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Impact of rainfall on the water quality of a tropical river: based on the Nilwala River in the southern province of Sri Lanka between March and October 2019

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ABSTRACT

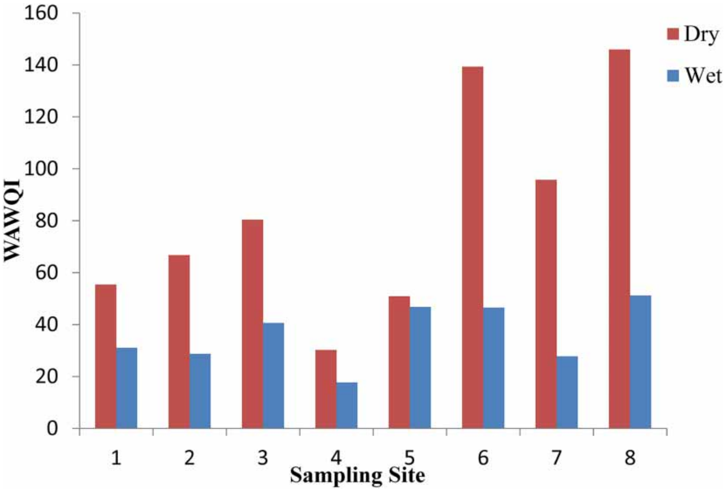
The study addresses the pressing need for an effective monitoring system to assess aquatic water quality, given the exacerbating impact of climate change on surface water bodies. Focusing on the Nilwala River, the research pursues three main objectives: comparative analysis of the Weighted Arithmetic Water Quality Index (WAWQI) values across different river locations, exploration of correlations between monthly rainfall and various physicochemical parameters at distinct sampling sites, and examination of notable disparities in the WAWQI between dry and wet months. Data collected from eight river locations from March to October 2019 revealed significant temporal variations in pH, temperature, chemical oxygen demand (COD), electrical conductivity (EC), alkalinity, chloride (Cl^-), and nitrate (NO_3^-) content. The WAWQI increased across all sites during the drought, with only Site 4 (Wellathota) deemed suitable for drinking. Statistical analyses using an one-way ANOVA and multiple linear regressions unveiled significant relationships between rainfall and pH, biological oxygen demand (BOD), EC, and total alkalinity. The total alkalinity is the most affected parameter by the rainfall. Rainfall positively predicted BOD, COD, and NO_3^- concentration while negatively predicting other parameters.

Key words: climate change, Nilwala River, rainfall, tropical surface water quality, WAWQI

HIGHLIGHTS

- The Nilwala River is the main supply source of drinking water to the Matara district in Sri Lanka.
- The Weighted Arithmetic Water Quality Index (WAWQI) of the Nilwala River increased during the drought.
- Biological oxygen demand (BOD), chemical oxygen demand, and nitrate concentration are positively predicted by rainfall.
- pH, electrical conductivity, and total alkalinity significantly negatively correlated with rainfall.

GRAPHICAL ABSTRACT



NOMENCLATURE

Abbreviations	Expansion
BOD	biological oxygen demand
CCME WQI	Canadian Council of Ministers of the Environment Water Quality Index
CWQGs	Canadian Water Quality Guidelines
COD	chemical oxygen demand
CRI	Climate Risk Index
EC	electrical conductivity
DO	dissolved oxygen
OWQI	Oregon Water Quality Index
SMI	Seawater Mixing Index
TDS	total dissolved solids
TSS	total suspended solids
WQI	Water Quality Index
WAWQI	Weighted Arithmetic Water Quality Index

INTRODUCTION

It is now familiar that some human-induced climate change is unavoidable (Sengupta 2022). Climate change unfavorably impacts water quality and aquatic life in our surface water bodies in many ways (Green *et al.* 2017). Water quality refers to water's chemical, physical, and biological properties (Boyd 2020). Although scientific measurements define water quality, water quality is specific to the purpose for which it is intended to be used and describes the state of the water, including its chemical, physical, and biological properties, concerning its suitability for that particular purpose. Usually, the quality of the water used for drinking or swimming varies (Khanoranga & Khalid 2019). Therefore, physical, chemical, and biological parameters can be used to estimate the quality of water and are directly associated with water use.

Moreover, the Earth is a body of water, covering about 71% of the Earth's surface, and the oceans cover about 96.5% of the Earth's total water (Mocek-Płóciniak & Skowrońska 2021). Only 2.5% is freshwater or low-salinity water, and 1% is saline water. Although there is plenty of water on Earth, humans consume only a tiny amount for many natural and anthropogenic reasons (Munteanu *et al.* 2021). Globally, numerous rivers are declining in water quality, characterized by notable changes in sediment levels, salinity, and nutrient composition (Lintern *et al.* 2017).

Consequently, a significant volume of contaminants is carried away by storm water during precipitation occurrences (Zhao *et al.* 2018). The degradation of water quality in urban water environments is increasingly attributed to the contamination of storm runoff, posing a significant threat to the receiving water bodies. Hence, the regional distribution of precipitation significantly influences water quality dispersion (Ching *et al.* 2015). To achieve efficient water quality management, it is crucial to comprehensively comprehend the spatial variations in water quality within and within river catchments and the underlying factors contributing to these variations.

