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SPATIOTEMPORAL ANALYSIS OF WATER QUALITY VARIATION IN WETLANDS: A CASE STUDY OF THE COLOMBO METROPOLITAN AREA.

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ABSTRACT

Water quality is defined by its physical, chemical, and biological parameters per established standards for its various uses. This study primarily focused on analyzing temporal and spatial variations of water quality parameters in the Colombo Metropolitan Wetlands. Primary and secondary data were used for this study. SPSS and ArcGIS Pro software were used for data analysis. Water samples were collected from 18 water sampling locations for this research. Physical and chemical parameters such as pH value, Ammonia Concentration, Dissolved Oxygen (DO), Phosphate Concentration, Turbidity, and Temperature were used to assess water quality. The parameters used in this study were compared between 2012 and 2022 to assess whether they exhibited a declining trend. By 2022, the pH value has marginally increased in comparison to 2012. When considering Colombo Metropolitan wetlands, the ammonia levels were lower in 2022 that in 2012. In 2012, several locations had dissolved oxygen concentrations within the recommended limit of 6 mg/L. However, by 2022, multiple analyzed water sources showed dissolved oxygen levels falling below the acceptable threshold. A comparison of phosphate concentrations between 2012 and 2022 indicated slight fluctuations. Turbidity levels decreased by 2022 compared to 2012. Although the temperature showed minor variations, its overall value remained consistent between the two years.

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1.INTRODUCTION

Wetland ecosystems provide significant benefits in water quality management. They play a crucial role in sustaining biodiversity, regulating water cycles, controlling floods, and supplying essential nutrients are needed for aquatic plants and animals (Gell et al., 2023). Additionally, wetlands function as natural water filters, removing impurities, reducing water pollution, and maintaining a balanced nutrient cycle. Their importance is paramount in both urban and rural settings, as they contribute significantly to aquatic ecosystem health and sustainable water resource management.

As the world grapples with the adverse effects of industrialization and urbanization, maintaining water quality has become an increasingly complex challenge. A significant factor contributing to water quality degradation is the influx of pollutants into water bodies, often exacerbated by rapid urban expansion and industrial activities (UNESCO, 2020). This issue is particularly acute in urban areas, where growing populations, industrial expansion, and infrastructure development have heightened water demand and stress on freshwater sources (UN-Water Annual Report [WWAP], 2021). Consequently, industrialization and urbanization have severely contaminated rivers, lakes, and wetlands, which were once pristine sources of drinking water, leading to serious environmental and public health concerns (World Health Organization [WHO], 2011).

The Industrial Revolution of the late 18th century marked a critical turning point in the relationship between urbanization, industrial activities, and water resource use. In the United Kingdom and other Western European nations, water became an essential component of industrial production, leading to significant environmental consequences. Factories frequently discharged solid waste and untreated wastewater into local water bodies, drastically increasing global water pollution levels (Arcy et al., 2017). As industrialization expanded worldwide, this harmful practice became widespread, leading to long-lasting environmental challenges.

Industrial activities have had a profound impact on water quality. The infiltration of industrial waste into groundwater, combined with agricultural runoff and domestic wastewater, has been a leading cause of water pollution in both rural and urban regions. Agricultural practices, particularly the use of pesticides, herbicides, and fertilizers, contribute to pollution by introducing harmful chemicals into surface and groundwater systems. This has led to severe aquatic ecosystem degradation, threatening biodiversity and overall ecosystem health (Ann et al., 2021). Similarly, oceanic water quality has been adversely affected by industrial waste discharge, naval activities, and nuclear testing. These pollutants spread across vast marine areas, affecting marine life and disrupting global water cycles.

Extensive research on water quality is being conducted worldwide, particularly in countries such as the United States, India, China, and the United Kingdom. Studies have identified industrialization, urbanization, agricultural runoff, and domestic wastewater discharge as key factors contributing to water quality deterioration (Alikhani et al., 2021). Furthermore, research highlights the complex relationship between land use patterns, urban expansion, and water resource quality. The growth of the urban populations, combined with unsustainable waste management practices, have exacerbated natural water source pollution, making clean water access more challenging.

Water quality degradation is less visible in rural areas due to lower population densities and the absence of large-scale industrial activities. However, in urban environments, wastewater discharge into wetland ecosystems significantly impacts water quality. Wetlands, which naturally purify water and support diverse species, are heavily polluted due to the disposal of urban solid waste and wastewater. Industrial discharge, sewage, and agricultural runoff have further degraded urban wetlands, reducing their ability to filter harmful substances and maintain ecological balance (Hettiarachchi et al., 2011).

In Sri Lanka, water quality research focuses on both surface and groundwater resources. The Central Environmental Authority (CEA) and the Sri Lanka Land Development Corporation (SLLDC) play key roles in monitoring and assessing urban water quality, particularly in the Colombo district. Their studies emphasize the effects of urbanization and industrialization on water quality in rivers, lakes, and wetlands within the Colombo metropolitan area (Keshani, 2022).

