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Statistical Approach for Water Management in Goa.

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ARTICLE INFO **ABSTRACT**

Water quality is a critical resource for life on Earth, but pollution, climate change, and over-exploitation threaten its quality. A study at Salulim Dam in Goa statistically analysed raw and treated water parameters to determine suitability for human consumption. The results showed better water quality than BIS standards, with seasonal variations in turbidity and pH. However, the monsoon season requires additional treatment to address low pH and high turbidity. The treatment process throughout the year maintained water quality, adhering to BIS standards. Traditional methods of collection and testing were subject to human errors and delays in decision-making. Tools used in this study are descriptive statistics, Canadian Water Quality Index (CCMEWQI),box plots, control charts, 't'-statistics and one-way ANOVA . IoT could provide real-time statistical data, enabling informed decisions by policymakers, stakeholders, and the public.

Index Terms— Box plots, CCME WQI, Control charts, parameters of potable water.

I. INTRODUCTION

Managing potable water quality is crucial to public health and environmental sustainability. Effective auditing of the management components that play an essential role in the sustainability of water treatment plants is critical for the treatment and supply of safe drinking water to communities [1]. These components include management issues and practices, human resources, financial aspects, communication systems, safety, health, and environmental quality, as well as community involvement and awareness. The issue of freshwater resource depletion and contamination is a growing concern worldwide. As the demand for high-quality freshwater far exceeds the available supply in many areas, it is estimated that over 2 million deaths yearly are caused by pathogenic bacteria during the consumption of unsanitary water [3]. A study on the river Krishna by Prasad M. Pujar1 and Harish H. Kenchannavar [5] used IoT sensors for data collection. One-way ANOVA and Two-way ANOVA were utilized to identify significant differences in water quality parameters across different locations, seasons, and parameter interactions. The summer season showed high BOD and TDS values, indicating pollution levels near industrial sites. Rainy seasons showed increased DO levels due to rainfall's dilution effects. Winter season showed continued high levels of conductivity and BOD across multiple stations, indicating persistent quality issues and pointing to the impact of untreated waste. A study conducted by Zahraa A. H. Mahdi and Ahmed H.A. Hamdam**,** Spatial Variations of Water Quality Parameters in Basara Water Treatment, [6] Used Box plots and ANOVA to determine if there are significant spatial variations in water quality parameters. M.A. Hossen and A. Hoque's study on the Haldai River [7] used descriptive statistics and WQI to study the differences in water parameters at five different stations.
Moreover, this study presents an in-depth exploration of statistical tools and techniques used in water quality analysis. The study covers everything from basic concepts such as mean, median, and mode to advanced techniques like control charts and hypothesis testing.

II. MATERIALS AND METHOD

A. Study area

The Salaulim Dam is situated on the Guleli River in Goa, India. It is a vital part of the Salaulim Irrigation Project, which aims to supply irrigation and drinking water. The dam has a height of 42.7 meters and a water spread area of 24 km2 . It was planned to support irrigation for up to 14,326 hectares and provide potable water of 160 MLD, which has now increased to 380 MLD. Meeting drinking water standards [1] involves proper planning for operations and maintenance, routine operator duties, organisational alignment, capacity building, and political support for water issues. This is crucial for maintaining high-quality drinking water for community consumption. Supervision checks involve sanitation inspection, water sampling, water quality testing, and analysis of laboratory test results, recommendations, and follow-up [2]. To address these issues, various technologies and methods have been developed for online monitoring of water quality in supply water systems. Conventional water quality monitoring and control methods, such as manual collection of water samples and laboratory analysis, must be faster to enable an operational response and provide real-time public health security [2],[4]. Online monitoring technologies offer a more efficient and practical approach to water quality monitoring. This study aims to implement statistical skills to interpret complex water quality data and make informed decisions.

B. Methodology

The study aims to analyse water quality statistically, which invariably entails measuring various physical, chemical, and biological parameters, including pH, turbidity, dissolved oxygen, heavy metals, and microbial contamination. These 13 essential parameters are crucial indicators of water quality, with each parameter providing specific information about the safety and suitability of water for human consumption. To perform a thorough statistical examination of drinking water quality concerning BIS standards (IS 10500-2012). I adhered to the subsequent steps:

1. Sampling

• The process involves collecting representative raw water samples from various points within the Salulim dam catchment area and treated water samples at the dam's treatment plant.
• The collected samples are tested in a local laboratory, and data regarding water parameters are continuously recorded. This process was followed daily over 365 days, aiming to comprehensively and accurately portray the water quality over the entire year.

2. Statistical Tools used for data analysis

• Descriptive statistics summarise and interpret data using mean, median, mode, standard deviation, and range measures.
•CCME WQI is a comprehensive method for assessing water quality in Canada.
•Box plots provide insights into the variations and distributions of these parameters.
• Control charts monitor and analyse these parameters over time, providing insights into potential issues or changes in water parameters.
• 't'-statistics was used to compare means and assess the significance of differences between monsoon[11] and off-monsoon raw water parameters.
• One-way ANOVA was applied to compare raw and treated water for all 13 tested parameters.
•XLSTAT and Minitab 2019 were used for robust, in-depth, accurate data analysis.
•Following the BIS IS 10500-2012 standard for drinking water was used as a reference.