The primary factors influencing a watershed include land cover, atmospheric deposition, geology and soil type, climate, geography, and catchment hydrology (Lintern *et al.* 2017). The processes of climate change can potentially enhance the hydrological cycle, resulting in alterations in the expected frequency of occurrence and severity of climatological events. This phenomenon may be characterized by increased and temporally fluctuating precipitation, an amplified frequency and severity of floods and droughts, intensified tropical storms, and escalated occurrences of wildfires (Ching *et al.* 2015). Furthermore, studying these physical, chemical, and biological parameters independently does not easily define water quality. Therefore, a good preference is to integrate a set of physical and chemical variables to develop a Water Quality Index (WQI), in which a large number of water parameters respond to a single number that represents the degree of water quality (De La Mora-Orozco *et al.* 2017; Mukate *et al.* 2019; Wu *et al.* 2020).

Recently, the Weighted Arithmetic Water Quality Index (WAWQI) methodology has emerged as a widely accepted method as it categorizes the water quality according to the degree of pollution by using the most generally measured water quality variables (Liu *et al.* 2021). It describes the fitness of both surface and groundwater springs for consumption (Panneerselvam *et al.* 2021). Data from numerous water quality parameters are integrated into an equation that rates the body's health with a number. The WAWQI is applicable for communicating overall water quality information to citizens and policymakers (Chidiac *et al.* 2023). Moreover, the previous study on the Citarum River in West Java Province in Indonesia found that although many WQI assessment methods can be used to determine the quality status of surface water, the National Sanitation

Foundation WQI assessment method was deemed to be the best for determining the Citarum River's water quality rather than the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) and Oregon Water Quality Index (OWQI) assessment methods (Marselina *et al.* 2022).

Furthermore, a study of Dadahup Irrigation Area, Kalimantan, in Indonesia found that high-intensity rainfall can immediately raise water levels, impacting pH and decreasing salinity (Zevri *et al.* 2022). Also, a study in the central area of Beijing, China, found that water quality worsened during the rainy season, with a decline in dissolved oxygen (DO) and a decrease in nitrate nitrogen. However, ammonia nitrogen, total suspended solids (TSS), and total phosphorus concentrations increased significantly after rain (Jia *et al.* 2021).

Additionally, the previous studies in the Kalu River in Sri Lanka used the Sri Lankan Standards for drinking water guidelines, World Health Organization guidelines for the index for drinking and recreational water quality, and the CCME WQI, which is based on the Canadian Water Quality Guidelines (CWQGs), to analyze the irrigation and livestock indices (Mahagamage & Manage 2014).

The study by Chandrajith *et al.* (2022) found that the coastal sedimentary aquifer system in the northern part of Sri Lanka is already severely affected by seawater intrusion, which was characterized by integrated approaches such as mass balance calculations, the Seawater Mixing Index (SMI), and the WQI. While previous studies have explored various aspects of water quality in different regions, this comparative analysis allows for insights into how seasonal variations, particularly in rainfall, impact water quality along the Nilwala River in Sri Lanka, contributing valuable information for water resource management and environmental planning in the region.

Sri Lanka is an island located close to the equator. It has a warm, highly varying climate, moderated by ocean winds and considerable moisture from rainfall patterns and tropical monsoonal rains (Premaratne *et al.* 2021). The Climate Risk Index (CRI) analysis ranked Sri Lanka within the top ten countries most affected by climate change in 2018 (Eckstein *et al.* 2018). Sri Lanka has an expansive river network that flows through 103 distinct natural river basins. The river basins forming in the wet mounds are fed with rainfall, while numerous in the dry zone are seasonal (de Silva *et al.* 2018). The amount of water obtained from rainfall ranges between 127 billion and 130 billion m^3, of which approximately 35% is estimated to be surface water that flows along 4,500 km of rivers and streams (Athukorala 2010).

The present study focuses on the temporal variations of water quality along the Nilwala River as a matrix for assessing the composite water samples grabbed by eight locations along the main river by considering the primary tributary connections in the Matara district of Sri Lanka. In this light, we conducted this study with the objectives of (1) conducting a comparative analysis of the WAWQI values among different locations in the Nilwala River, (2) investigating the correlation between the monthly rainfall and a range of physicochemical parameters, such as pH, temperature, EC, BOD, COD, total alkalinity, hardness, Cl^- concentration, NO_3^- concentration, and PO_4^{-3} concentration, within distinct sampling sites, and (3) conducting an analysis and identification of any notable disparities in the WAWQI between the water samples in dry months and wet months at different sampling sites.

