https://doi.org/10.3126/juem.v3i1.84861

COMPREHENSIVE ASSESSMENT OF WATER TREATMENT PERFORMANCE: A CASE STUDY OF BHADGAUN WATER SUPPLY PROJECT

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Submission Date: 12 July 2025
Revised Date: 24 July 2025
Accepted Date: 28 July 2025
Published Date: 30 Sept. 2025

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Cite this: Chuwai, B. and Pokhrel, R., (2025)., Comprehensive Assessment of Water Treatment Performance: A Case Study of Bhadgaun Water Supply Project, JUEM 3(1), 124 – 132, https://doi.org/10.3126/juem.v3i1.84861

ABSTRACT

Ensuring an adequate supply of potable water in rapidly urbanizing regions poses increasing challenges due to limited water resources, aging infrastructure, and climate variability. This study evaluates the treatment efficiency of the Bhadgaun Water Supply Project by analyzing key physical (Turbidity, Electrical Conductivity (EC), pH, Total Dissolved Solid (TDS)) and microbiological (E. coli, Total Coliform) parameters across major treatment stages—sedimentation, roughing filtration, slow sand filtration, and chlorination—during both monsoon and dry seasons. Results showed significant seasonal variation, with monsoon water exhibiting turbidity up to 4.63 NTU, EC of 361 µS/cm, and E. coli counts as high as 96 CFU/100ml. The Slow Sand Filter achieved up to 84% turbidity and 71% E. coli reduction. Post-chlorination, microbial contamination was fully removed, ensuring compliance with National Drinking Water Quality Standard (NDWQS) 2022. TDS levels dropped from 261 mg/L to 103 mg/L during monsoon and from 112 mg/L to 76 mg/L during the dry season. Slight reductions in overall efficiency were observed in the dry season due to lower contaminant loads, affecting filter performance. It shows the effectiveness of the existing system and the need for regular monitoring and timely maintenance to ensure consistent delivery of safe drinking water.

Keywords: *Water quality, treatment efficiency, seasonal variation, NDWQS, Bhadgaun Water Supply Project.*

1. Introduction

Access to safe water is essential for life, public health, and economic development of the locality. Both water quantity and quality impact human well-being and ecosystem health (Pandey & Anand, 2021). Chemical contaminants such as arsenic, fluoride, and nitrate continue to pose risks. However, improvements in water and sanitation have notably reduced diarrheal deaths, particularly during the Millennium Development Goal era (WHO, 2024). Reliable water access also supports hygiene, household needs, and overall health outcomes (Howard et al., 2020). The Sustainable Development Goals (SDGs), particularly Goal 6, call for universal and equitable access to water and sanitation by 2030. Achieving this in Nepal requires coordinated efforts from the Department of Water Supply and Sewerage Management (DWSSM), the Ministry of Water Supply (MoWS), and various local and non-governmental stakeholders (MoWS, 2023).

Conventional water treatment plants typically use coagulation, flocculation, sedimentation, filtration, and disinfection. Their effectiveness depends on source water quality, system design, operation, and maintenance. Emphasis should be placed on optimizing the overall system to ensure consistent delivery of safe water (Piri et al., 2010; Okonko et al., 2008). Inadequate treatment remains a major cause of waterborne diseases, especially among children (Hossain & Hassan, 2015). The Bhadgaun Water Supply Project, serving Vyas Municipality-01 in Tanahu, sources water from Chhabdi Khola and Karadi Khirkhadi and supplies two plants: Ameli Bhanjhyang and Dhupkholsa. These facilities use sedimentation, roughing filtration, slow sand filtration, and chlorination, with both gravity and pumping systems. However, water quality is impacted by seasonal variability, urban encroachment near sources, aging infrastructure, and operational constraints. Overcapacity and nearby development have led to increased turbidity, high total dissolved solids, and microbial contamination. This study evaluates the treatment efficiency of the Ameli Bhanjhyang and Dhupkholsa plants and assesses whether the treated water complies with National Drinking Water Quality Standards (NDWQS) 2022. The findings aim to guide improvements for a safe, reliable water supply in the community and also generalized the quality of supplied water by introducing the similar types of treatment plants in nearby similar area.

