A Review of Physical and Chemical Water Quality in Rural Water Supply Schemes and Community Perceptions

I.A Kalyanarathna, W.R.A.C.D Ranasinghe

Abstract: Monitoring the water quality index of rural water supply schemes is an effective approach to a sustainable community-driven water supply system. In Sri Lanka, the drinking water supply of most rural populations managed by community-based organizations where the water sources are tube wells, shallow wells, streams, rivers, and rainwater collection. Regular water quality testing of regional CBO-based water supply schemes is currently done by both the Water Supply and Drainage Board and the Department of National Community Water Supply CBO-based Laboratories. This study aimed to evaluate the physical and chemical characteristics of the water supplied by wet and intermediate climatic zone CBOs to their consumers and the consumer perspectives on them. Primary data was collected from the Information System of the DNCWS and questionnaires from the above randomly selected CBO water consumers. Through data analysis, it became evident that the implementation of routine maintenance alongside an appropriate water purification system and consumer awareness can significantly improve the overall water quality within rural water supply schemes.

Keywords: Community-Based Organizations, Consumer Perceptions, Physical and Chemical Water Quality, Rural

1. Introduction

Water is a renewable natural resource that has a significant impact on the existence of humans (Custodio, 2021). In the rural regions of Sri Lanka, Community Based Organizations play a vital role in managing their own water supply schemes and ensuring the quality of accessible water (Bellanthudawa, 2022).

The sustainability of community-driven water supply schemes not only relies on water availability but also on the assurance of its safety for the consumption (Maréchal, 2023).

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Numerous research projects have been conducted to gauge water quality, involving factors like pH, dissolved oxygen, turbidity, total dissolved solids, phosphates, nitrates, and heavy metals. These elements are often organized into indices for assessment (Othman, 2018).

The way land is used such as Agricultural practices, deforestation, and inappropriate disposal of livestock waste have the potential to release heavy metals, organic substances, nutrients, and various kinds of pathogens into the water (Anh, 2023).

Sri Lanka has three main climatic zones as Dry, Wet and Intermediate (Arandara, 2010). This research endeavors to the dynamic interplay of rural water quality and consumer perceptions within wet and intermediate climatic zones of Sri Lanka. By bridging the gap between water quality assessment and consumer perceptions, a comprehensive understanding of the challenges and opportunities can be recognized.

2. Aims and Objectives

The primary goal of this study is to assess the number of physical and chemical water quality such as Color, Turbidity, Electrical Conductivity, pH, Total Alkalinity, Nitrate as NO_3^- & NO_2^-, Total Phosphate, Total Dissolved Solids, Total Hardness, Total Iron, Sulphate in CBOs. Utilizing scientific information can aid in developing efficient regulations, standards, and strategies concerning water quality and it ultimately supports sustainable development in rural regions by promoting responsible water resource management. A continuous long-term monitoring system makes the water scheme more livable and any water quality issue can be identified when everything is observed and documented.

In this context, consumer views of water quality are also taken into account as they are the primary beneficiaries of the improvements in water quality.

3. Methodology

This investigation employs a merged methodology that involves both the analysis of physical and chemical water quality and the consumer survey. The sampling frame was made under the selection of climatic conditions of Sri Lanka since water quality varies with the climatic behavior.

3.1 Study Area

Sri Lanka is characterized by three primary climatic regions known as Dry, Wet, and Intermediate zones (Karunaweera, 2014). For the current research, investigations were carried out across randomly selected six districts, encompassing three districts from each wet and intermediate climatic zones, with the inclusion of four random Community-Based Organizations (CBOs) from each of the chosen districts.

As shown in Table 1, for the wet zone, Matara, Nuwara Eliya, and Rathnapura districts were selected while for the intermediate Zone, Kurunegala, Matale, and part of Ampara districts were selected. Although the Ampara district is typically classified within the dry climatic zone, the study was conducted in the part of the Ampara district that falls under the intermediate climatic zone.

