and perceptions of safe drinking water.

3. Results and Discussion

Description of Sampling Stations

Two Samples of groundwater (as raw water source) from three groundwater pumping stations which are being used to satisfy the total water demand of the BITP Campus were collected. Similarly, two samples of treated water (from a water purifier installed in the hostel) from each hostel (BH-1, BH-2, and GH) were collected. The water samples were collected and preserved in the Environmental Engineering Laboratory of the Civil Engineering Department, BITP Campus for carrying out various water quality tests.

Physicochemical analysis of groundwater samples

All the water samples were analyzed for the water quality parameters: pH, Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Total Hardness (TA), and Total Alkalinity (TA), as per Standards (APHA 2017; IS 3025). Each test was carried out five times to determine the average water quality parameters. The results of the water quality analysis are tabulated in Table 2. A summary of variations among water quality parameters at BIT Patna Campus is also tabulated in Table 3.

Table 2: Summary of physicochemical analysis of water samples

Water Quality Parameter	Permissible limits as per		Raw water sources		Treated water sources	
	IS 10500	WHO 2000	Sample ID	VALUE	Sample ID	VALUE
pH	6.5-8.5	6.5-8.5	R1	7.28	T1	7.16
			R2	7.32	T2	7.2
			R3	7.44	T3	7.3
EC (µS/m)	-	750-1500	R1	610	T1	590
			R2	590	T2	590
			R3	720	T3	710
Turbidity (NTU)	1	0.2	R1	1	T1	1
			R2	2	T2	1
			R3	2	T3	1
TDS (mg/L)	500	600-1000	R1	398	T1	295
			R2	331	T2	272
			R3	352	T3	302
TH (as $CaCO_3$, mg/L)	200	500	R1	314	T1	300
			R2	326	T2	297
			R3	380	T3	354
	200	-	R1	280	T1	260

TA (as $CaCO_3$, mg/L)			R2	277	T2	265
			R3	298	T3	264

Table 3: Variation of water quality parameters for BIT Patna Campus

Water Quality Parameter	Minimum value	Maximum value	Average value	No. of samples	No. of samples within permissible limits	% of samples within permissible limits	No. of samples beyond permissible limits	%of samples beyond permissible limits
pH	7.16	7.44	7.30	6	6	100	0	0
EC	590.0	720.0	655.0	6	6	100	0	0
Turbidity	1.0	2.0	1.5	6	6	100	0	0
TDS	272.0	398.0	335.0	6	6	100	0	0
TH	297.0	380.0	338.5	6	0	0	6	100
TA	260.0	298.0	279.0	6	0	0	6	100

All tested parameters, including pH, electrical conductivity, turbidity, and total dissolved solids, conform to the acceptable limits set by IS 10500, 2012, and WHO, 2006, indicating no treatment necessity. However, the observed total hardness and total alkalinity in all samples suggest that existing treatment facilities may not effectively mitigate hardness from the raw water sources. Methods such as water softening, reverse osmosis, chemical treatment, or chelating agents can be used to reduce excess hardness in raw water. Similarly, alkalinity can be treated with techniques like ion exchange, reverse osmosis, or lime softening.

Resident's Health Survey

A comprehensive survey among students revealed several key insights into their living conditions and water usage patterns. While water quality is generally perceived as clean in the hostel and home environments, issues such as hardness, muddiness, and bad odours are reported in the water supplied in hostels.

This suggests potential challenges in maintaining water quality standards within hostel premises, necessitating further investigation and remedial measures. Based on the survey conducted among 50 students following insights have been drawn:

Student Residences and Water Utilization Insights

Demographics

Approximately 62% of surveyed students are aged between 20-30 years, while the remaining 38% are within the 15-20 years age group as shown in Fig. 2.

Residence Details

Over 94% of students reside in various hostels on the college campus, indicating a significant reliance on on-campus housing. The remaining students live outside the campus in Patna, suggesting a smaller proportion of off-campus residents among the surveyed population as shown in Fig. 3.

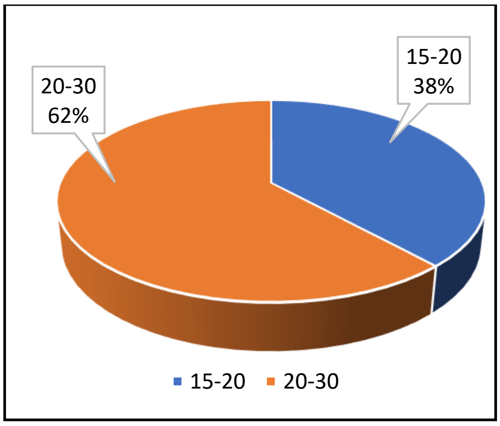

Fig. 2: Demographic detail (age group)

