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RESEARCH PAPER

Evaluating Water Quality in Northern and Eastern Coastal Zones of Sri Lanka: A Baseline Study for Environmental Monitoring and Conservation

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Abstract

The coastal area of Sri Lanka, spanning approximately 1,650 km, serves as a major source of livelihood, habitat, tourism, aquaculture, and trade. Although the coastal region provides numerous benefits to nearly 55% of Sri Lanka's population, it faces severe threats from factors such as aquatic pollution, coastal erosion, ecosystem degradation, urbanization, and sand mining. To ensure ecosystem stability and conserve the coastal environment, it is crucial to conduct environmental monitoring of coastal waters. However, a significant number of water quality assessments conducted so far have primarily targeted the Western and Southern coastal zones of Sri Lanka. This study, therefore, aims to assess the marine water quality in selected locations (26 locations in total) within the Northern (Mannar, Pooneryn, Kilinochchi, Jaffna, and Mullaithivu) and Eastern (Trincomalee) coastal zones. The results showed statistically significant differences in TDS ($P = 0.004$), COD ($P = 0.036$), and nitrite levels ($P = 0.009$) between all the locations. However, no significant variation in COD was observed in the HSD test. Heat map analysis of the water quality index model indicated that some locations in Mannar, Pooneryn, and Jaffna had very poor water quality, while Trincomalee and Mullaithivu exhibited moderate to good water quality in selected locations. Overall, these findings provide a clear understanding of the current water quality status in each of the selected locations. Therefore, it can be concluded that regular water quality monitoring and the application of the Water Quality Index approach should be conducted in each coastal district. This will help to develop a robust database that can serve as baseline information for coastal ecosystem management, conservation efforts, and emergency mitigation measures, such as oil spills or ship fire incidents.

Introduction

Sri Lanka, an island nation in the Indian Ocean, boasts an extensive coastline that plays a pivotal role in the country's economic well-being, particularly through fisheries, tourism, aquaculture, and maritime trade (Manage et al., 2022). According to the Census of Sri Lanka, around 57% of the total population resides in the coastal zones (Weerasekara et al., 2015). The coastal area also serves as a natural buffer against storm surges and coastal erosion, protecting inland regions and communities (Dong et al., 2024). Especially, the Northern and Eastern coastal regions host a large number of coastal communities relying on coastal resources for their livelihood. Since the ocean is considered as an open-access resource, unrestricted access to coastal resources and ecosystem services has led to significant impacts on marine ecosystems, primarily due to coastal aquatic pollution (Li et al., 2017; Manage et al., 2022). These coastal regions hold substantial ecological and economic importance due to their unique marine ecosystems and strategic locations. They support diverse aquatic life and provide essential resources for local communities.

Despite their importance, these coastal zones are increasingly threatened by various anthropogenic activities, including overfishing, coastal development, urbanization, and pollution from agricultural and industrial sources (Myers et al., 2019; Suresh, 2024). For instance, over 60% of Sri Lanka's small, medium, and large-scale enterprises operate along the coastal areas, often discharging industrial effluents directly into the area with minimal or no treatment (Weerasekara et al., 2015). Additionally, accidental oil spills, waste disposal from ships, mining activities and industrial operations are major contributors to marine pollution in Sri Lanka (Bandara, 2003). These activities raised significant concerns regarding water quality degradation, which poses serious threts to marine biodiversity, aquatic animal health, human health, and the sustainability of local livelihoods (Pires de Souza Araujo et al., 2021). As a result of coastal pollution, Sri Lanka reanked 213 out of 220 coastal countries and territories to Ocean Health Index Scores. This indicates that, goals including clean waters, coastal protection, livelihood and economies, biodiversity, tourism and creation are not being sustainably managed in the country (Ocean Health Index, 2023). Moreover, efforts to combat water contamination have depicted relatively slow in Sri Lanka, despite the laws and government regulations (Bandara, 2003). Therefore, the preservating and sustainably managing these coastal ecosystems is vital for mitigating the impact of climate change and ensuring long-term ecological and economical stability in Sri Lanka.

In order to preserve and manage the coastal environment, it requires a clear understanding of current status of the marine environment, as well as the identifing and acknowledging the potential threats. Continuous water quality monitoring in these regions is particularly necessary to assess the current status, detect pollution, and implement effective measures to mitigate its impacts. However, comprehensive studies on the water quality across these coastal regions in Sri Lanka are limited, particularly in the context of recent environmental changes and development pressures in the Northern and Eastern provinces.