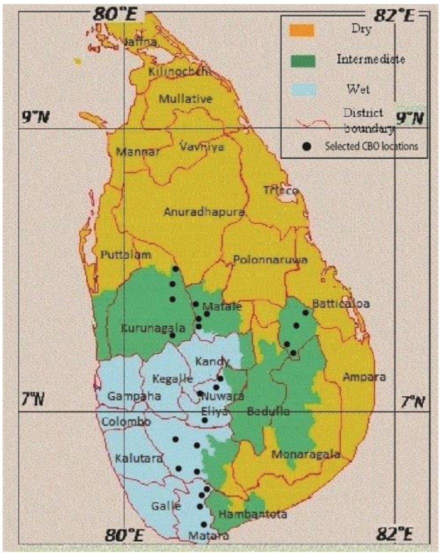

Figure 1 - Map of the randomly selected locations within the Wet and the Intermediate Climatic Zones. Source: (Karunaweera, 2014)

Pipe-born water quality data of the selected CBOs were taken from the Department of National Community Water Supply Management Information System. Time frame taken to analyze water quality is from the year 2022 to 1st half of 2023. Consumer perceptions were gathered from three individuals of each selected CBO about the water quality that they have been consuming for the last two years.

3.2 Limitations

In this context, we used a primary reference framework for selecting Community-Based Organizations (CBOs) from regions categorized as having Wet and Intermediate climatic conditions in Sri Lanka. As there were no severe weather conditions like floods due to intense rainfall or prolonged drought, weather conditions were not taken into account within the specified time period. All of the water quality data are from DNCWS MIS and we are in a position in the accuracy and the precision of the test results since all of the reports are generated under the supervision of government officials within the year 2022 to 2023. When gathering consumer perceptions, consumer gender, age, and educational background were not considered.

The original water source (Surface or Ground) was not taken into account when analyzing the water quality report. The dry climatic zone was not considered because of the complexity and unavailability of the data.

4. Results and Discussion

All the water quality data were systemically collected (Table 2 and Table 3). Subsequent analysis was conducted following consumer perceptions (Figure 2).

Table 1 – Randomly Selected CBO Locations

Climatic Zone	District	L1	L2	L3	L4
Wet	**Matara**	Hettiyawala CBO	Pasgoda Janashakthi CBO	Batadola Samagi CBO	Nepathalla Ranmal CBO
	Nuwara Eliya	Koboneela CBO	Madurapanee CBO	Minuwandeniya Minidiyadahara CBO	Samagi CBO
	Rathnapura	Bandige Ella CBO	Borangamuwa Ekamuthu CBO	Kalawana small town CBO	Suwadivi CBO
Intermediate	**Ampara**	Wewmedaga ma Randiya CBO	Mawanagama Lathminimuthu CBO	Ihalagama Nilupul CBO	Mindiya CBO
	Kurunegala	Prajashakthi Jala Samithiya	Monnekulama Arakshitha CBO	Randiya CBO	Pillawa Randiyawara CBO
	Matale	Ihala Ovala Pinimuthu	Watagoda Vikasitha CBO	Singha CBO	Aluviharaya Nildiya CBO

4.1 Physical Parameters

The color of water is a valuable indicator of the dissolved humic substances in water. Findings claimed that the color of intermediate climatic zone water was at an acceptable level (below 15 Hazen Unit) and Rathnapura Bandige Ella (111 Hazen Units) and Nuwaraeliya Samagi (143 Hazen Units) of wet climatic zone CBOs color were in unacceptable high value. All the intermediate climatic zones' turbidity was in the permissible range (2 Nephelometric Turbidity Unit) and Matara Janashakthi CBO (3.07 NTU) and Nuwaraeliya Samagi CBO (3.62 NTU) of the wet climatic zones showed deviation from the standard value. Electrical conductivity is a measure of the ability to carry an electrical current(Custodio,2021). Although conductivity does not have a direct impact on human health, it demonstrates the presence of dissolved minerals such as Calcium, Chlorine and Potassium which carries electrical current through water (Rahmanian, 2015). All of the conductivity values were within the acceptable range (750 µS/cm). Findings illustrate that electrical conductivity was less than 22 (µS/cm) in the CBOs where Reverse Osmosis was conducted.