METHODOLOGY

Study area

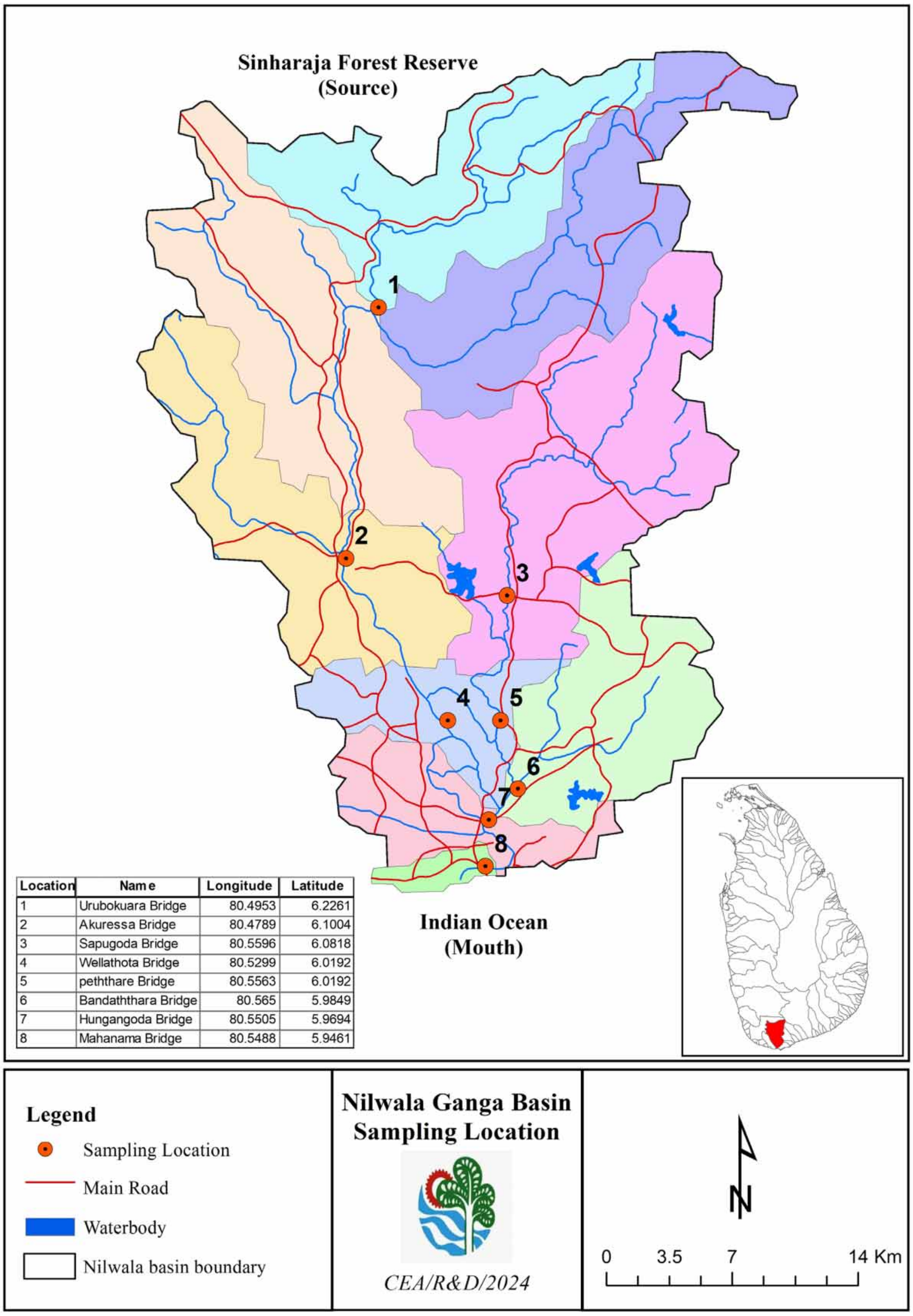
The Nilwala River, spanning a length of 72 km, is the third-largest river in the southern province of Sri Lanka. Originating from the Sinharaja rainforest in Panilkanda, Deniyaya, it traverses through municipal, agrarian, and commercial areas before meeting the Indian Ocean at Thotamuna, Matara (Panditharathne *et al.* 2022). The river basin, situated in the southern part of the wet zone in Sri Lanka, covers an area of 1,010 km^2 and is crucial for the Matara district.

With elevations ranging from 6 to 988 m above sea level, the watershed is defined by the Gin and Polwatta creeks on the western side and the Kirama and Urubokka Oya in the south. The Nilwala River is a vital water source for drinking, agriculture, and industrial activities in the Matara district, emphasizing the significance of maintaining its water quality (Dhanapala *et al.* 2022).

The Matara district, encompassing the Nilwala River basin, experiences a tropical rainforest climate with a distinct wet and dry season. The northeastern monsoon, prevailing from October to December, brings heightened rainfall to the southern province. This climatic pattern influences the water levels and flow of the Nilwala River, impacting its role in supporting various activities within the region (Abeysiriwardana & Wijesekera 2022).

The seasonal variations in rainfall contribute to the river's significance in supplying water for domestic use, irrigation, and other essential functions. Understanding the interplay between the Nilwala River and the regional rainfall patterns is necessary for effective water resource management and sustainable utilization in the Matara district (Chathuranika *et al.* 2022).

From March to October 2019, this study focused on eight sampling sites strategically chosen based on their connections to primary tributaries within the region. These sites, depicted in Figure 1, span a latitude range of 6.2261N to 5.9461N and a longitude range of 80.4953E to 80.5488E along the main river course.