2. Materials and Methods

This study employed a descriptive, quantitative approach to evaluate the treatment efficiency of the Bhadgaun Water Supply Project in Vyas-01, Tanahun. Water samples were collected at five key stages—Plain Sedimentation Tank (PST)-in, Horizontal Roughing Filter (HRF)-in, Slow Sand Filter (SSF)-in, SSF-out, and Reservoir Tank (RVT)-post-chlorination and tested for physical and microbiological parameters during both monsoon and dry seasons at the Federal Water Supply and Sewerage Management Project (FWSSMP) Laboratory in Pokhara. The project, operating two treatment plants (Ameli Bhanjhyang and Dhupkholsa), sources water from streams and sump-wells, serving around 2,680 households across 28 toles.

Water samples were collected from five critical treatment stages—Plain Sedimentation Tank (PST)-inlet, Horizontal Roughing Filter (HRF)-inlet, Slow Sand Filter (SSF)-inlet, SSF-outlet, and Reservoir Tank (RVT) post-chlorination—during both the monsoon and dry seasons. These five sampling points were chosen to represent the main treatment units and assess their individual contribution to overall water quality improvement. A total of 10 samples were collected: one from each of the five treatment stages during the monsoon (mid-July) and dry season (mid-March), respectively. Samples were collected on a single representative day per season to reflect typical water quality conditions during peak (monsoon) and low (dry) contamination periods. This sampling strategy was adopted to provide a comparative snapshot of seasonal treatment performance across stages.

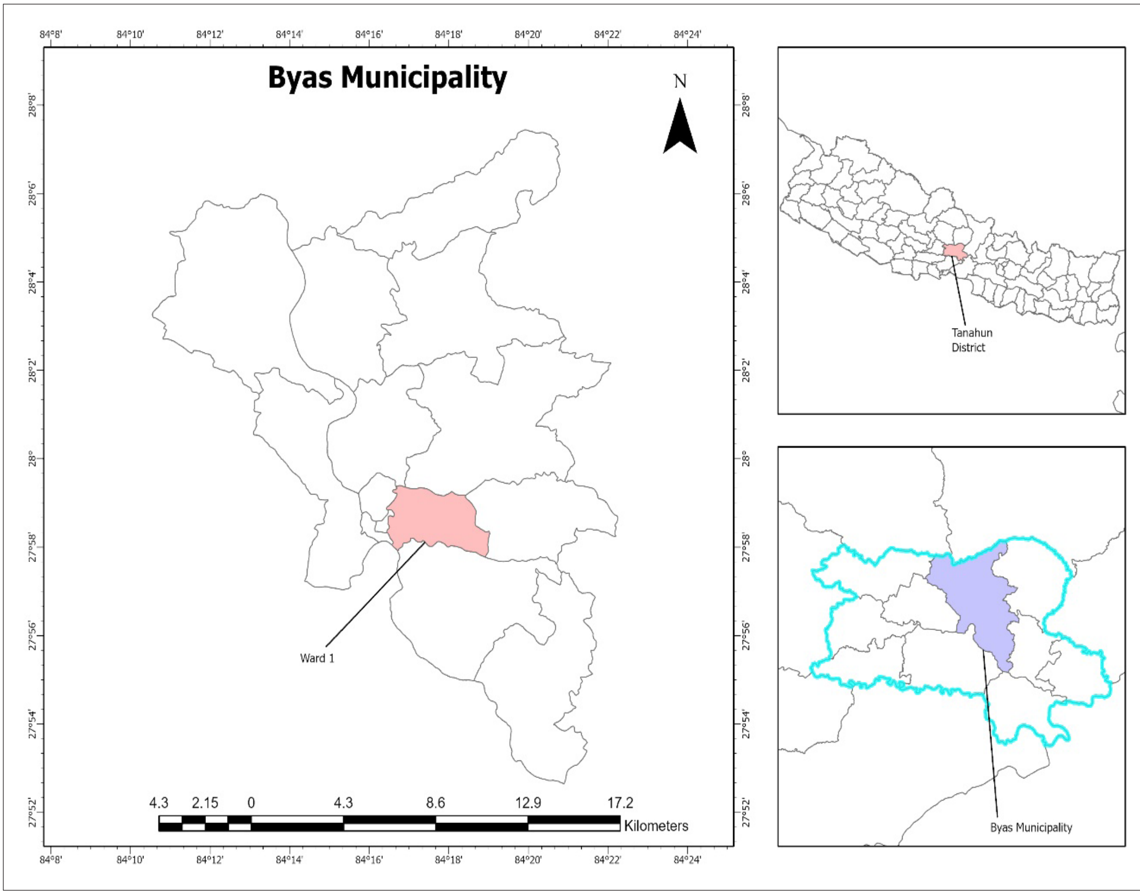


Figure. 1 Magnifying view of Study Site in the Map of Nepal

While a higher sampling frequency could improve temporal resolution, resource limitations—such as field access, and budget—necessitated a focused approach. Although a larger sample set could enhance statistical robustness, the selected approach captures key seasonal contrasts and provides a practical yet scientifically valid assessment of treatment efficiency under typical operating conditions