Table 1 BIS IS 10500-2012

Characterstics	Units		BIS IS 10500-2012 (Acceptable Limit)
pH	-	range	6.5-8.5
Turbidity	NTU	Max	5
DO	mg/L	range	6.5-8
Alkalinity	mg/L	max	200
Chloride (Cl)	mg/L	max	250
Hardness CaCO3	mg/L	max	200
Specific Conductivity	μ mhos/cm	max	500
Total Dissloved Solids	mg/L	max	500
Calcium Ca++	mg/L	max	75
Magnesium Mg ++	mg/L	max	30
Bacteriological Test MPN of Coli form	organism /100	max	0
Bacteriological Test MPN of E Coli	organism /100	max	0
Manganese Mn	mg/L	max	0.1

III. RESULTS AND DISCUSSIONS

A. Descriptive Statistics

Using the available data, descriptive statistics were conducted on raw water. The mean and range for each of the 13 parameters for twelve months were sorted out to comprehensively understand the trends and variations over the entire year. Highlights indicate parameters that exceed BIS drinking water standards.

Results show there is a seasonal variation in pH and turbidity. Bacterial contamination of Coli, E coli , and heavy metal manganese is found present in raw water year round.

Table II Descriptive statistics for raw water

Characterstics		pH	Turbidity	DO	Alkalinity	Chloride (Cl)	Hardness CaCO3	Specific Conductivity	Total Dissloved Solids	Calcium Ca++	Magnesium Mg ++	Bacteriological Test MPN of Coli form	Bacteriological Test MPN of E Coli	Manganese Mn
Units		-	NTU	mg/L	mg/L	mg/L	mg/L	µ mhos/cm	mg/L	mg/L	mg/L	organism/100	organism/100	mg/L
Acceptable Limits		Range	Max	Range	max	max	max	max	max	max	max	max	max	max
		6.5-8.5	5	6.5-8	200	250	200	500	500	75	30	0	0	0.1
Jan-23	Range	6.24-6.77	1.20-2.57	6.90-7.50	16.00-17.00	6.00-6.5	0	48.20-50.90	30.90-32.60	3.20-4.00	1.50-2.00	43.00-95.00	21.00-43.00	0.09-0.45
	Mean	6.58	1.88	7.24	16.16	6.02	16.00	49.61	31.76	3.63	1.73	66.20	27.50	0.24
Feb-23	Range	6.63-6.84	1.62-1.97	7.00-7.50	17.00-21.00	6.00-7.50	14.00-16.00	48.60-49.80	31.10-31.90	3.20-3.60	1.50-2.00	23.00-75.00	4.00-23.00	.05-.21
	Mean	6.73	1.81	7.21	19.75	7.27	14.71	49.34	31.58	3.27	1.63	41.00	10.25	0.13
Mar-23	Range	6.65-6.99	1.38-2.19	6.80-7.40	19.00-21.00	6.50-7.50	15.00-16.00	49.50-52.90	31.70-33.90	2.80-4.00	1.50-2.00	9.00-23.00	4.00-9.00	0.02-.021
	Mean	6.81	1.76	7.08	19.97	6.69	15.42	51.56	33.00	3.61	1.60	16.00	6.67	0.13
Apr-23	Range	6.83-7.08	1.54-2.27	6.80-7.40	15.00-20.00	6.00-7.00	14.00-16.00	50.50-54.10	32.30-34.60	3.60-4.80	1.00-1.75	20.00-75.00	9.00-23.00	0.05-0.17
	Mean	6.99	1.88	7.06	17.67	6.47	14.90	52.07	33.32	4.04	1.20	36.00	15.50	0.09
May-23	Range	6.90-7.09	1.98-3.43	7.00-7.50	17.00-20.00	6.50-7.50	14.00-19.00	53.60-58.20	34.30-37.30	3.20-4.00	1.00-2.25	75.00-240.00	15.00-95.00	0.01-0.27
	Mean	6.98	2.74	7.18	19.77	7.10	17.74	55.80	35.72	3.91	1.99	154.00	49.80	0.11
Jun-23	Range	6.57-7.15	2.92-13.46	6.70-7.60	19.00-22.00	6.00-7.00	17.00-20.00	53.10-56.6.0	27.60-36.40	4.00-4.80	1.75-2.25	210.00-460.00	95.00-240.00	0.05-0.26
	Mean	6.95	4.77	7.12	20.40	6.33	19.40	55.51	35.31	4.32	2.03	335.00	158.75	0.13
Jul-23	Range	5.93-6.89	5.46-11.24	6.70-7.50	15.00-20.00	0.1	14.00-20.00	45.10-56.80	28.90-36.40	3.20-4.80	1.25-2.00	75.00-11000	43.00-210.00	0.25-0.62
	Mean	6.21	8.37	7.09	16.94	6.00	15.48	51.39	32.91	3.78	1.52	417.00	112.40	0.44
Aug-23	Range	5.76-6.01	1.53-8.80	6.80-7.60	14.00-16.00	5.50-7.00	14.00-15.00	38.90-45.20	24.90-28.90	2.80-3.60	1.25-1.75	120.00-460.00	21.00-240.00	0.22-0.42
	Mean	6.21	8.37	7.09	16.94	6.00	15.48	51.39	32.91	3.78	1.52	417.00	112.40	0.44
Sep-23	Range	5.90-6.07	1.27-1.76	6.70-7.30	14.00-15.00	5.50-6.00	14.00-15.00	37.20-44.50	21.80-28.50	2.40-3.60	1.50-2.00	120.00-460.00	23.00-150.00	0.50-0.68
	Mean	6.00	1.47	6.97	14.70	5.88	14.50	40.26	25.58	3.07	1.71	257.50	85.75	0.59
Oct-23	Range	5.92-6.09	1.36-3.67	6.00-7.20	15.00-16.00	5.50-6.00	14.00-15.00	41.80-43.50	26.80-37.40	2.80-4.00	1.25-1.75	95.00-210.00	15.00-95.00	0.45-0.72
	Mean	6.05	2.20	6.95	15.45	5.85	14.65	42.59	27.90	3.25	1.63	149.00	57.40	0.53
Nov-23	Range	6.00-6.17	1.31-1.69	6.80-7.30	15.00-16.00	5.50-7.00	14.00-16.00	41.70-47.90	26.70-30.70	3.60-4.40	0.1	64.00-150.00	23.00-95.00	0.21-0.50
	Mean	6.09	1.49	7.04	15.30	5.99	15.00	43.94	28.12	4.01	1.25	109.00	53.67	0.30
Dec-23	Range	6.05-6.20	1.28-1.72	6.80-7.40	15.00-16.00	5.50-6.80	14.00-16.00	43.00-47.90	27.50-34.50	3.20-4.40	1.25-1.75	95.00-240.00	23.00-150.00	0.18-0.25
	Mean	6.13	1.51	7.02	15.90	6.03	15.10	47.10	30.29	3.49	1.62	166.25	85.25	0.21
Annual Mean		6.25	4.45	7.04	16.62	5.15	15.75	47.51	30.46	3.70	1.38	280.75	96.73	0.40