Location	Name	Longitude	Latitude
1	Urubokuara Bridge	80.4953	6.2261
2	Akuressa Bridge	80.4789	6.1004
3	Sapugoda Bridge	80.5596	6.0818
4	Wellathota Bridge	80.5299	6.0192
5	peththare Bridge	80.5563	6.0192
6	Bandaththara Bridge	80.565	5.9849
7	Hungangoda Bridge	80.5505	5.9694
8	Mahanama Bridge	80.5488	5.9461

Figure 1 | Sampling sites along the Nilwala River basin with GPS coordinates.

The study begins in the rural setting of Uru Boku Aru (Location No. 1), surrounded by vast tea plantations, and then progresses downstream to Sapugoda (Location No. 3), which also features significant paddy fields. Wellethota (Location No. 4), Piththare (Location No. 5), and Hungangoda (Location No. 7) continue the rural theme, characterized by agricultural activities like paddy cultivation, tea farming, and small-scale industries.

At Bandaththara (Location No. 6), the landscape changes with the presence of a power plant near the riverbank, introducing industrial impacts. Finally, the Mahanama Bridge in Matara town (Location No. 8), the eighth sampling site, represents an urban area with diverse industries, hospitals, vehicle service centers, hotels, and construction activities. Situated close to the river estuary, this site marks the transition from freshwater to marine environments.

With their mix of rural, industrial, and urban settings, the chosen sampling sites provide a comprehensive view of the environmental dynamics and human interactions along the Nilwala River. This sampling strategy allows for a thorough examination of water quality variations and their implications for different land use practices, contributing to a deeper understanding of the challenges facing the Nilwala River basin.

Sample collection

Composite water samples were collected monthly from March 2019 to October 2019, covering the second and first inter-monsoon seasons. Due to the challenge of obtaining compact samples by crossing the river, all other samples were composite samples collected from bridges.

The monthly rainfall data from January to December 2019 was collected from six rainfall stations, including Morawaka (01MT0348), Deegala (01MT079D), Goluwaththa (01MT134B), Telijjawila (01MT0491), Deyiyandara (01MT085B), and Matara (01MT0232), by the Sri Lanka Meteorology Department.

Sample analysis

In accordance with APHA standards, water samples were collected using glass bottles. Subsequently, the samples were appropriately stored at 4 °C and then transferred to the laboratory for conducting laboratory tests, which included COD, BOD-5 days, alkalinity, hardness, Cl^-, NO_3^-, and PO_4^{3-}. The analysis of water quality parameters followed the procedures outlined in the APHA 23rd edition of standard methods for examining water and wastewater.

Near the sampling site, temperature, pH, and EC were promptly determined. *In situ* measurements of pH, EC, and temperature were conducted using a portable multi-parameter water quality analyzer (Horiba U52).

The estimation of BOD-5 days utilized Winkler's method after a 5-day incubation period for water samples. Total alkalinity and hardness were measured through titrimetric methods, while chloride was assessed using the argonometric method. Laboratory measurements of NO_3^- and PO_4^{3-} were performed using the HACHDR2700 spectrophotometer.

Each parameter underwent testing with three replicates, and in adherence to ISO 17025 quality requirements, all chemical and physical analyses were conducted to mitigate random and systematic measurement errors.

Data analysis

The time series of physicochemical parameters, such as pH, temperature, EC, total alkalinity, hardness, Cl^- concentration, NO_3^- concentration and PO_4^{3-} concentration, were plotted to understand the temporal variation (diurnal and seasonal variations) of the parameters with time in each sampling site by using approximately 240 samples (Figure 2).

The Nilwala River is considered a drinking water body as it is the main water source in the Matara district. Therefore, the WAWQI was calculated by considering the drinking water guidelines mentioned in the ambient WQI in the National Environmental Act No. 47 of 1980 No. 2148/20 to compare the water quality variations during rainy and dry sessions.

The calculation of the WQI was made by using the following equation (Equation (1)):

$$\mathrm{WAWQI} = \Sigma W_i \times Q_i / \Sigma w_i \tag{1}$$

Here,

Q_i – is a relative value of the water quality specific to each parameter.
W_i is the unit weight.