Hence, this study aims to assess the water quality of six key coastal locations within the Northern and Eastern Provinces of Sri Lanka: Mannar, Pooneryn, Jaffna, Kilinochchi, Mullaithivu, and Trincomalee. The water quality parameters were analyzed using a newly developed water quality index model, with data collected from each location providing a snapshot of the current state of the marine environment in these areas. The findings of this study are expected to contribute to the broader understanding of coastal water quality in Sri Lanka and to inform future conservation and management efforts.

Materials and methods

Study Area and Sample Collection

Seawater samples were collected from the off-shore to open sea at Kalpitiya (1 location), Mannar (4 locations), Pooneryn (6 locations), Jaffna (7 locations), Kilinochchi (1 location), Mullaitivu (4 locations), and Trincomalee (3 locations) as shown in Figure 1, in 2023.

Samples were collected according to the National Field Manual for the collection of water quality data (National Field Manual for the Collection of

Water-Quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, 2015). The polypropylene vessels were soaked in the 1:4 nitric acid for a few days and then washed using distilled water. The sampling vessels were sealed after collecting the samples. A total of 52 samples were analyzed for a variety of parameters, including physico-chemical and biological variables. The sampling locations were selected representing the environmental conditions present in this study area.

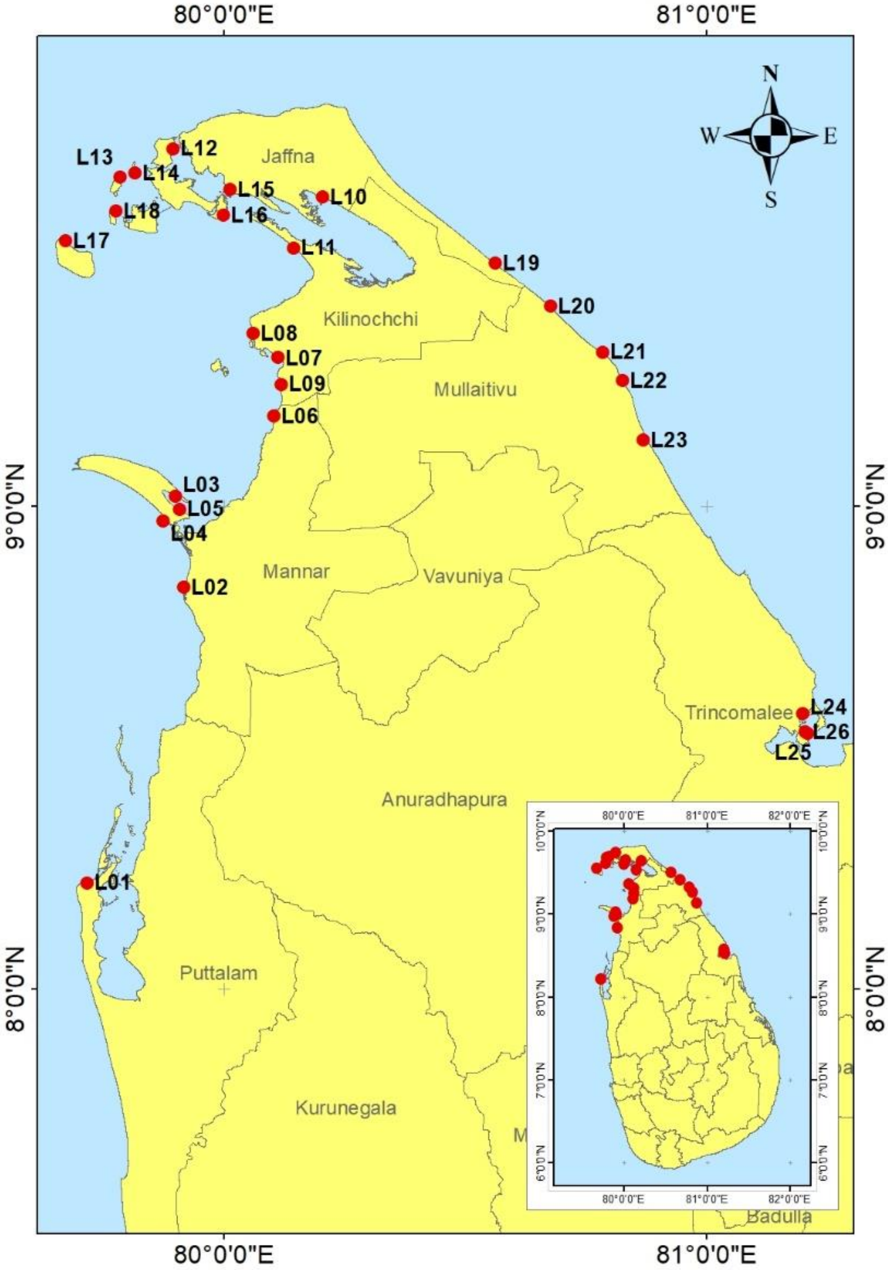

Figure 1. The Study Area

Table 1. Samples collected locations under each study area

No.	Study Area	Locations	No.	Study Area	Locations
1	Kalpitiya 1	Kandakuliya	**15**	Jaffna 3	Eluvathivu
2	Mannar 1	Achchan Kulam	**16**	Jaffna 4	Guru Nagar
3	Mannar 2	Pallimunei	**17**	Jaffna 5	Mandathivu
4	Mannar 3	South Bar	**18**	Jaffna 6	Delft
5	Mannar 4	North Bar	**19**	Jaffna 7	Nainathivu
6	Mannar 5	Iranathivu	**20**	Kilinochchi 1	Chundikkulam
7	Pooneryn 1	Thewampitei	**21**	Mulativu 1	Chalei
8	Pooneryn 2	Kiranchi	**22**	Mulativu 2	Mulliwaikkal
9	Pooneryn 3	Waleypadu	**23**	Mulativu 3	Kalaipadu
10	Pooneryn 4	Nachchikuda	**24**	Mulativu 4	Nayaru
11	Pooneryn 5	Palavi	**25**	Trincomalee 1	Cod-bay
12	Pooneryn 6	Kavuthurumunei	**26**	Trincomalee 2	Marble beach
13	Jaffna 1	Karainagar	**27**	Trincomalee 3	Clappernburge beach
14	Jaffna 2	Analathivu			

Analytical method of sample analysis

The pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO) and turbidity were measured at the site using a DO meter (HANNA, Romania), a Multimeter (HANNA, Romania) and a turbidity meter (LOVIBOND, Germany). The biochemical oxygen demand (BOD) was measured after a 5-day incubation at 20°C in a BOD incubator using Winkler's titration method (APHA, 2019). Total suspended solids (TSS) were determined by filtering 1 L of seawater through pre-dried and pre-weighed filter papers (Millipore GF/C) and washing them with Milli-Q water to remove salt content (APHA, 2019). Phosphate, nitrate, nitrite and chemical oxygen demand (COD) were analyzed using standard methods from APHA 2019.