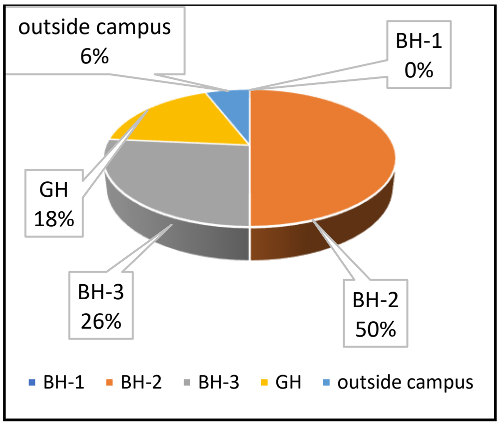

Fig. 3: Residence detail

Water Resources

More than 91% of students use subsurface water sources in their homes and the remainder 9% use surface water as water resources for domestic purposes as shown in Fig. 4.

Groundwater Depth

12% of students use groundwater deeper than 200 meters, while 9% access water between 150 and 200 meters deep. Around 24% draw water from depths of 100-150 meters, 23% from 50-100 meters, and 6% from under 50 meters. Additionally, 26% are unsure about their groundwater's exact depth as shown in Fig. 5.

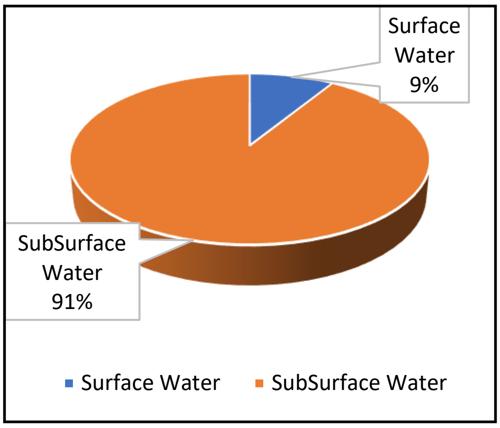

Fig. 4: Type of water resources

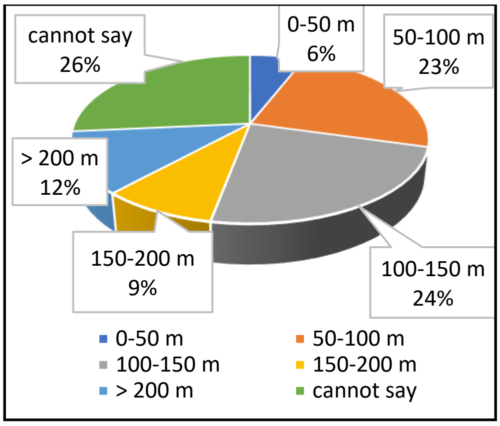

Fig. 5: Depth of groundwater resources

Rainwater Harvesting

Only 9% of students practice rainwater harvesting at their homes, indicating a low adoption rate of this sustainable water management method as shown in Fig. 6.

Water Quality Issues

The perception of water quality is generally positive in both hostel and home environments as shown in Fig. 7. Among 34 students surveyed, 82% agree that the water provided in the hostel is clean and 97% believe that the water resources at their homes are clean. However, 24% of respondents frequently encounter muddy water in the hostel. Additionally, 56% of students perceive the water in the hostel as hard, while 15% report the same hardness in water at their home. Concerningly, 21% of students suspect fluoride contamination, and 26% suspect arsenic contamination in water at the hostel. In comparison, 6% of students believe that the water is contaminated with fluoride in their homes, and 12% suspect arsenic contamination also.

Water Purification Methods at Home

According to a survey on home water purification practices, around 88% of surveyed students purify their drinking water. Among them, 85% choose water purifiers, with only 3% using candle filters. Interestingly, none of the respondents use boiling, despite it being widely considered the most effective and economical method. Moreover, 12% of participants do not practice any form of water purification. These results as shown in Fig. 8 highlight the preference for water purifiers among students and suggest a possible lack of awareness regarding alternative purification techniques.