Canadian Water quality index

The raw water quality index, a quantifiable measure of overall water quality, was calculated monthly using the CCME method. This index facilitated comparisons between different periods, enhancing the study's scientific validity and reliability. We used F1(scope), F2(frequency), and F3(amplitude) for 13 raw water parameters. The individual parameter scores were calculated and combined to produce an overall water quality index. CCME WQI was calculated for each month to note seasonal variations in results. June, July, August, and September are monsoon seasons at this location, and WQI obtained in this period is in the range of good to fair. Off monsoon season the WQI is good and so the water during this period is fit for human consumption. The month of October showed WQI as fair because there was an extension of rains in this month for this particular year, 2023.

Table III Results for CCME Water Quality Index.

Season	Month	F1	F2	F3	CCMEWQI	Categorisation
		Scope	Frequency	Amplitude		
Off Monsoon	Jan-23	30.77	7.60	3.84	81.57	Good
	Feb-23	23.08	3.65	2.85	86.41	Good
	Mar-23	23.08	4.28	2.90	86.35	Good
	Apr-23	23.08	3.15	2.63	86.47	Good
	May-23	23.08	3.65	3.26	86.38	Good
Monsoon	Jun-23	30.77	5.99	3.62	81.78	Good
	Jul-23	38.46	21.34	8.16	74.17	Fair
	Aug-23	38.46	18.65	5.97	75.08	Fair
	Sep-23	30.77	14.83	5.31	80.04	Good
Off Monsoon	Oct-23	38.46	15.20	5.40	75.92	Fair
	Nov-23	30.77	14.70	4.44	80.15	Good
	Dec-23	30.77	13.35	4.29	80.48	Good

Box plots for raw water parameters.

Individual box plots were plotted for water parameters highlighted in descriptive statistics. The same is used for data visualization, which can be valuable. Understanding the variations and distributions of these parameters through box plots can offer insights into the overall quality of potable water. It can reveal outliers, the data spread, and each parameter's central tendency. It can be concluded that during the rainy seasons, specific parameters such as pH, turbidity, Coli, E coli, and Manganese show large variations exceeding standards. This indicates additional treatment is required during the rainy season. Between June and December, the pH remains low, unlike during the first half of the year.

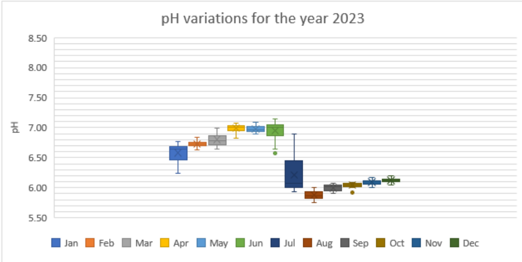

Figure 1. Box plot for pH variation in raw water.

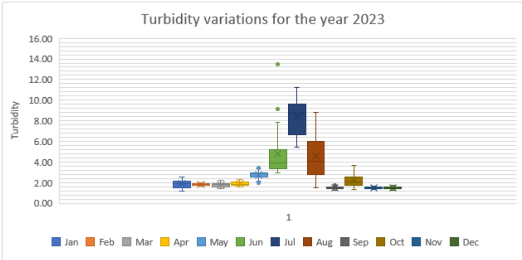

Figure 2. Box plot for Turbidity variations in raw water.