Statistical Analysis

ANOVA (Analysis of Variance)

ANOVA was employed to determine whether there were statistically significant differences in water quality parameters between different locations (Montgomery, 2013). A significant ANOVA result indicates that at least one location's water quality differs from the others.

Tukey's Honest Significant Difference (HSD) Test

For the significant ANOVA results, the Tukey's HSD test was performed to identify which specific locations had significantly different water quality (Tukey, 1949).

Correlation Analysis

Correlation analysis was conducted to examine the relationships between the selected water quality parameters. The Pearson's correlation coefficient was used to quantify the strength and direction of the relationships between pairs of variables (Mukaka, 2012)

Moran's I Test for Spatial Correlation

The global spatial autocorrelation technique was employed to assess the correlation between adjacent observations, identifying patterns and the extent of spatial clustering across neighboring locations. Moran's I, a statistic analogous to the Pearson correlation coefficient (Tsai et al., 2010) is computed by Eq. 1.

$$I = \frac{n}{W} * \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} \quad (1)$$

Where n represents the number of observations, W denotes the sum of the weights, w_{ij} represents the weight between locations i and j, x_i and x_j are values at locations i and j and $\bar{x}$ denotes the mean of the values.

Water Quality Index (WQI)

$$WQI = \sum_{i=1}^{n} W_i S_i \quad (2)$$

Where n represents the number of water quality parameters, W_i denotes the weight assigned to the i^{th} parameter, and S_i is the score of the i^{th} parameter. The weight W_i was derived based on the outcomes of the Principal Component Analysis (PCA) and Factor Analysis (FA). The score S_i representing the standardized value of each of the 10 water quality parameters, was determined using Equations 3 and 4. These 10 parameters were categorized into three groups: "the more the better," "the less the better," and "neutral." The "more the better" group included only the Dissolved Oxygen (DO) parameter, the "neutral" group included pH, and the "less the better" group included the remaining 8 parameters. For the "more the better" and "neutral" parameters, the score S_i was calculated following Eq. 3 (Le et al., 2023).

$$S_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (3)$$

For the "the less the better" parameters, S_i was determined following Eq. 4.

$$S_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} \quad (4)$$

Where X_i, X_{min}, and X_{max} were the analyzed, minimum, and maximum values of the parameter i, respectively.