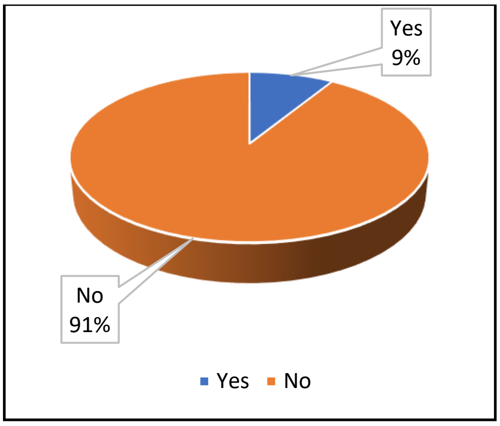

Fig. 6: Rainwater harvesting facility

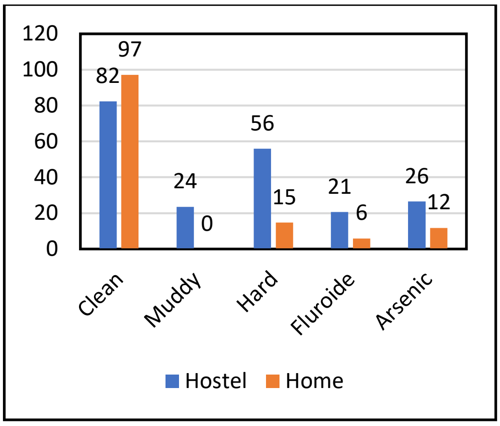

Fig. 7: Water quality issues

Perception of Water Safety

The survey findings indicate that perceptions of water safety vary among respondents. For hostel water, 32% believe it is safe, 29% disagree, and 38% are uncertain. In contrast, for home water, a vast majority (97%) consider it safe, with only 3% expressing doubts. Interestingly, no respondents chose the "can't say" option for home water. When asked about other places with safe water, only 6% responded positively, while 18% said no, and 76% were unsure. These insights as shown in Fig. 9 highlight the need for greater awareness and clarity regarding water safety among respondents.

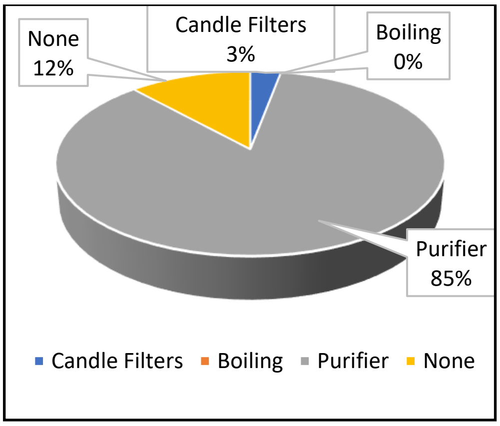

Fig. 8: Water purification methods adopted in the home

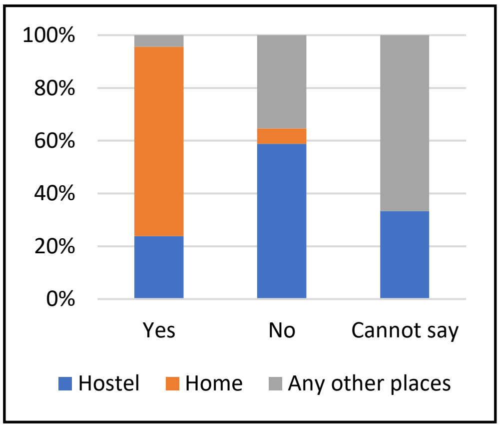

Fig. 9: Perception towards safe water sources

Incidence of Waterborne Diseases

In a recent survey on waterborne diseases among students conducted over the past year, it was discovered that 50% of the participants fell ill during this period. Among those who fell ill, a significant majority (76%) attributed their illnesses to waterborne diseases, with skin ailments being the most prevalent. Specifically, 23% reported suffering from diarrhea, 15% experienced jaundice, and 6% had dysentery. Additionally, 39% of respondents reported skin diseases, while 15% were affected by typhoid. These findings as shown in Fig. 10 highlight the pressing need for enhanced measures to address water quality issues and prevent the spread of waterborne diseases among students.

Awareness of Waterborne Diseases

In a survey concerning water-borne diseases, participants showed different levels of identification (Fig. 11): 18% recognized one disease only; 15% recognized two diseases; 21% recognized three diseases; 24% recognized four diseases; 15% recognized five diseases; 3% recognized six diseases; and 6% accurately identified all seven water-borne diseases which included diarrhea, skin diseases, jaundice, cholera, typhoid, dental fluorosis, and dysentery. These detailed findings provide valuable insights into the water-related challenges faced by college students, including issues related to water quality, purification practices, awareness of waterborne diseases, and perceptions of water safety. Addressing these challenges requires a multi-faceted approach encompassing infrastructure improvements, education, and public health interventions.