3. Results and Discussions

The physical and microbiological water quality parameters were analyzed and discussed for both Ameli Bhanjhyang and Dhupkholsa treatment plants during Monsoon and Dry seasons.

3.1 Treatment Plant Operational Status

Both Ameli Bhanjhyang and Dhupkholsa treatment plants were functional but exhibited structural deterioration, including weathered walls and plaster degradation, likely from prolonged environmental exposure. The filtration media in the HRF appeared overloaded, necessitating cleaning or replacement. Open-top PST and filters presented potential airborne contamination risks despite secure boundary walls. Regular maintenance, encompassing structural repairs and safeguarding of open tanks, is crucial for prolonging plant lifespan and ensuring water quality.

Regular maintenance generally alleviates the performance of treatment plan. Similarly, Kumar et al. (2018) also highlight the importance of consistent upkeep to sustain the efficacy of community water treatment systems.

3.2 Water Quality Treatment Efficiency

3.2.1 pH Variation Across Treatment Stages

At both treatment plants, pH values remained within the NDWQS 2022 acceptable range (6.5–8.5) throughout the treatment process (Table 1 & Table2). Minor seasonal fluctuations were observed, with slightly higher pH during Monsoon at PST inlet.

Maintaining stable pH is crucial for effective disinfection and water safety (WHO, 2017). Slight pH decreases after filtration likely result from biological activity in slow sand filters (Tebbutt, 1998).

3.2.2 Electrical Conductivity (EC)

EC values showed a progressive decline from PST inlet through HRF and SSF to RVT, with higher Monsoon values reflecting increased dissolved solids from runoff. All values remained well below the NDWQS 2022 limits of 1500 µS/cm. This reduction evidences efficient removal of dissolved ions, supporting findings by Adefemi and Awokunmi (2010), who linked seasonal surface runoff to EC variations and treatment efficiency.

3.2.3 Turbidity Removal

Turbidity significantly decreased through treatment stages, despite higher levels during Monsoon due to increased sediment loads. HRF and SSF showed major removal efficiencies, achieving turbidity below the NDWQ threshold of 5 NTU. Results align with Pathak et al. (2020), who reported 30–40% turbidity reduction in sedimentation tanks during Monsoon. Combined HRF and SSF filtration effectively reduces suspended solids, as also shown by Shrestha et al. (2018).

3.2.4 Total Dissolved Solids (TDS)

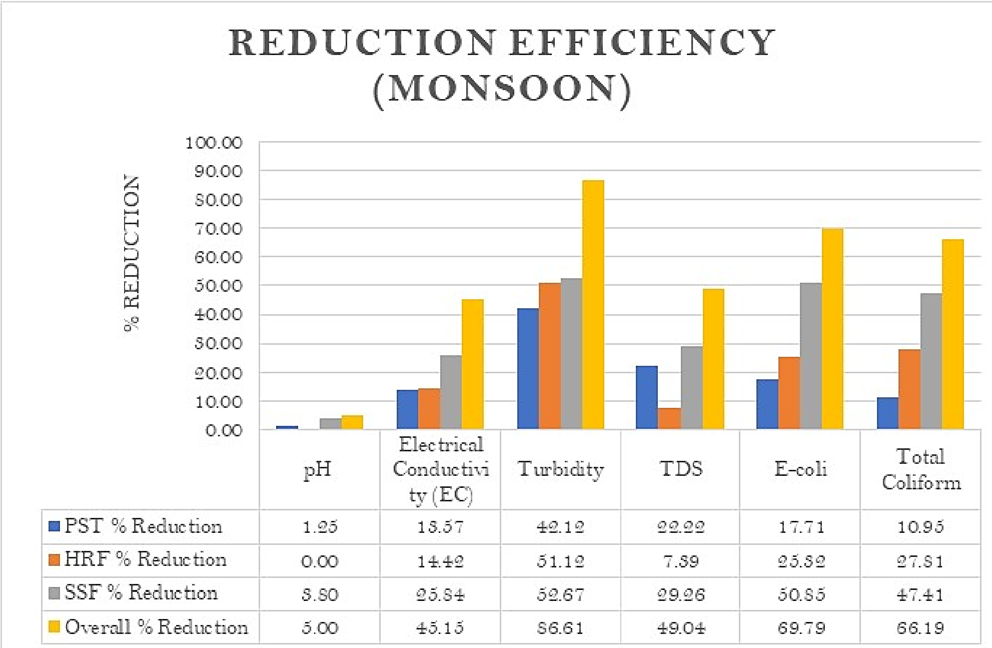
TDS declined consistently through treatment units, with elevated Monsoon values reflecting runoff impacts. Treated water TDS levels were within NDWQS 2022 limits (1000 mg/L). The decrease highlights the physical and biological filtration roles of HRF and SSF, confirming their effectiveness in removing dissolved solids and pathogens (Huisman & Wood, 1974).