Assigning accurate weights to each parameter in the WQI is essential, as it signifies the relative significance of each parameter in assessing overall water quality. The raw data were first subjected to Z-score normalization to standardize the parameters, ensuring they are comparable across different measurement scales. Following this, PCA was applied to the normalized dataset to identify the principal components that account for the majority of the variance within the data. The weights for each water quality parameter were derived from the loadings of the principal components that explained the highest proportion of variance. These weights were then utilized to calculate the WQI by aggregating the weighted scores of each parameter for each location and beach. The resulting WQI values, which represent the overall water quality, were expressed as a percentage, enabling comparative analysis across the different beaches.

Results and Discussion

The water quality data across the different study areas (Kalpitiya, Mannar, Pooneryn, Jaffna, Kilinochchi, Mulativu, and Trincomalee) highlight both consistencies and significant deviations in key environmental parameters, offering insights into the varying conditions of these coastal regions. pH levels consistently range between 7.9 and 8.3 across all locations, indicating slightly alkaline waters typical of coastal environments, which is generally favorable for aquatic life (Jiang et al., 2019). However, even minor fluctuations in pH can influence the solubility and toxicity of chemical compounds, potentially impacting ecosystem health. TDS are remarkably stable across all sites, hovering around 28 mg/L, reflecting the salinity of the water in these coastal regions. This consistency suggests limited freshwater intrusion or significant saline contamination, maintaining the typical saline nature of these coastal waters. In contrast, turbidity shows notable variability, particularly in Mannar and Mulativu, with Mannar's Location 2 and Mullaitivu's Location 4 exhibiting elevated turbidity levels of 70.4 NTU and 26.9 NTU, respectively. High turbidity can decrease light penetration, adversely affecting aquatic plants and indicating possible sediment or organic matter presence, which could stem from runoff or local disturbances (Hinga, 2002). This can, in turn, harm aquatic life and increase the risk of fish mortality (Rahmania et al., 2024). DO levels also vary, with most locations maintaining adequate levels for aquatic life, except for some sites in Pooneryn and Jaffna, where lower DO levels compared to other locations (as low as 6.6 mg/L) might indicate localized organic pollution or stagnant water conditions. Conversely, higher DO levels in Mulativu and Trincomalee suggest well-aerated waters, potentially due to increased water movement or photosynthetic activity. Dissolved oxygen levels are typically higher at the water's surface due to the diffusion of oxygen from the air and the process of photosynthesis. As depth increases, the concentration of dissolved oxygen declines due to the reduced occurrence of photosynthetic activity (Rahmania et al., 2024).

The current study provides a complete investigation of water quality along Sri Lanka's Northern and Eastern beaches. Table 2 compares the findings of this study with earlier studies done at Pasikuda (Sivakumar, 2019) and Arugam Bay (Sivakumar, 2016). The WT (29.8±0.5 °C) and pH (8.0±0.1) observed in this study are consistent with previous findings, but higher values were recorded for EC (57.9±0.2 mS/cm), TDS (28.6±0.1 mg/L), and salinity (38.6±0.2 ppt). This could be most likely reflecting spatial or temporal variations in environmental conditions. DO levels had exceeded 4 mg/L in all studies indicating improved oxygenation. Nutrient concentrations, such as nitrates (0.019±0.010 mg/L) and phosphates (0.142±0.127 mg/L), were much lower than previously investigated locations. Nevertheless, it cannot be concluded that water quality has been improved and further monitoring is recommended.

Table 2. The comparison of water quality parameters with previous studies done in Eastern coastal areas

Parameter	**Unit**	**Eastern Coasts (This Study)**	**Eastern Coastal Areas**	
			Pasikuda (Sivakumar, 2019)	Arugam Bay (Sivakumar, 2016)
WT	ºC	29.8±0.5	30.2	30.9±1.9
pH		8.0±0.1	8.0	8.2±0.1
EC	mS/cm	57.9±0.2	53.8	55.3±3.6
TDS	mg/L	28.6±0.1	26.4	27.1±1.7
Salinity	ppt	38.6±0.2	31.6	32.2±0.6
Turbidity	NTU	8.5±6.0	9.9	9.5±0.6
DO	mg/L	8.6±0.8	7.2	7.5±0.3
COD	mg/L	43.3±10.6	-	-
BOD	mg/L	7.5±2.1	-	-
Nitrates	mg/L	0.019±0.010	0.63	0.068±0.075
Nitrites	mg/L	0.004±0.002	-	-
Phosphates	mg/L	0.142±0.127	1.36	2.970±4.350
Ammonia	mg/L	0.406±0.091	-	-
TSS	mg/L	33.7±12.5	-	-