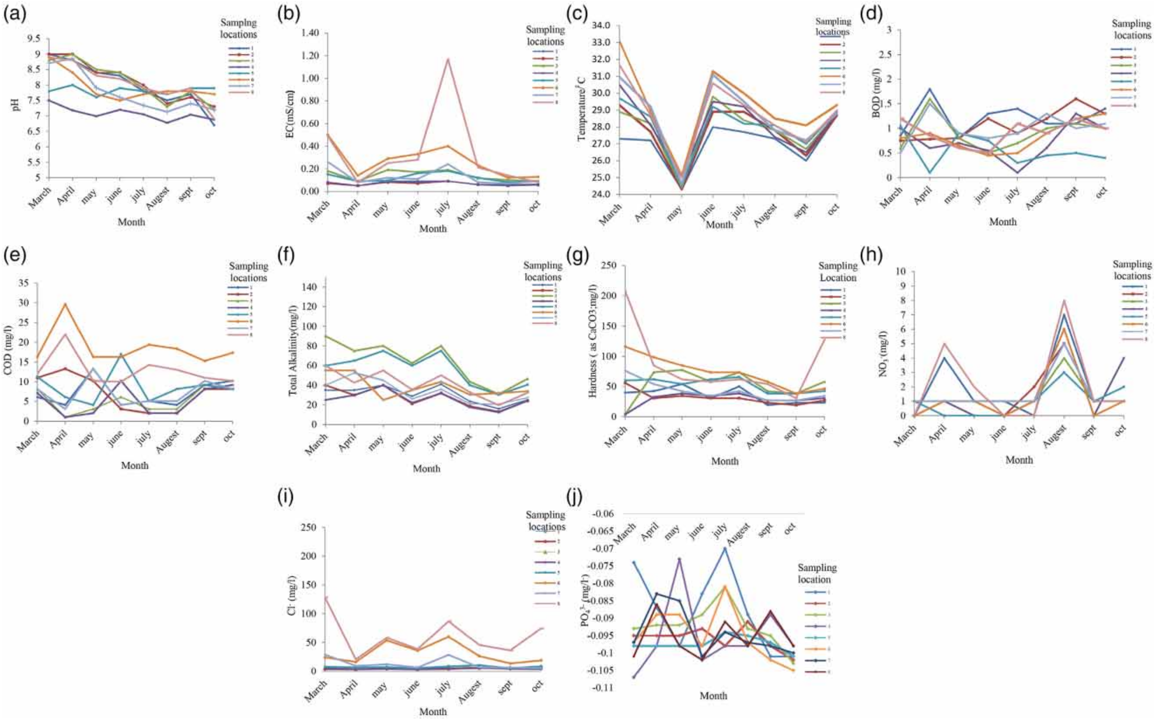


Figure 2 | Temporal variability of (a) pH, (b) electrical conductivity (EC), (c) temperature, (d) biological oxygen demand (BOD), (e) chemical oxygen demand (COD), (f) total alkalinity, (g) hardness, (h) nitrate (NO_3^-), (i) chloride (Cl^-) and (j) phosphate $(PO_4^3)^-$. Along the Nilwala River: insights from monthly measurements (March 2019–October 2019).

The quality rating scale (Q_i) for each parameter is calculated by using this expression (Equation (2)):

$$Q_i = 100 \times V_i - V_0/S_i - V_0 \tag{2}$$

V_i is the actual value of the water quality parameter obtained from the analysis.
V_0 is the ideal value of this parameter in pure water $V_0 = 0$ (except pH = 7.0 and DO = 14.6 mg/l)
S_i is the recommended standard value.

The unit weight (W_i) is calculated by using the following formula (Equation (3)):

$$W_i = K/S_i \tag{3}$$

where K is the proportionality constant and can also be calculated by using the following equation (Equation (4)):

$$K = 1/\Sigma(1/S_i) \tag{4}$$

The water quality levels at each site were categorized into five statuses according to the WAWQI (Table 1).

WAWQI values of the Nilwala River at eight locations were considered to identify the temporal distribution patterns of WAWQI in different locations in Matara district, while the time duration for the temporal variation was accounted for from March to October 2019. A one-way ANOVA (Tukey's pairwise test) at a 5% significance level was conducted to investigate the significant difference between the WAWQI in different sessions along the main river. Before analysis, the data were assessed for normality and homogeneity of variance using IBM SPSS 26.0 software using Anderson Darling's test.

Finally, a regression analysis with some shared parameters (COD, BOD, pH, EC, temperature, alkalinity, hardness, Cl^-, and NO_3^-) was conducted to understand the relationship of the monthly rainfall with other physicochemical parameters.

Table 1 | Classification of the Water Quality Status based on the Weight Arithmetic Water Quality Index (WAWQI) ranges

WQI range	**Water Quality Status**
0–25	Excellent water quality
26–50	Good water quality
51–75	Poor water quality
76–100	Very poor water quality
>100	Unsuitable for drinking and propagation of fish culture

RESULTS

Temporal variation of water quality parameters along the Nilwala River

Figure 2 provides a visual representation of the monthly variations in pH, EC, temperature, BOD, COD, total alkalinity, hardness, NO_3^- content, Cl^- content, and phosphate content at eight sampling sites along the Nilwala River from March to October 2019. However, while Figure 2 offers insight into the temporal trends of these parameters, it may not fully elucidate the fluctuations observed during rainy and dry seasons. Various anthropogenic and natural factors can influence these fluctuations, contributing to the complexity of water quality dynamics.

To further explore the impact of seasonal variations and other influencing factors on water quality, Table 2 presents the ANOVA summary of different parameters across the sampling months. The analysis reveals that parameters, with the exception of BOD, hardness, and Cl^-, exhibit statistically significant variations over time. This underscores the multifaceted nature of water quality dynamics, where seasonal changes interact with a myriad of environmental influences to shape the observed patterns.