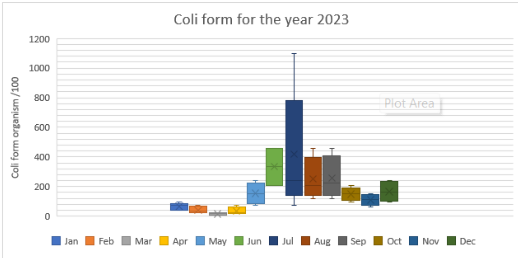

Figure 3. Box plot for Coli form variations in raw water.

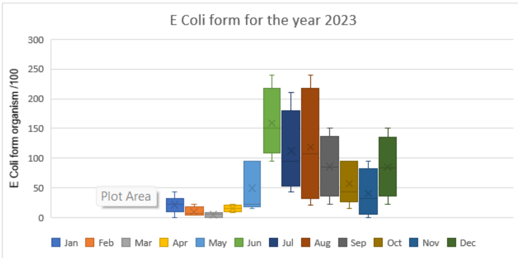

Figure 4. Box plot for E Coli form variations in raw water.

B. Control charts for raw water and treated water

Control Charts were carefully analysed for each of the 13 tested water parameters for raw and treated water for each month. Charts plotted the values of a parameter against time and were used to monitor the water quality over the year. The upper control limit(UCL) and lower control limit(LCL) for drinking water are specified by BIS standards IS 10500-2012. This enables the detection of any unusual variations or trends in the water quality parameters