4.2 Chemical Parameters

For the Chemical parameters, pH, Chloride, Total Alkalinity, Nitrate, Nitrite, Fluoride, Total Phosphate, Total Dissolved Solids, Total Hardness, Total Iron, and Total Sulphate levels were analyzed.(Table 2 and Table 3) Consumers exhibited a lack of awareness of these chemical parameters.

pH value relates to acidity and the alkalinity of water. Significantly all the pH values were in the acceptable

Table 2 - Water Quality Results of Wet Zone CBOs

Parameter	Requirement - Maximum (SLS 614: 2013)	Matara				Nuwara Eliya				Rathnapura			
		L1	L2	L3	L4	L1	L2	L3	L4	L1	L2	L3	L4
Color (Hazen Units)	15	10	20	5	10	15	5	5	143	111	2.5	0	0
Turbidity (Nephelometric Turbidity unit)	2	1.11	3.07	0.96	0.62	2	1.78	0.94	3.62	2.6	2.7	0.8	0.26
Electrical Conductivity (µS/cm)	750	428	117.7	318	30.9	151.7	109.2	5.9	25.7	28.9	30	50	162.2
pH	6.5-8.5	6.8	7	7	6.4	8.09	8.23	7.3	8.32	9.51	6.8	6.78	9.59
Chloride (as Cl) (mg/l)	250	22	40	20	11	28	22	20	27	48	6	24	22.8
Total Alkalinity (as $CaCO_3$) (mg/l)	200	188	36	120	10	68	28	5.6	12	68	12	148	85
Nitrate (as NO_3) (mg/l)	50	0.27	0.01	0.02	0.01	0	3.08	1.5	3.2	1.2	1.3	1.2	1.2
Nitrite (as NO_2) (mg/l)	3	0.01	0.002	0.003	0.003	0.03	0.002	0.002	0.002	0.004	0.03	0.02	0.003
Fluoride(as F) (mg/l)	1	0.01	0.2	0.36	0	0.29	0.4	1.2	1	0.12	0.03	0.08	0.02
Total Phosphates (as PO_4^{3-}) (mg/l)	2	0.28	0.08	0.31	0.08	0.25	0.85	0.89	1.45	0.16	0.11	0.25	0.75
Total Dissolved Solids (mg/l)	500	282.48	77.68	209.9	20.39	31	109	3.9	26	19	13.4	190	108
Total Hardness (as $CaCO_3$) (mg/l)	250	8	48	96	12	148	70	52	56	6	12	108	63.2
Total Iron (as Fe) (mg/l)	0.3	0.25	0.44	0.22	0.21	0.01	0.05	0.12	1.57	0.23	0.6	0.02	0.02
Sulphate (as SO_4) (mg/l)	250	6	8	11	0	2	1	0	0	0	5.6	2	0

range (6.5 - 8.5), except for two CBOs in Rathnapura District which showed more basic behavior in the pH range (9.5 and 9.6). All the Chloride levels, and Fluoride (as F^-) were in the acceptable range (250 mg/L and 1 mg/L respectively).

Exceeding specific concentrations of heavy metals can lead to adverse effects on human health (Rahmanian, 2015). In this research, Iron (Fe^{2+}) was analyzed and the values found from the test results were in the acceptable range (Maximum 0.3 mg/L) except, the tested Iron (Fe^{2+}) concentration of Matara Janashakthi (0.44 mg/L), Nuwaraeliya Samagi (1.57 mg/L), and Rathnapura Ekamuthu CBOs