Table 3. The comparison of water quality parameters with previous studies done in Northern coastal areas

Parameter	**Unit**	**Northen Coasts (This Study)**	**Northern Coastal Areas**					
			Mathgal (Gobiraj et al., 2022)	Point Pedro (Gobiraj et al., 2022)	Charty Beach (Gobiraj et al., 2022)	Gurunagar Beach (Anandakrishnan Sivanandan et al., 2023)	Charty Beach (Moksha S. Usgoda et al., 2024)	Nayaru (Jayawardena et al., 2023)
WT	⁰C	30.8±1.4	29.3±1.9	29.1±1.6	29.4±1.4	30.3±1.4	29.2±1.4	28.7±0.2
pH		8.0±0.1	8.2±0.2	8.1±0.2	8.1±0.3	-	8.1±0.2	7.2±0.1
EC	mS/cm	57.3±3.9	52.9±6.1	52.7±5.1	53.5±5.1	-	49.4±2.6	47.6±0.7
TDS	mg/L	28.3±2.0	31.8±2.8	31.8±2.4	32.1±2.8	-	30.2±1.5	29.3±0.5
Salinity	ppt	38.0±3.3	32.5±3.3	32.5±2.9	32.9±3.2	36.5±13.5	29.8±1.4	31.3±0.4
Turbidity	NTU	12.1±14.4	-	-	-	27.0±29.1	8.0±0.1	5.8±1.3
DO	mg/L	7.8±1.1	6.8±0.9	9.6±1.3	6.4±1.4	-	6.7±1.8	7.3±0.1
COD	mg/L	35.0±15.9	-	-	-	135.7±154.6	-	-
BOD	mg/L	7.5±1.9	-	-	-	62.3±69.7	1.2±0.6	-
Nitrates	mg/L	0.013±0.008	-	-	-	24.270±31.480	2.660±2.080	0.005±0.001
Nitrites	mg/L	0.013±0.022	-	-	-	-	-	-
Phosphates	mg/L	0.216±0.547	-	-	-	0.853±0.553	0.150±0.060	0.005±0.001
Ammonia	mg/L	0.415±0.275	-	-	-	-	-	-
TSS	mg/L	45.7±20.8	-	-	-	21.3±12.9	-	32.8 ± 22.2

The water quality paramters analysed for Northern region in this study revealed siginificant variations across different coastal regions in the Northern province, which may be attributed to the differences in geographical, and environmental factors (Table 3). The average water temperature (30.8±1.4 ºC) observed in the Northern coastal areas alignsed closely with other studies previously carried out in Charty beach, Gurunagar, Point Pedro and Nayaru (Sivanandan et al., 2023; Gobiraj et al., 2022; Jayawardena et al., 2023; Usgoda et al., 2024). Slight variation in water temperature could have occured due to seasonal differences or localized infleunces. The pH levels of coastal water samples (8.0±0.1) recorded within the slightly alkaline range which are typical for marine environments (Jiang et al., 2019). This value is comparable to the values shown in previous studies (Sivanandan et al., 2023; Gobiraj et al., 2022; Usgoda et al., 2024) except for Nayaru (7.2±0.1) (Jayawardena et al., 2023). In this study, EC (57.3±3.9 mS/cm) values were found relatievly higher compared to other coastal areas. Neverthless (Usgoda et al., 2024) obtained a low EC value in 2024 compared to (Gobiraj et al., 2022) 2022 for the same location. The TDS values are within the similar range with previous studies. The DO had greater values than 4 mg/L in this study as well as the previous studies indicating proper mixing of water. It was observed that BOD and COD were higher in (Sivanandan et al., 2023) compared to this study. (Sivanandan et al., 2023) carried out the sampling at the fishery harbour, Gurunagar and the discards of fish waste could be the reason for having higher BOD and COD values (Weerasekara et al., 2015). The overall findings incidate that Northern coastal stretch exhibit relatively stable water quality with paramteres generally within the acceptable ranges for marine ecosystems as well as similar to the previous studies. However, variation across regions highlight the importance of localized and area based management strategies to mitigate pollution impacts and ensure the sustainability of coastal resources.