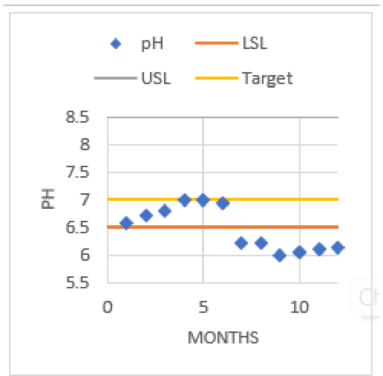

Figure .5 pH in raw water

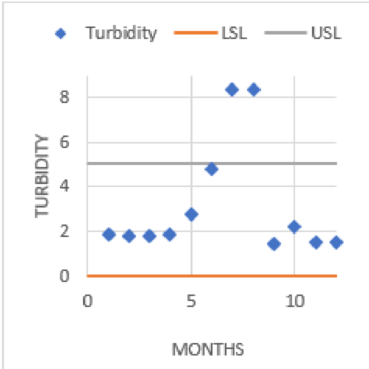

Figure 6. Turbidity in raw water

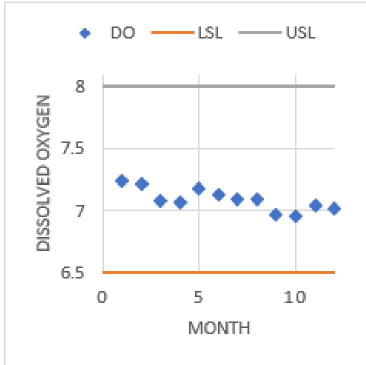

Figure 7. Dissolved oxygen in raw water

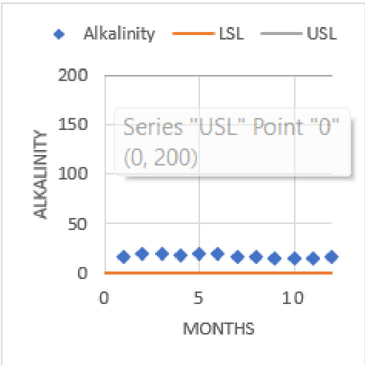

Figure 8. Alkalinity in raw water

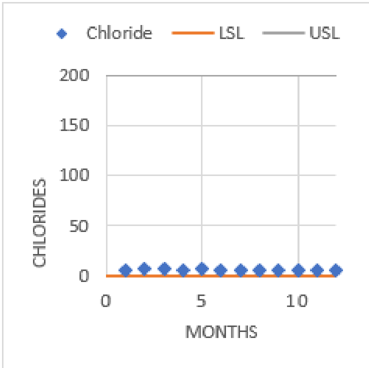

Figure 9. Chloride in raw water

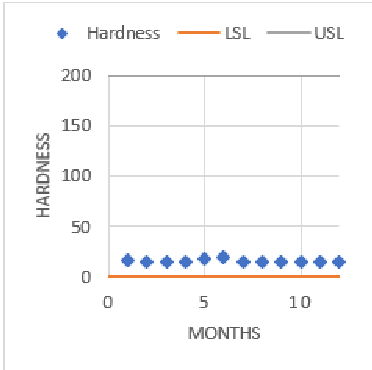

Figure 10. Hardness in raw water

Figure 11. Specific conductivity in raw water

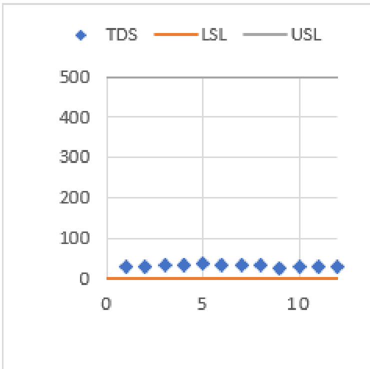

Figure 12. Total dissolved solids in raw water

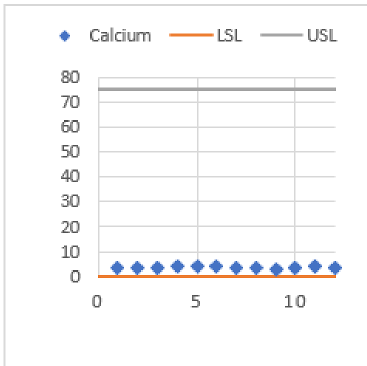

Figure 13. Calcium in raw water

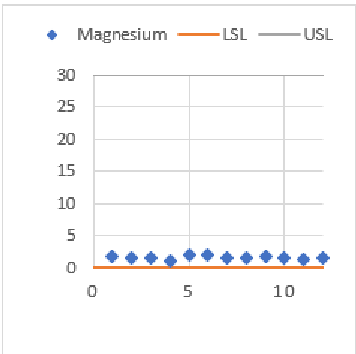

Figure 14. Magnesium in raw water

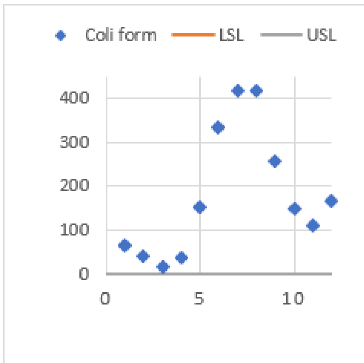

Figure 15. Coli form in raw water

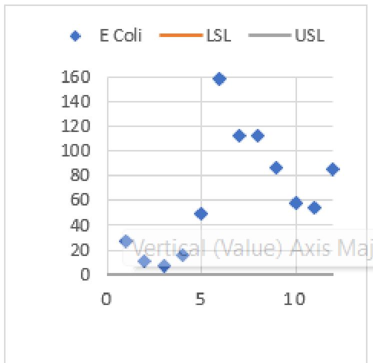

Figure 16. E coli in raw water

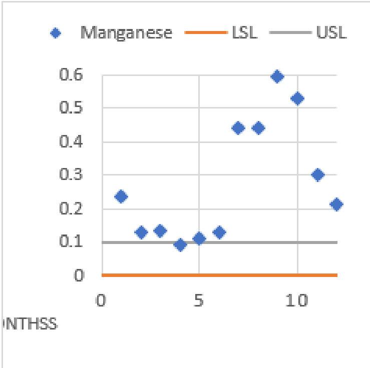

Figure 17. Manganese in raw water

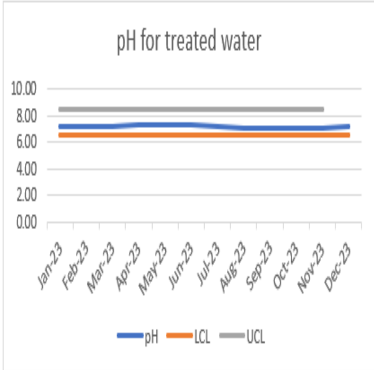

Figure 18. pH in treated water

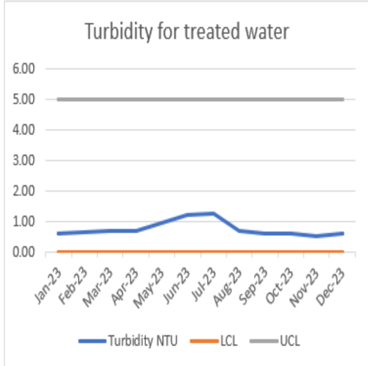

Figure 19. Turbidity in treated water

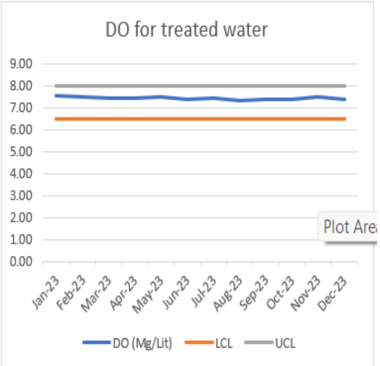

Figure 20. Dissolved oxygen in treated water

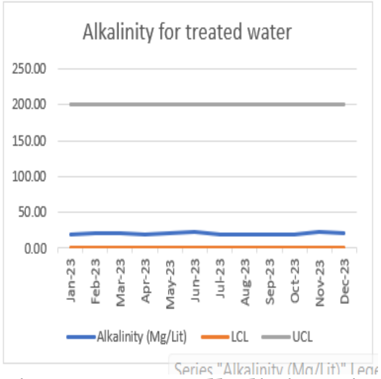

Figure 21. Alkalinity in treated water