Table 2 | Temporal variation of water quality parameters: one-way ANOVA summary (March–October 2019)

	pH				**Temperature**				**EC**			
	df	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**
Month	2	0.085	31.2	<0.001	2	0.013	21.3	0.017	2	1.687	9.099	0.001
	BOD				**COD**				**Alkalinity**			
	df	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**
Month	2	0.645	2.133	0.132	2	1.28	5	0.012	2	1.84	26.876	<0.001
	Hardness				**Cl^-**				**NO_3^-**			
	df	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**	**df**	**M.S.**	**F**	***P*-value**
Month	2	0.467	1.5	0.236	2	0.12	0.736	0.485	2	2.298	4.84	0.017

Temporal variation of the WAWQI

The changes in the WAWQI in September (the wettest month) and March (the driest month) along the along the Nilwala River are illustrated in Table 3. When considering the WQI in the dry session, it is observed that Nilwala River water is deemed poor water quality at all locations except Wallethota (location 4).

Notably, water at location 4 exhibits good water quality during the rainy session (26–50). Conversely, during the dry session, the WQI at all locations, except Wellethota (location 4), reaches 50, signifying that the river becomes poor quality as well as unsuitable for drinking in some parts of the river (location 6, location 7, and location 8).

Consequently, the average WQI at all locations is comparatively higher during drought. The one-way ANOVA test results demonstrated significant differences between the WAWQI values of eight months from March to October ($p > 0.05$). The highest mean WAWQI value was recorded in March (the driest month), followed by the second highest in July, and the lowest mean WAWQI value was recorded in October (Figure 3).

Table 3 | Temporal variability of the Weighted Arithmetic Water Quality Index (WAWQI) from March to October 2019 at eight sampling sites along the Nilwala River, Sri Lanka

	WAWQI							
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**
March	55.37	66.74	80.32	30.16	50.93	139.30	95.73	145.92
April	49.93	49.93	58.67	15.70	37.36	64.64	54.57	58.48
May	49.31	46.37	67.51	20.05	33.55	76.96	47.05	77.72
June	46.43	43.24	61.75	24.35	55.08	80.33	36.46	80.83
July	38.10	39.49	56.35	19.89	52.28	99.04	58.20	254.15
August	27.82	25.16	33.75	12.62	40.86	73.46	25.73	63.25
September	31.01	28.74	40.62	17.65	46.74	46.52	27.74	51.16
October	15.61	23.86	27.96	17.17	38.13	49.07	28.11	21.08

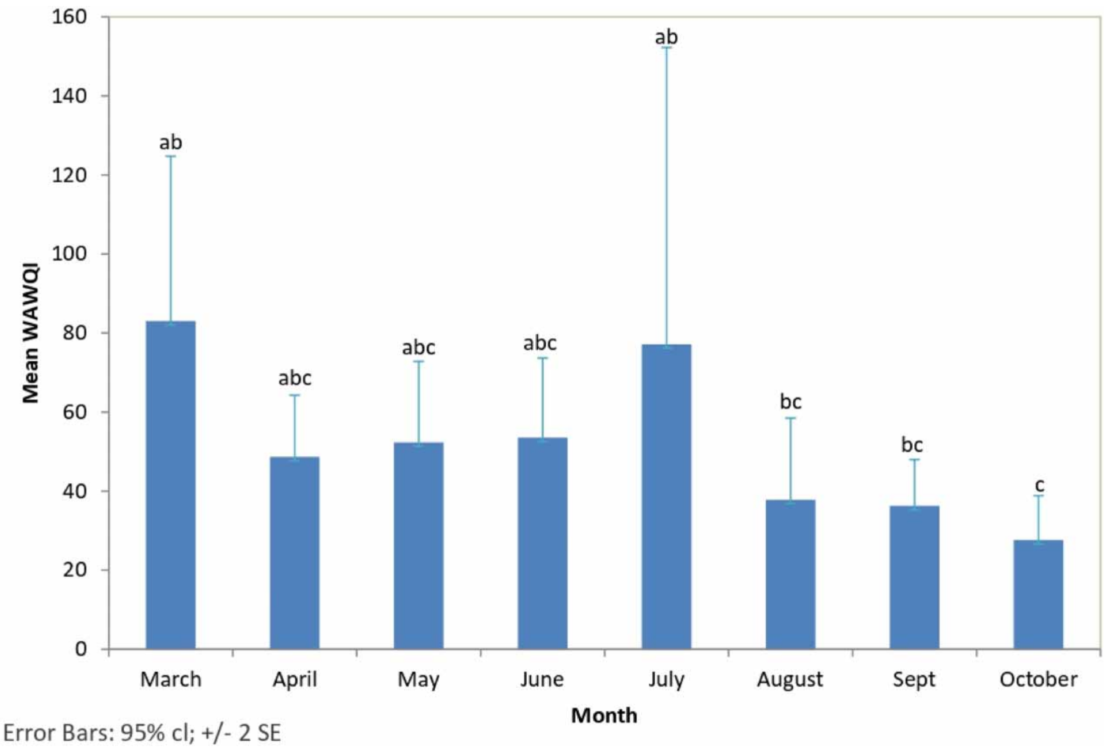


Figure 3 | Temporal variation of the Weighted Arithmetic Water Quality Index (WAWQI) in eight sampling points along the Nilwala River from March to October 2019 (September; highest rainfall, March; lowest rainfall).