ANOVA Test

One way ANOVA test was conducted with the location as the independent variable and the water quality parameters as the dependent variables. This compared the means of a single dependent variable across multiple independent groups or categories to examine whether there are any significant differences in the mean of the water quality parameter between the different locations. The obtained Pr (>F) values for each parameter is listed in Table 4.

Table 4. ANOVA test results

Parameter	DF	Sum Sq.	Mean Sq.	F value	Pr (>F)
pH	6	0.0184200	0.00306900	0.251	0.95300
TDS	6	0.9288000	0.15480000	4.612	0.00474 **
Turbidity	6	733	122.100000	0.617	0.71500
DO	6	5.9610000	0.99340000	0.900	0.51500
COD	6	1121	186.900000	2.871	0.03650 *
BOD	6	2.6300000	0.43800000	0.101	0.99500
Nitrates	6	0.0004255	0.00007092	2.014	0.11400
Nitrites	6	0.0035180	0.00058640	3.948	0.00989 **
Ammonia	6	0.0005590	0.00009312	0.537	0.77400
TSS	6	985	164.200000	0.547	0.76600

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1

If the p-value associated with the F-statistic is less than the significance level (0.05), it can be concluded that there is a statistically significant difference between the locations. It can be seen that all the parameters do not have any significant difference between locations except for TDS, COD and Nitrites. Therefore, Tukey's Honest Significant Difference (HSD) test was conducted for the TDS, COD and Nitrites (Table 5).

Tukey's Honest Significant Difference (HSD) test

For TDS, Mannar-Jaffna (p adj = 0.0010434) and Mullaitivu-Mannar (p adj = 0.0228076) had p-values less than 0.05, indicating that the TDS levels in these pairs of locations are significantly different from each other. But other pair of locations had p-values greater than 0.05, indicating that there is no statistically significant difference in TDS levels. For Nitrites, Mannar-Jaffna (p adj = 0.0061325), Mullaitivu-Mannar (p adj = 0.0291910), Pooneryn-Mannar (p adj = 0.0292759) and Trincomalee-Mannar (p adj =0.0198157) had p-values less than 0.05 indicating a significant difference in mean Nitrites levels between stated locations. The ANOVA test yielded a p-value of 0.0365 for COD, indicating a statistically significant difference in COD levels across the locations overall. However, the subsequent Tukey's HSD test did not reveal any statistically significant differences between specific pairs of locations. This means that although the ANOVA suggests an overall variation in COD levels among the locations, the differences between individual pairs of locations are not substantial enough to reach statistical significance after accounting for multiple comparisons. This outcome implies that the overall difference detected by ANOVA does not translate into significant pairwise differences when using the more conservative Tukey's HSD test.

Table 5. Tukey's Honest Significant Difference (HSD) test results

	Location	Difference*	lower**	upper***	p adj****
TDS	Mannar-Jaffna	-0.58571429	-0.96288311	-0.20854546	0.0010434
	Mullaitivu-Mannar	0.475000000	0.04949618	0.90050382	0.0228076
Nitrites	Mannar-Jaffna	0.032707143	0.007619137	0.057795149	0.0061325
	Mullaitivu-Mannar	-0.030575000	-0.058878088	-0.002271912	0.0291910
	Pooneryn-Mannar	-0.027900000	-0.053737066	-0.002062934	0.0292759
	Trincomalee-Mannar	-0.034750000	-0.065320829	-0.004179171	0.0198157

*The difference in mean TDS levels between the two locations

**lower: The lower bound of the confidence interval for the difference

***upper: The upper bound of the confidence interval for the difference

****p adj: The adjusted p-value for the comparison, indicating whether the difference between the means is statistically significant

Correlation Analysis

Correlation analysis was done to investigate the correlations between different water quality parameters. Several important relationships were identified in correlation analysis. Notably, nitrites and nitrates displayed a moderate positive correlation ($r = 0.47$), indicating that higher nitrite levels tend to coincide with increased nitrate levels, possibly due to shared sources or nitrogen cycling processes. Similarly, TSS showed a positive correlation with ammonia ($r = 0.35$), suggesting that particulate matter may be associated with higher ammonia concentrations, potentially from organic materials in the water.