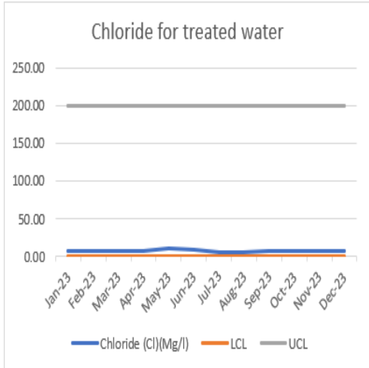

Figure 22. Chloride in treated water

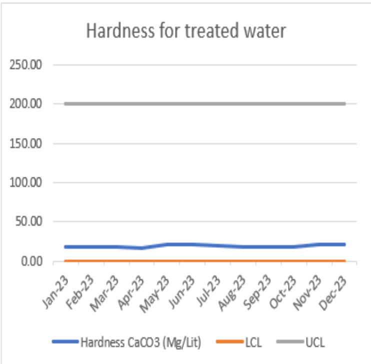

Figure 23. Hardness in treated water

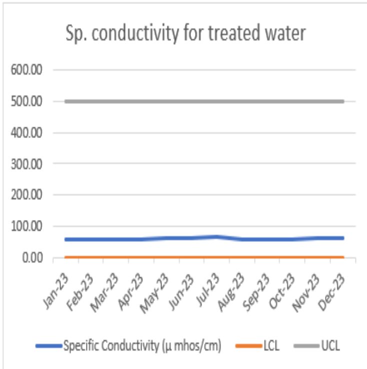

Figure 24. Specific conductivity in treated water

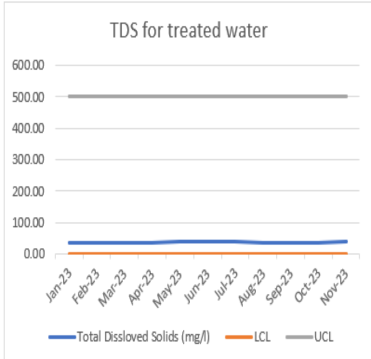

Figure 25. Total dissolved solids in treated water

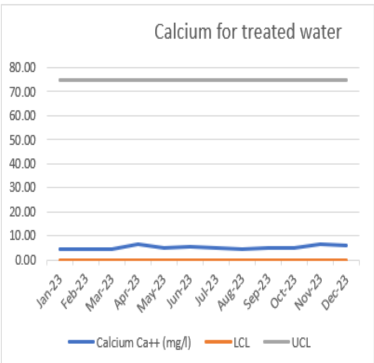

Figure 26. Calcium in treated water

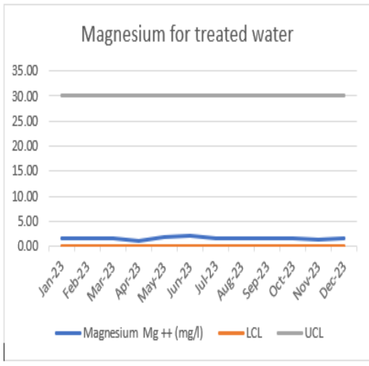

Figure 27. Magnesium for treated water

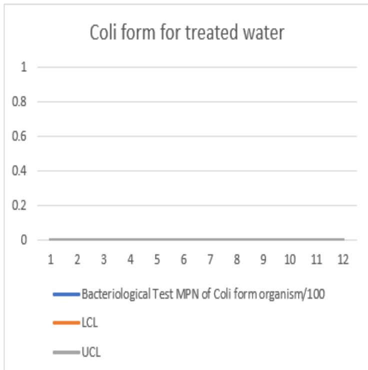

Figure 28. Coli form in treated water

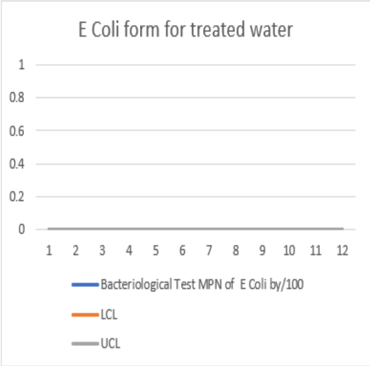

Figure 29. E coli form in treated water

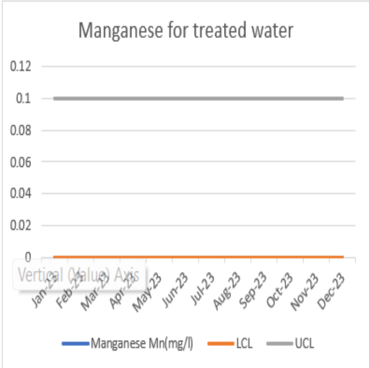

Figure 30. Manganese in treated water

C. *'t'- test for raw water parameters during and off monsoon season.*

The above analysis showed that the value of raw water parameters varies with seasonal changes. ' t '-tests were conducted on each of the 13 raw water parameters to compare their variations between the monsoon and off-monsoon seasons. These tests, which compare the means of two groups, were used to identify significant differences in the water quality between the two seasons, offering insights into the seasonal variations and their potential impact on water quality.