Regression analysis

A multiple linear regression analysis using the enter method examined the relationships of physicochemical parameters with monthly rainfall in different sampling locations. The models for pH, F (1, 21) = 5.149, $p = .034$, BOD, F (1, 21) = 7.345, $p = 0.013$, EC, F (1, 21) = 7.093, $p = 0.015$, and total alkalinity, F (1, 21) = 8.328, $p = 0.009$, were significant by explaining 19.7% ($R^2 = 0.197$), 25.9% ($R^2 = 0.259$), 26.2% ($R^2 = 0.262$) and 29.4% ($R^2 = 0.294$) of the variance in the outcome variables, respectively (Supplementary material, Appendix 2) (Appendix 3). Therefore, total alkalinity is the parameter most affected by the rainfall.

Looking at the unique individual contributions of the predictors, the result shows that BOD ($\beta = 0.509$, $t = 2.71$, $p = 0.013$), COD, and NO_3^- concentration are positively predicted by rainfall, as well as other parameters that are negatively predicted by monthly rainfall (Figure 4).

Figure 4 depicts the correlations between rainfall and physico-chemical parameters with regression equations. Here, the residual value (E), the difference between the actual and expected outcomes, accounts for such slide variations (Hayes 2023).

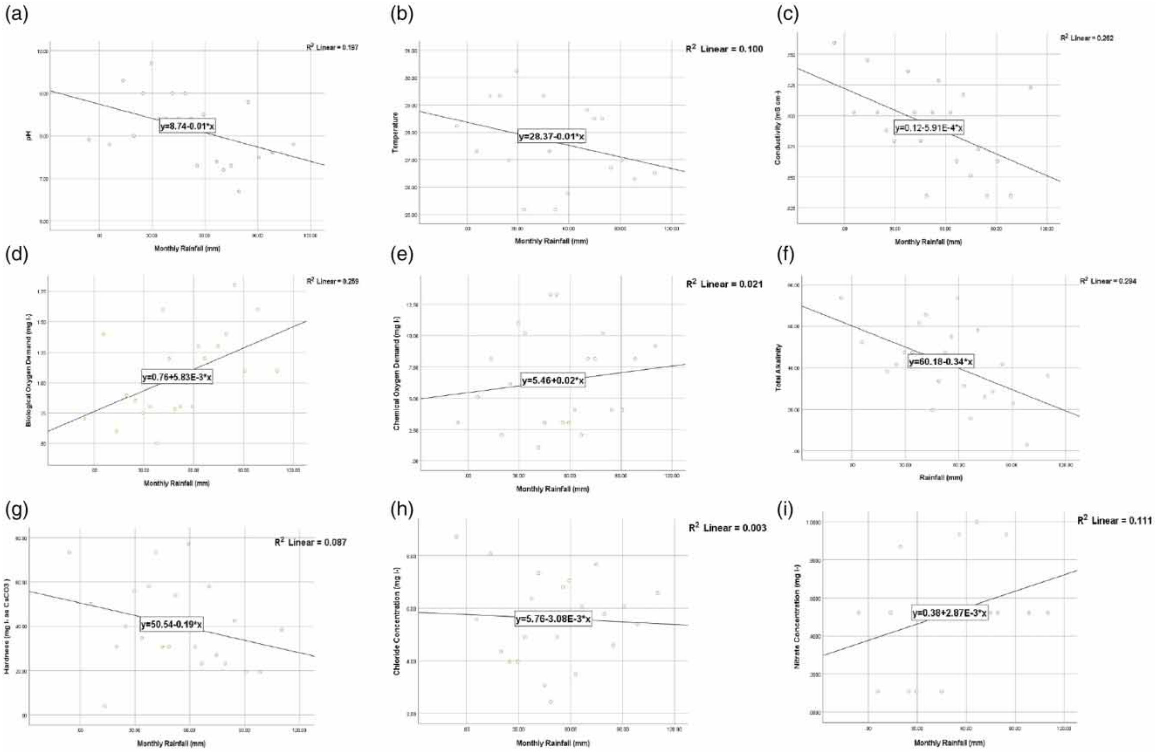


Figure 4 | Correlations between (a) pH, (b) electrical conductivity (EC), (c) temperature, (d) biological oxygen demand (BOD), (e) chemical oxygen demand (COD), (f) total alkalinity, (g) hardness, (h) nitrate (NO_3^-), (i) chloride (Cl^-) and monthly rainfall: scatter diagrams with linear regression.

DISCUSSION

This comprehensive analysis aims to thoroughly examine recent research findings about the variation of water quality in a tropical water body. It explores the temporal dimensions of WAWQI and pysico-chemical parameters and investigates the correlation between rainfall and various parameters. The objective is to facilitate a comprehensive understanding of the WAWQI of the Nilwala River in the Matara district.