Table 3- Water Quality Results of Intermediate Climatic Zone CBOs

Parameter	Requirement - Maximum (SLS 614 : 2013)	Ampara				Kurunegala				Matale			
		L1	L2	L3	L4	L1	L2	L3	L4	L1	L2	L3	L4
Color (Hazen Units)	15	1	1	1	1	2	5	6	7	0	0	1	1
Turbidity (Nephelometric Turbidity unit)	2	0.23	0.24	0.41	0.45	0.24	0.42	0.39	1	0.26	0.26	0.09	0.73
Electrical Conductivity (µS/cm)	750	130.1	124.8	21.31	111.4	0	0	0	0	454.4	149.5	401	50.6
pH	6.5-8.5	7.5	7.6	7.6	7.5	7.82	6.3	7.21	6.9	6.02	6.42	8.04	6.71
Chloride (as Cl) (mg/l)	250	19	0	0	0	96	2	40	24	6	25	32	15
Total Alkanity (as $CaCO_3$) (mg/l)	200	41	21	11	32	240	1	180	120	220	62	172	26
Nitrate (as NO_3) (mg/l)	50	2.3	2.8	1.5	2.5	3.08	1.32	3.96	1.76	0.8	0.7	0.5	0.4
Nitrite (as NO_2) (mg/l)	3	0.013	0.01	0.01	0.01	0.01	0.03	0.01	0.03	0.02	0.02	0.01	0.02
Fluoride(as F) (mg/l)	1	0.11	0.24	0.31	0.47	0.89	0.07	0.06	0.55	0.02	0.05	0.1	0.05
Total Phosphates (as PO_4^{3-}) (mg/l)	2	0.02	0.03	0	0	0.91	2	1.02	0.35	0.1	0.15	0.92	0.02
Total Dissolved Solids (mg/l)	500	58.6	56.3	9.5	49.9	459	33	386	231	50	36	22	52
Total Hardness (as $CaCO_3$) (mg/l)	250	49	51	14	38	270	7	160	144	212	55	144	17
Total Iron (as Fe) (mg/l)	0.3	0.01	0.01	0.01	0.02	0.03	0.02	0.06	0.16	0.03	0.03	0.03	0.04
Sulphate (as SO_4) (mg/l)	250	1	1	0.03	1	10	2	8	3	0	1	0	2

(0.6 mg/L). Early findings reveal that increased Fe^{2+} concentrations (elevated levels of Fe^{2+} arising from uneven reduction of Fe^{3+} oxide minerals) are closely linked to the oxidation and breakdown of easily degradable organic carbon (Cooray, 2019).

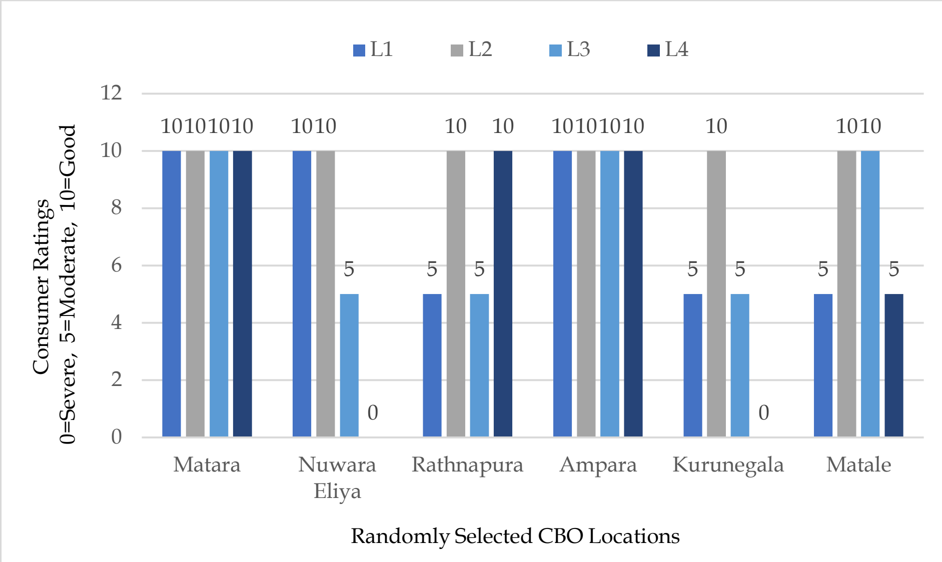

Figure 2 – Analysis on consumer perceptions of the CBOs

Further, total alkalinity as $CaCO_3$ (maximum 200 mg/L), Total Hardness as CaCO3 (250 mg/L), Nitrate as NO_3^- (maximum 50 mg/L), Nitrite as NO_2^- (maximum 3 mg/L), Total Phosphates as PO_4^{3-} (maximum 2 mg/L), and Sulphate as SO_4^{2-} (maximum 250 mg/L) of all the samples were less than the standard maximum values.