Moran's I Test for Spatial Correlation

The spatial distribution of water quality parameters was assessed using Moran's I statistic to identify any significant spatial autocorrelation. For all the parameters, the Moran's I values were close to zero, with p-values greater than 0.05, indicating no significant spatial clustering or dispersion of water quality measurements across the study area. Specifically, the Moran's I for all the parameters was calculated as -0.04, with an expectation of -0.04 and a p-value of 0.5, confirming the absence of significant spatial autocorrelation. The results suggest that the water quality variations in Northern and Eastern coasts are largely spatially random. These results imply that water quality across different sampling locations does not follow a distinct spatial pattern and may be influenced by local factors rather than regional spatial trends.

Table 6. Moran's I statistic standard deviate and variance for each parameter

Parameter	Moran I statistic standard deviate	Variance
pH	0	4.748806e-17
TDS	-2.0372e-09	4.640385e-17
Turbidity	0	1.864828e-17
DO	1.0782e-09	4.141652e-17
COD	1.0046e-09	4.77049e-17
BOD	0	4.18502e-17
Nitrate	0	4.87891e-17
Nitrite	2.4253e-09	3.274291e-17
Ammonia	0	4.748806e-17
TSS	0	4.943962e-17

Water Quality Index

When calculating the WQI, the threshold values for each parameter were taken from the ASEAN marine water quality guidelines and the wastewater discharge limits defined by the Central Environmental Authority of Sri Lanka. The weights were calculated comprehensively to all the locations using the PCA (Figure 2) and shown in the Table 7.

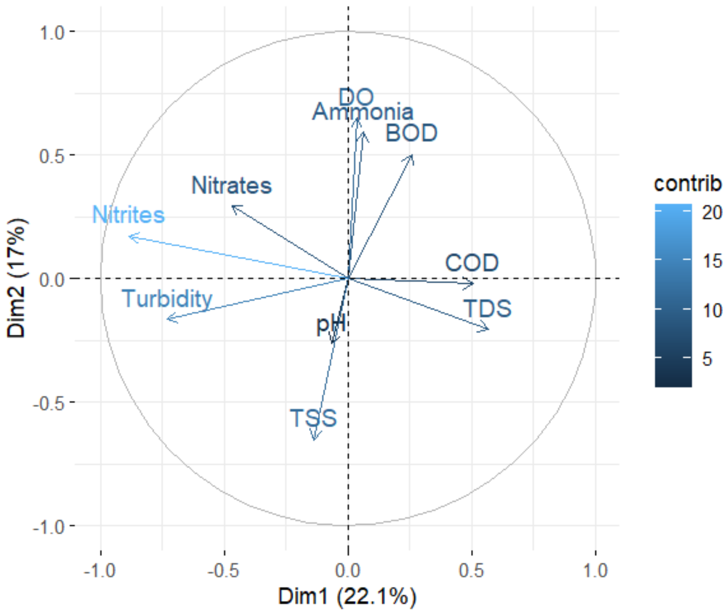

Figure 2. The contribution by parameters for weightage

Table 7. Assigned weightages for each parameter

Parameter	Assigned weightage by PCA
pH	0.0173699
TDS	0.1528968
Turbidity	0.1966145
DO	0.0095867
COD	0.1359924
BOD	0.0698287
Nitrate	0.1263624
Nitrite	0.2375299
Ammonia	0.0165927
TSS	0.0372260
	1.0000000

In order to develop the WQI classification, the distribution of the obtained WQI values for each location were analyzed and the natural breaks were determined. Then the quintiles were used to define the thresholds (Table 8). The minimum quintile was assinged for the lowest obtained WQI value and the maximum quintile was assigned for the highest WQI value. After identifying the WQI per each quantile, the WQI classification was developed (Table 9).

Table 8. Quintiles, WQI and interpretation

Quintiles		WQI	Interpretation
0%	Minimum	-70.65	Same as the minimum value.
20%	1st Quintile	44.45	The WQI value below which 20% of the data fall.
40%	2nd Quintile	60.95	The WQI value below which 40% of the data fall.
60%	3rd Quintile	67.27	The WQI value below which 60% of the data fall.
80%	4th Quintile	77.14	The WQI value below which 80% of the data fall.
100%	Maximum	80.29	Same as the maximum value.

Table 9. WQI Classification

WQI Classification	WQI value
Very Poor	WQI < 44.45
Poor	44.45 ≤ WQI < 60.95
Moderate	60.95 ≤ WQI < 67.27
Good	67.27 ≤ WQI < 77.14
Excellent	WQI ≥ 77.14

The minimum WQI was received for the Location 1 of Mannar (Achchankulam) and the maximum was received for the Location 1 of Kilinochchi (Chundikulam). The heat map shows the WQI for all the locations selected for the study (Figure 3).