3.2.5 E. coli Reduction

E. coli concentrations decreased steadily through treatment stages, with complete elimination after chlorination at RVT in both seasons. Higher Monsoon loads reflect contamination from runoff. The substantial reductions, especially in SSF and chlorination stages, meet WHO (2017) recommendations and align with Shrestha, A., Smith, J., & Lee, K. (2020) on microbial removal efficiency.

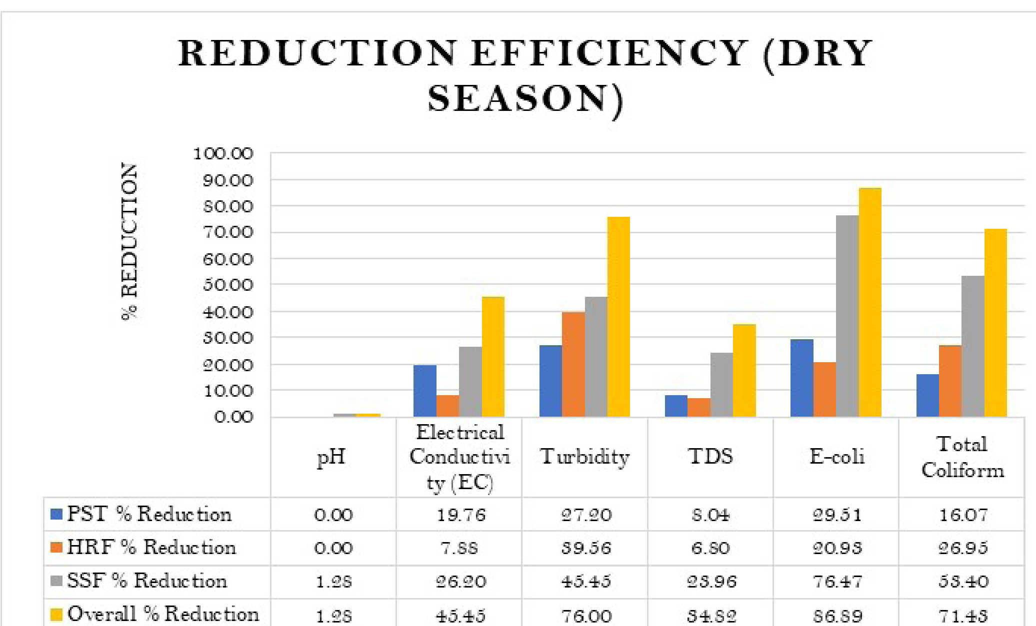
3.2.6 Total Coliform Reduction

Total Coliform counts showed a similar decreasing pattern, completely removed at RVT post-chlorination. Elevated Monsoon counts indicate increased fecal contamination during this period. Biological activity within SSF is crucial for pathogen removal (Gupta & Sharma, 2019). Final chlorination ensures microbial safety compliant with NDWQ standards.



	pH	Electrical Conductivity (EC)	Turbidity	TDS	E-coli	Total Coliform
PST % Reduction	1.25	13.57	42.12	22.22	17.71	10.95
HRF % Reduction	0.00	14.42	51.12	7.39	25.32	27.81
SSF % Reduction	3.80	25.84	52.67	29.26	50.85	47.41
Overall % Reduction	5.00	45.15	86.61	49.04	69.79	66.19