Total Dissolved Solids comprise inorganic substances along with trace quantities of organic matter that exist in a dissolved state of the water (Rahmanian, 2015). The current finding reveals TDS values are within the standard limit (maximum 500 mg/L).

4.3 Consumer perceptions

Generally, rural water consumers can identify the quality of water only through their own sensory evaluations such as color, odor, and taste (Thoradeniya & Bulathsinhala, 2015). When analyzing consumer perceptions as Figure 2, marks are given for the water quality as 10=Good, 5=Moderate and 0=Severe.

Matara district CBO-based water consumers mentioned the reason for their positive feedback is Chlorination and a series of water purifications with correct maintenance of the water scheme.

In Nuwara Eliya district Koboneela (L1) and Madurapanee (L2) CBOs maintain a series of water purification systems and all considered water quality parameters are within the standard values. Meanwhile, Minidiyadahara (L3) consumers are not satisfied with the quality of the water even though the water quality results are within standard values, since it has no treatment method. As per the results, Samagi CBO (L4) of Nuwara Eliya district has a higher content of iron, higher turbidity, and a substantially higher value of color. Consumers claimed that they were strongly unsatisfied with the quality and a valid reason was given that the water scheme has no purification system.

Rathnapura district water consumers of Bandige Ella (L1) face physical water quality issues even through the chlorination and purification are done. Hence, some consumers are not using the water for drinking. They identified mud water comes into the storage tank on rainy days. Likewise, Kalawana small town CBO (L3) consumers are moderately satisfied with water quality since the Chlorination is done in their water scheme and they also point out the mud water comes to the storage tank on rainy days. Suwadivi CBO (L4) water consumers are Satisfied with water quality since they have a purification process and daily water quality testing is done with the correct maintenance of the water scheme.

When considering Ampara and Matale districts, apart from Watagoda Vikasitha (L2) which employs chlorination, other chosen CBOs do not utilize a purification system. All others believe the water is safe to drink directly and taste is different when treatment is done.

However, Kurunegala Monnekulama Arakshitha (L2) consumers reported implementation of the Reverse Osmosis plant has led to an improvement in water quality. Consequently, the measured parameters of water quality align with the standard values. Other CBO water consumers of Kurunegala point out the difference in taste even though their water schemes have RO Plants. Randiyawara (L4) consumers are not using the water for drinking purposes because of the difference in water taste.

5. Conclusion

With these observations of physical and chemical water quality with the perceptions of the consumers, this study justified the importance of regular maintenance of the water supply schemes and enhancement of consumer awareness regarding water quality aspects and the water purification technology. With elevating physical and chemical water quality awareness levels it become possible to prevent consumer myths associated with rural water supply and it ultimately facilitates the decision making for sustainable practices.

Water quality monitoring requires regularly collecting water samples from multiple locations and analyzing numerous physical and chemical characteristics.

Hence, the Water Quality Index (WQI) can be introduced to CBO-based water supply schemes because of its simplicity. The Water Quality Index (WQI) is regarded as a useful approach to assessing water quality since it enables straightforward numerical comparisons between different water samples. Utilizing indices is pivotal for water resource management, offering insights to both the public and decision-makers about the state of water quality (Tyagi, 2020).

Acknowledgment

Deepest gratitude to the Assistant General Manager (R&D) of the NWSDB and his team for invaluable guidance, unwavering support, and arranging a great symposium.

We would like to extend our special appreciation to the Director General of the DNCWS for the opportunity given to conduct the research.

Last but not least, we extend our gratitude to the DNCWS district officer in charge and their teams, who generously shared their time and insights, without whom this study would not have been possible. Their willingness to engage in the research enriched our understanding and added depth to our findings.

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