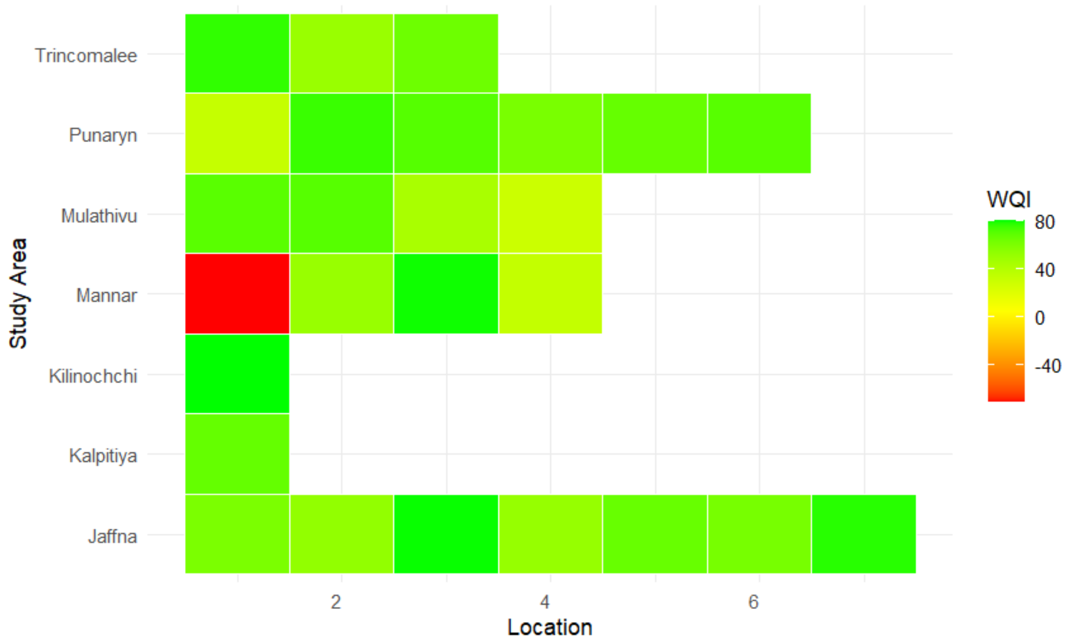

Figure 3. Graphically representation of WQI

It can be observed that the water quality at most of the chosen locations is classified as good or excellent based on the WQI, with the exception of Location 1 in Mannar. The proximity of Achchankulam to the river mouth, which carries a high nutrient load from terrestrial sources to the coastal waters, could explain the poor water quality observed there in terms of WQI.

Conclusions

This baseline study with special reference to the coastal water quality of Northern and Eastern coastal zones provides essential insights into the present status of these vital coastal ecosystems of Sri Lanka. The results reveal that the water quality parameters including DO, Nitrate, Nitrite, and Ammonia assessed from all the locations have not exceeded the standards according to the ASEAN guidelines for coastal waters. However, our study findings highlight significant variations in water quality across these locations for a few parameters including TDS, COD, and Nitrates, mainly influenced by anthropogenic factors such as industrial and fisheries activities. Further, according to the WQI applied in this study, certain locations in Mannar, Jaffna, and Pooneryn were identified with very poor water quality as the study locations are notably associated with fisheries landing sites. The collected data serves as a critical reference point for future conservation efforts and environmental monitoring activities, and this will inevitably enable policymakers and conservationists to prioritize conservation efforts accordingly, the observed trends and variations found in locations emphasize the importance of integrating site-specific pollution control management efforts to safeguard the coastal and marine environment of these selected locations. Moreover, this study underscores the need for more continued and enhanced monitoring activities where the coastal zones are experiencing severe impacts due to anthropogenic activities. To ensure the long-term sustainability of these coastal zones to reap the economic, social, and environmental benefits for the island, this study recommends increasing collaborative efforts both from government, nongovernment, and local coastal communities.

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Ethical approval

The author declares that this study complies with research and publication ethics.

Informed consent

Not available

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this paper.

Data availability statement

The authors declare that data are available from authors upon reasonable request. In case of unavailable data due to conditionals of funding organizations, etc., a clear explanation should be given.

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Author contribution

Jayawardena, N.K.R.N: Writing original draft, Conceptualization, Investigation, Data curation, Software, Formal analysis, Thirukeswaran, S.: Methodology, Funding acquisition, Writing original draft, Weerasekara, K.A.W.S: Supervision, Validation, Visualization, Project administration, Resources, Review, Editing

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