Figure 2: Percentage Reduction by different Treatment Plant Components during Monsoon Season at Ameli Bhanjyang



	pH	Electrical Conductivity (EC)	Turbidity	TDS	E-coli	Total Coliform
PST % Reduction	0.00	19.76	27.20	8.04	29.51	16.07
HRF % Reduction	0.00	7.88	39.56	6.80	20.93	26.95
SSF % Reduction	1.28	26.20	45.45	23.96	76.47	53.40
Overall % Reduction	1.28	45.45	76.00	34.82	86.89	71.43

Figure 3: Percentage Reduction by different Treatment Plant Components during Dry Season at Ameli Bhanjyang

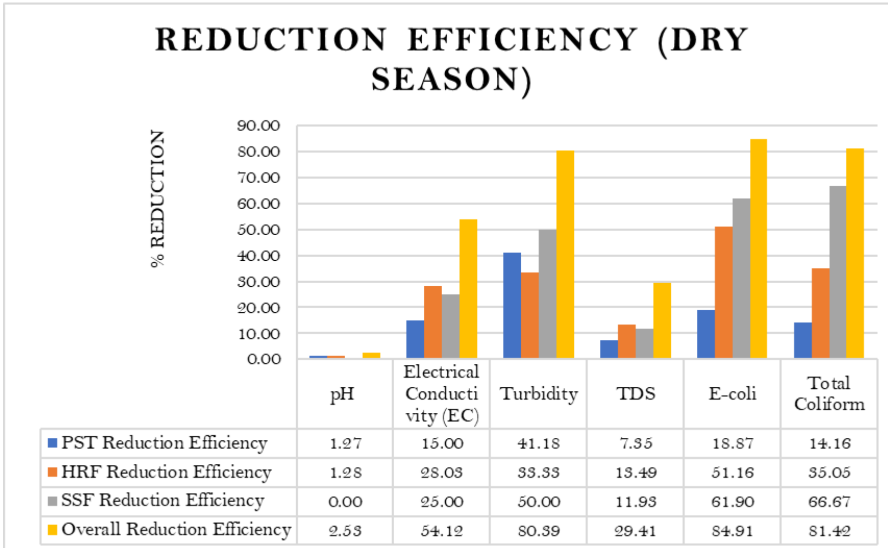


Figure 4: Percentage Reduction by different Treatment Plant Components during Dry Season at Dhupkholsa

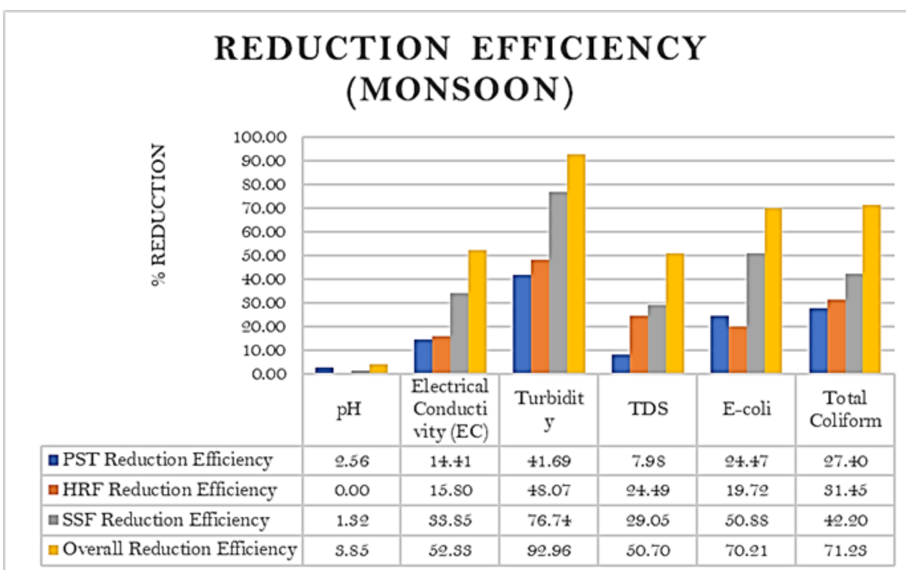


Figure 5: Percentage Reduction by different Treatment Plant Components during Monsoon Season at Dhupkholsa