Null hypothesis H0: The difference between the means is equal to 0.
Alternate hypothesis Ha: The difference between the means is different from 0
Confidence interval on the difference between the means: 95%
Number of observations for monsoon season: 8
Number of observations for non-monsoon season: 8

Table IV Results for 't'-statistics

Sr.no.	Parameters	Period of the year	Minimum	Maximum	Mean	Std. deviation	t-tet	p	Null hypothesis
1	pH	monsoon	5.9970	6.9483	6.3436	0.3851	1.0199	0.3251	cannot reject
		Off monsoon	6.0455	6.9880	6.5437	0.3995			
2	Turbidity	monsoon	1.4713	8.3723	5.7459	3.0717	-3.5037	**0.0035**	**reject**
		Off monsoon	1.4917	2.7381	1.9080	0.4041			
3	DO	monsoon	6.9667	7.1233	7.0660	0.0633	0.7801	0.4483	cannot reject
		Off monsoon	6.9548	7.2419	7.0990	0.1013			
4	Alkalinity	monsoon	14.7000	20.4000	17.2427	2.1793	0.2392	0.8144	cannot reject
		Off monsoon	15.3000	19.9677	17.4964	2.0612			
5	Chloride	monsoon	5.8833	6.3333	6.0542	0.1797	1.8401	0.0871	cannot reject
		Off monsoon	5.8548	7.2679	6.4270	0.5442			
6	Hardness	monsoon	14.5000	19.4000	16.2169	2.0110	-0.9732	0.3470	cannot reject
		Off monsoon	14.6452	17.7419	15.4401	1.0262			
7	Sp. Conductivity	monsoon	40.2600	55.5100	49.6377	6.0608	-0.8091	0.4330	cannot reject
		Off monsoon	42.5871	55.8032	49.0005	4.3601			
8	TDS	monsoon	25.5833	35.3067	31.6790	3.9047	-0.1315	0.8973	cannot reject
		Off monsoon	27.9000	35.7161	31.4595	2.6523			
9	Calcium	monsoon	3.0667	4.3200	3.7370	0.4760	-0.4212	0.6800	cannot reject
		Off monsoon	3.2516	4.0400	3.6523	0.3117			
10	Magnesium	monsoon	1.5242	2.0333	1.6975	0.2223	-0.9733	0.3469	cannot reject
		Off monsoon	1.2000	1.9919	1.5812	0.2545			
11	Coli form	monsoon	257.5000	417.0000	356.6250	70.8796	-8.0627	**0.0001**	**reject**
		Off monsoon	16.0000	166.2500	92.1813	59.8491			
12	E Coli	monsoon	85.7500	158.7500	117.3250	28.0893	-5.6716	**0.0001**	**reject**
		Off monsoon	6.6667	85.2500	38.2542	27.6752			
13	Manganese	monsoon	0.1269	0.5933	0.3996	0.1813	-2.2187	**0.0435**	**reject**
		Off monsoon	0.0924	0.5262	0.2181	0.1437			

D. One-way ANOVA between raw water and treated water parameters.

In this study, one-way ANOVA was applied to the 13 tested water quality parameters to compare water quality before and after treatment. Results showed a significant change in water parameters after treatment. Magnesium in off-monsoon and monsoon seasons showed no significant difference between raw and treated water. Also, hardness was not affected by treatment during monsoon season.

Table V Results for One-way ANOVA during off-monsoon.

ANOVA between Raw water and treated water parameters , off monsoon season									
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*Remarks*	Remarks
pH	Between Groups	1.659439	1	1.659439155	19.78607766	0.000551348	4.60011	p < 0.05	F > Fcrit
Turbidity	Between Groups	6.201929	1	6.201929386	67.93408215	9.66084E-07	4.60011	p < 0.05	F > Fcrit
DO	Between Groups	0.528745	1	0.528745112	74.63464972	5.53557E-07	4.60011	p < 0.05	F > Fcrit
Alkalinity	Between Groups	37.90686	1	37.9068615	11.97630448	0.003822605	4.60011	p < 0.05	F > Fcrit
Hardness	Between Groups	47.56682	1	47.56681855	18.70826349	0.000698519	4.60011	p < 0.05	F > Fcrit
Sp.conductivity	Between Groups	390.0796	1	390.0795653	31.73895734	6.16655E-05	4.60011	p < 0.05	F > Fcrit
Chloride	Between Groups	7.281428	1	7.281427637	9.364118485	0.008478402	4.60011	p < 0.05	F > Fcrit
TDS	Between Groups	153.6299	1	153.6298847	33.5254574	4.68343E-05	4.60011	p < 0.05	F > Fcrit
Calcium	Between Groups	9.938474	1	9.938474166	19.46490939	0.000591118	4.60011	p < 0.05	F > Fcrit
Magnesium	Between Groups	9.89E-07	1	9.89276E-07	1.5284E-05	0.996935855	4.60011	p > 0.05	F < Fcrit
Coli form	Between Groups	33989.53	1	33989.53141	18.97838692	0.000657795	4.60011	p < 0.05	F > Fcrit
E coli	Between Groups	5853.525	1	5853.525069	15.28497893	0.001571776	4.60011	p < 0.05	F > Fcrit
Manganese	Between Groups	0.190338	1	0.190337867	18.42530212	0.00074431	4.60011	p < 0.05	F > Fcrit

Table VI Results for One-way ANOVA during monsoon.