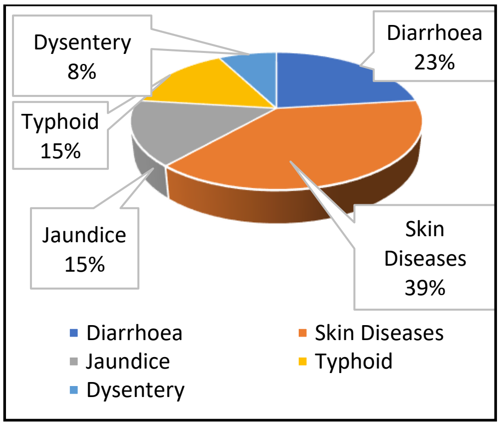

Fig. 10: Incidence of waterborne diseases

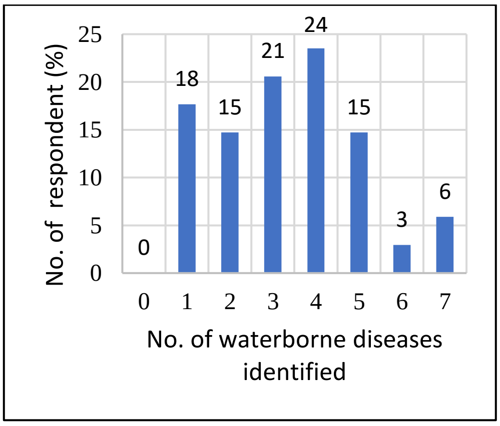

Fig. 11: Awareness of waterborne diseases

Implications and Recommendations

Considering both the survey results and the physicochemical analysis of collected water samples, certain mitigation measures are also recommended.

- ***Infrastructure Improvement:*** Addressing issues related to water quality in hostels, such as hardness, muddiness, and contamination, requires infrastructure upgrades and regular maintenance.
- ***Education and Awareness:*** Implementing educational programs to correct misconceptions about waterborne diseases, such as malaria, and raise awareness about proper water purification methods is essential.
- ***Health Interventions:*** Given the high incidence of waterborne diseases among students, public health interventions, including regular testing of water sources and vaccination programs, are necessary to mitigate health risks.
- ***Promotion of Rainwater Harvesting:*** Encouraging more students to adopt rainwater harvesting practices can alleviate pressure on groundwater sources and promote sustainability.
- ***Collaboration with Local Authorities:*** Collaboration between educational institutions and local authorities in Patna can facilitate the improvement of water infrastructure and the implementation of water quality regulations.
- ***Groundwater modeling***: Many researchers have proposed various analytical methods for forecasting groundwater contamination originating from both point and non-point sources (Crank, 1975; A. Kumar et al., 2010; M. K. Singh et al., 2008, 2010). These approaches could prove beneficial in safeguarding the integrity of aquifers. Employing Laplace transform techniques and solutions derived from the Advection-Dispersion Equation (ADE) offers avenues for identifying potential solute transport, thereby aiding in the effective management of groundwater resources (Jaiswal et al., 2011, 2023; P. Singh, 2011; P. Singh et al., 2012, 2014).

In conclusion, addressing the challenges identified in the survey requires a comprehensive approach involving infrastructure improvements, educational initiatives, and collaboration between stakeholders to ensure access to safe and clean water for college students in Patna.

4. Conclusion

The study highlights that while the general quality of water, including parameters like pH, electrical conductivity, turbidity, and total dissolved solids, conforms to acceptable standards (IS 10500, 2012, and WHO, 2006), issues with total hardness and alkalinity persist. This suggests that current water treatment facilities may not effectively address these specific concerns. To mitigate hardness, methods such as water softening, reverse osmosis, chemical treatments, or chelating agents are recommended. Alkalinity can be treated using ion exchange, reverse osmosis, or lime softening.

The resident health survey conducted among students provided critical insights into their living conditions and water usage patterns. Although the majority of students perceive the water quality in both hostel and home environments as generally clean, there are notable issues with hardness, muddiness, and bad odors in hostel water. Additionally, suspicions of fluoride and arsenic contamination were reported.

Demographically, the majority of students (62%) are aged between 20-30 years, and 94% reside in hostels, indicating a high dependency on campus-provided water. More than 91% of students use subsurface water sources at home, with a notable depth variation of groundwater accessed. However, rainwater harvesting practices are minimally adopted (9%).

Water quality perception varies significantly, with 32% considering hostel water safe, compared to 97% for home water. Despite this, a substantial number of students report incidences of waterborne diseases, particularly skin ailments, diarrhea, and jaundice, highlighting the urgent need for improved water quality and health interventions.

Recommendations include infrastructure improvements to address water quality issues in hostels, educational programs to correct misconceptions about waterborne diseases, and increased awareness about effective water purification methods. Health interventions such as regular testing and vaccinations are essential, alongside promoting rainwater harvesting and fostering collaboration with local authorities for better water infrastructure and quality regulation. Utilizing advanced groundwater modeling techniques can also aid in safeguarding groundwater resources. Addressing these challenges requires a comprehensive, multi-faceted approach to ensure access to safe and clean water for college students in Patna.

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