3.3 Impact of Seasonal Variation on Treatment Performance

Monsoon season increased turbidity, EC, TDS, and microbial loads due to surface runoff, while treatment units effectively reduced these to safe levels. Seasonal fluctuations necessitate adaptive operational strategies, consistent with studies reporting similar seasonal water quality impacts globally (Adefemi & Awokunmi, 2010). Figures 2-5 demonstrates the different water pollutions removal efficiencies of different treatment components installed on Ameli Bhanjyang and Dhupkholsa treatment plant in dry and monsoon season. Percentage reductions of turbidity and microbial contaminants were generally higher during Monsoon due to greater absolute loads. SSF consistently contributed the highest removal efficiencies. SSF's biological filtration capacity is key to managing seasonal contamination variations, supported by Pathak et al. (2020) and Gupta and Sharma (2019). Tables 1 and 2 show all treated water parameters met NDWQS 2022 limits, with significant improvements in turbidity and microbial parameters critical for public health.

Table 1: Water Quality Test Report at Different Points at Ameli Bhanjyang TP

S. N.	Category	Time Period	Parameter	Unit	PST-In	HRF In	SSF In	SSF Out	RVT (after CDU)	Concentration Limits
1	Physical	Dry Season	pH		7.8	7.8	7.8	7.7	7.5	6.5-8.5
		Monsoon			8.0	7.9	7.9	7.6	7.6	
2		Dry Season	Electrical Conductivity (EC)	μs/cm	253	203	187	138	131	1500
		Monsoon			361	312	267	198	188	
3		Dry Season	Turbidity	NTU	1.25	0.91	0.55	0.3	0.2	5
		Monsoon			4.63	2.68	1.31	0.62	0.46	
4		Dry Season	TDS	mg/L	112	103	96	73	76	1000
		Monsoon			261	203	188	133	103	
5	Microbiological	Dry Season	E-coli	CFU /l00 ml	61	43	34	8	0	Nil
		Monsoon			96	79	59	29	0	
6		Dry Season	Total Coliform	CFU /l00 ml	168	141	103	48	0	Nil
		Monsoon			210	187	135	71	0	

4. Conclusions

Surface water and ground water are the major sources of drinking water in Nepal. Different water treatment facilities have been installed to make water potable, however most of the water user committee were unable to monitor the performance of treatment units regularly. This study evaluated the seasonal performance of the Bhadgaun Water Supply Project's treatment system, which includes PST, HRF, and SSF. The system consistently delivered treated water NDWQS 2022, despite fluctuations in raw water quality between Monsoon and dry seasons. Results confirm that the plant's robust design enables it to handle elevated turbidity and contaminant levels during the Monsoon.

Key findings include the PST effectively reduced turbidity and suspended solids during both seasons; the HRF enhanced solid and microbial removal, particularly in peak runoff periods; and the SSF provided consistent microbial quality control. Seasonal variations notably influenced raw water quality, yet all components functioned effectively without major deviation from NDWQS 2022. It reveals that similar kind of water treatment components act significant for treating surface and ground water provided for drinking in the similar mountainous region of Nepal.

Table 2: Water Quality Test Report at Different Points at Dhupkholsa TP

S. N.	Category	Time period	Parameter	Unit	PST - In	HRF -In	SSF -In	SSF -Out	RVT (after CDU)	Conc. Limits
1	Physical	Dry Season	pH		7.9	7.8	7.7	7.7	7.9	6.5-8.5
		Monsoon			7.8	7.6	7.6	7.5	7.6	
2		Dry Season	Electrical Conductivity (EC)	µs/cm	340	289	208	156	165	1500
		Monsoon			451	386	325	215	204	
3		Dry Season	Turbidity	NTU	1.02	0.6	0.4	0.2	0.3	5
		Monsoon			7.1	4.14	2.15	0.5	0.32	
4		Dry Season	TDS	mg/L	136	126	109	96	84	1000
		Monsoon			213	196	148	105	97	
5	Microbiological	Dry Season	E-coli	CFU/l00 ml	53	43	21	8	0	Nil
		Monsoon			94	71	57	28	0	
6		Dry Season	Total Coliform	CFU/l00 ml	113	97	63	21	0	Nil
		Monsoon			219	159	109	63	0	

Conc. Limits - Concentration Limits

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