ANOVA between Raw water and treated water parameters , monsoon season									
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*Remarks*	Remarks
pH	Between Groups	1.421932	1	1.421932002	15.0114232	0.008223297	5.987378	p < 0.05	F > Fcrit
Turbidity	Between Groups	46.23954	1	46.23953847	8.314459902	0.027930401	5.987378	p < 0.05	F > Fcrit
DO	Between Groups	0.211982	1	0.21198225	77.46140195	0.000119376	5.987378	p < 0.05	F > Fcrit
Alkalinity	Between Groups	13.89338	1	13.89337882	3.529120624	0.109367786	5.987378	p < 0.05	F > Fcrit
Hardness	Between Groups	18.21123	1	18.21123003	5.365244214	0.059750984	5.987378	p > 0.05	F < Fcrit
Sp.conductivity	Between Groups	285.9033	1	285.9033097	10.76974221	0.016786288	5.987378	p < 0.05	F > Fcrit
Chloride	Between Groups	3.109908	1	3.109908137	4.178670202	0.086939801	5.987378	p < 0.05	F > Fcrit
TDS	Between Groups	120.9413	1	120.9413014	11.15931508	0.015600952	5.987378	p < 0.05	F > Fcrit
Calcium	Between Groups	2.96743	1	2.967429931	16.85274779	0.006320263	5.987378	p < 0.05	F > Fcrit
Magnesium	Between Groups	0.000897	1	0.000897201	0.016887533	0.900851595	5.987378	p > 0.05	F < Fcrit
Coli form	Between Groups	254362.8	1	254362.7813	86.79503019	8.66068E-05	5.987378	p < 0.05	F > Fcrit
E coli	Between Groups	27530.31	1	27530.31125	59.81550666	0.000245333	5.987378	p < 0.05	F > Fcrit
Manganese	Between Groups	0.319389	1	0.319389181	16.65966847	0.006490186	5.987378	p < 0.05	F > Fcrit

III. RESULTS AND DISCUSSIONS

Raw and treated water were analysed for 13 parameters: pH, turbidity, dissolved oxygen, alkalinity, hardness, specific conductivity, chloride, dissolved solids, calcium, Magnesium, coliform, E. coli form, and manganese. Various statistical tools were used, including descriptive statistics, which included range, mean, maximum data, Canadian water quality index (CCME WQI), box plots, control charts, ' t'-statistics, and one-way ANOVA. These statistics were applied to monthly data as well to study seasonal variations. The statistical analysis involved analysing the data for measures of central tendency, variability, and distribution of the parameters. Monthly variations of each parameter of raw water were plotted on a box plot. Control charts were analysed monthly for each raw and treated water parameter, with UCL and LCL specified per BIS standards. The' t '-test was performed between monsoon and off-monsoon seasons of raw water for each of the 13 parameters. The results showed that the water quality was better than the specified BIS standards, with seasonal variations in turbidity and pH. The obtained CCME Water Quality Index (WQI) was compared to the standard CCME WQI, showing that the water quality is fit for drinking.

During the monsoon season, June, July, August, and September, there was a considerable difference in the pH, turbidity, coli, E. coli, and manganese parameters. Therefore, the study's conclusion underscores the necessity of continuous treatment of raw water throughout the year to bring coli, E. coli, and manganese within control limits. The monsoon season, in particular, demands additional treatment to address the challenges of low pH and high turbidity.

The statistical analysis was further conducted on treated water supplied to the public. One-way ANOVA was performed between raw and treated water for each of the 13 parameters. One-way ANOVA was conducted separately for monsoon and off-monsoon periods because the earlier findings showed a seasonal change in water parameters. So, there will be a seasonal change in the raw and treated water treatment process. Statistical analysis of treated water showed that during the monsoon season, a rise in the pH, turbidity, coli, E. coli, and manganese parameters were brought under control throughout the monsoon season. Bacteriological tests of coli, E. coli, and heavy metals such as manganese were within control limits throughout the year. One-way ANOVA also showed that the treatment process throughout the year succeeded in maintaining potable water quality and adhering to BIS standards. However, ANOVA results showed F < Fcrit for hardness during monsoon season and Magnesium during monsoon and off-monsoon season. This investigation can be further extended to the detailed process of treating water and establishing relations as to how the treatment process affects each water parameter. Using IoT in data collection of various water parameters will enable trigger alerts when these thresholds are exceeded by setting predefined thresholds for water quality parameters. Real-time data on water quality and usage patterns can help optimize water resource management, reduce water waste, and improve the efficiency of treatment processes, thereby optimising potable water management.

CONCLUSION

The study analysed water quality in various parameters such as pH, turbidity, dissolved oxygen, alkalinity, hardness, specific conductivity, chloride, dissolved solids, calcium, Magnesium, coliform, E. coli form, and manganese. Statistical analysis showed that the water quality was better than BIS standards, with seasonal variations in turbidity and pH. However, the monsoon season showed significant differences in parameters, highlighting the need for continuous treatment to control coli, E. coli, and manganese. The study also examined treated water, showing that during the monsoon season, a rise in pH, turbidity, coli, E. coli, and manganese parameters was brought under control. Bacteriological tests of coli, E. coli, and heavy metals were within control limits throughout the year. One-way ANOVA showed that the treatment process successfully maintained potable water quality and adhered to BIS standards.

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