Temporal variation of water quality parameters along the Nilwala River

The present study depicts significant temporal fluctuations between time and pH, temperature, COD, EC, alkalinity, and NO_3^- content. Similarly, previous studies collectively affirmed significant disparities across multiple parameters, including turbidity, DO, BOD, COD, pH, color, temperature, TDS, hardness, alkalinity, chloride, and EC during the sampling period (Al-Noor & Kamruzzaman 2013; Aregbe *et al.* 2018; Zelenakova *et al.* 2018; Xu *et al.* 2022). These investigations consistently documented temporal fluctuations in both physical and chemical parameters, underscoring the dynamic nature of water quality assessments and the necessity for continuous monitoring to accurately capture variations over time. However, a study in the Calabar River Niger Delta observed that there is no significant variation in temperature and BOD across stations and seasons (He & Gn 2015).

Temporal variation of the WAWQI

In the present study, WAWQI of all sampling sites along the river increased during the drought, indicating poor water quality and unsuitability for drinking in certain areas. Furthermore, according to the ANOVA results, although September had the highest rainfall (621 mm) in both the upper and lower parts of the river, the lowest WAWQI (27.6245) was recorded in October (401 mm), while March, with the lowest rainfall, had the highest WAWQI (83.0608). Therefore, the effect of dilution and the corresponding reduction in pollution correspond well with the optimized WAWQI values in rainy sessions (Nandi *et al.* 2022).Moreover, changes in air temperature and rainfall ought to affect river flows and, hence, the mobility and dilution of contaminants. Increased water temperatures will affect chemical response kinetics and lead to the deterioration of the quality of freshwater (Mujere & Moyce 2017). However, heavy storms that cause changes in the patterns and quantity of rainfall are degenerating water quality through the runoff of pollutants (USEPA 2023). Also, rains that occur just after tsthe drought period flush nutrients from urban and rural or acidic areas. Furthermore, actions aimed at minimizing climate change will significantly impact freshwater quality (Capon *et al.* 2021). Further, natural processes and anthropogenic activities influence surface water quality (Roşca *et al.* 2020).

Correlations between water quality parameters and monthly rainfall

The present study records that BOD, COD, and Cl^- concentration are positively predicted by rainfall, while other parameters (pH, EC, temperature, total alkalinity, hardness, and NO_3^-) are negatively predicted by monthly rainfall (Figure 4). Similarly, in Ekerekana and Buguma Creeks in the Niger Delta, Nigeria, seasonal variations were observed in all the parameters except for pH, alkalinity, and water hardness. Conversely, temperature, EC, salinity, and NO_3^- were significantly higher in the dry season, while the values of BOD, turbidity, TDS, SO_4^{2-}, and Cl^- were elevated in the wet season (Kingsley & Ndubuisi 2021).

However, in a previous study conducted by Pourfallah Koushali *et al.* (2021) in the Zarjoub River in Guilan Province, Iran (a coastal river), it was found that with the increase in precipitation and flow rate, the concentration of all parameters, except pH and sulphate (SO_4^{2-}), decreased. Moreover, the study by Bhutekar *et al.* (2018) on the Godavari River in India reported significant seasonal variations in water quality parameters. During the monsoon season, the river exhibited elevated levels of turbidity, pH, TDS, NO_3^-, PO_4^{3-}, and BOD, indicating increased pollution levels. Conversely, in the summer season, higher temperatures were observed along with the highest COD, while the BOD levels were comparatively lower.

According to a previous study on the Mpape River, Abuja, Nigeria, during the dry season, levels of pH, EC, TDS, BOD, SO_4^{2-}, and Cl^- in water were higher, while DO, PO_4^{3-}, and NO_3^- increased in the rainy season (Eze *et al.* 2018).

CONCLUSION

A significant temporal variation of pH, temperature, COD, EC, alkalinity, Cl^- and NO_3^- content can be observed in different months of 2019. The WAWQI at all the sampling sites in the river went up during the drought session. Site 4 (Wellathota) was the only place suitable for drinking during the dry session. According to the ANOVA results, the lowest WAWQI (27.6245) was recorded in October, while March had the highest WAWQI (83.0608). It is of inferior quality on the scale. The WAWQI in March and July were significantly different from other months.

The relationship of rainfall with pH, BOD, EC, and total alkalinity was significant, explaining 19.7, 25.9, 26.2, and 29.4% of the variance in the outcome variables, respectively. Furthermore, looking at the unique individual contributions of the predictors, the result shows that BOD ($\beta = 0.509$, $t = 2.71$, $p = 0.013$), COD, and NO_3^- concentration are positively predicted by rainfall, as well as other parameters that are negatively predicted by monthly rainfall. It can be provided as helpful information for the design and management of water in the Nilwala River, making predictions more realistic for future trends.

RESEARCH LIMITATIONS AND FUTURE RESEARCH DIRECTIVES

This river has no complete water, sediment, or soil analysis except for the locations with primary tributary connections. Therefore, the findings of this study can serve as a foundational reference point for conducting future research with a specific purpose.

The recommendations based on the findings of this study are presented for careful consideration. The discharges in the Nilwala River change due to the expansion of industrial and commercial activities, as well as the subsequent increase in population. These changes primarily stem from non-point sources of emitted pollutants.

Hence, it is imperative to implement ongoing monitoring protocols to evaluate water quality.

ACKNOWLEDGEMENTS

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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