Colombo, Sri Lanka’s commercial capital, is built on a wetland ecosystem and has experienced extensive urban development. Unlike rural regions, where water sources remain relatively undisturbed, Colombo's wetlands have suffered significant water quality deterioration due to rapid urban expansion and increased industrial and domestic wastewater discharge. As the country’s primary urban hub, Colombo has faced immense pressure on its water resources due to rising population density and industrial activities. Consequently, the water quality of the city's rivers, canals, and wetlands has progressively declined (International Water Management Institute [IWMI], 2022). The Colombo metropolitan area comprises 37 natural and artificial canal systems, many of which now function as urban wastewater disposal outlets.

The Kelani River and Diyawanna Oya are the primary natural watercourses in Colombo. However, these water bodies have been significantly polluted due to the discharge of sewage, industrial waste, and agricultural runoff. This contamination threatens not only surface water quality but also aquatic biodiversity. Colombo's urban wetlands, which once played a crucial role in water purification and flood control, have been severely impacted by the unchecked disposal of waste. The continuous dumping of pollutants has been exacerbated by rapid urbanization and the rising demand for water resources (Nishanthi & Ramachandran, 2021).

The declining water quality in Colombo's urban wetlands poses serious implications for public health, environmental sustainability, and overall quality of life. Contaminated water sources contribute to the spread of waterborne diseases such as cholera and dysentery, particularly in the areas with poor sanitation infrastructure. Polluted water bodies also cause long-term environmental damage, disrupting aquatic ecosystems and threatening biodiversity. As wetland ecosystems deteriorate, their ability to regulate water quality diminishes, affecting both human populations and wildlife.

The spatial and temporal variations in water quality within Colombo's wetlands are notable. These fluctuations are influenced by multiple factors, including seasonal rainfall patterns, temperature changes, and varying human activities. For example, during the monsoon season, heavy rainfall washes pollutants from urban areas into nearby water bodies, increasing contamination levels. In contrast, during dry periods, reduced water levels concentrate pollutants, further diminishing water quality (Hettiarachchi et al., 2011).

This study aims to comprehensively assess the temporal and spatial variations in water quality parameters within Colombo's urban wetlands and assess their environmental impacts.

2. Literature review

Water is one of the most abundant natural resources on the Earth, covering approximately 70% of the planet's surface in various forms, including solid, liquid, and gas. It enters the environment through precipitation processes such as rain, hail, frost, and ice, eventually accumulating in lakes, rivers, marshes, oceans, and groundwater reserves under different climatic conditions(Zhang, X.-H. (2014). These water bodies play a crucial role in supporting both environmental and human systems, serving as essential resources for agriculture, industry, and domestic use.

Water quality is determined by the physical, chemical, and biological parameters that define its suitability for various applications. Any alteration in these parameters can have adverse effects on human health and the environment (CEA, 2023). On a global scale, water consumption is distributed as follows: 42% for agriculture, 39% for hydroelectric power generation, 11% for commercial and residential use, and 8% for manufacturing and industrial processes (Food and Agriculture Organization [FAO], 2021). While water use is essential for sustaining human activities, excessive and improper usage can lead to significant environmental degradation, particularly affecting surface water, groundwater, and marine ecosystems.

Water quality assessment involves evaluating the biological, chemical, and physical characteristics of different water sources, including surface, groundwater, and marine waters. Surface water quality refers to the monitoring of fresh and brackish water bodies such as rivers, canals, reservoirs, lakes, ponds, and marshes (Chapra, 2014). Ensuring drinking water quality is a global public health priority, as water contamination poses severe health risks. According to WHO, each country maintains specific water quality standards to mitigate potential health hazards associated with contaminated water (WHO, 2011). Additionally, groundwater quality varies due to the presence of biological, chemical, and physical contaminants. Similarly, human activities have a direct and indirect impact on marine water quality by introducing pollutants into the ecosystem.

Declining water quality has led to numerous environmental and health concerns worldwide. The WHO estimates that approximately 80% of diseases are waterborne, with water pollution contributing to 3.1% of global fatalities (United Nations Environment Programme [UNEP], 2016). Heavy metal contamination in rivers, particularly in Asia, Africa, and Latin America, poses significant health risks to millions of rural inhabitants. The discharge of industrial waste, sewage, and agricultural runoff into water bodies exacerbates these challenges, contributing to the spread of waterborne diseases such as cholera and dysentery. According to WHO estimates, contaminated drinking water accounts for 58% of all deaths in low- and middle-income countries (Khan et al., 2022).

One of the significant environmental issues related to declining water quality is eutrophication, a condition caused by excessive nutrient loading—primarily phosphorus and nitrogen—into water bodies. This leads to algal blooms that block sunlight penetration, disrupting aquatic ecosystems and reducing oxygen levels. The high phosphate content in aquaculture feed, particularly for catfish species, further contributes to eutrophication, resulting in hypoxic conditions that threaten marine and freshwater life. Additionally, cyanobacterial blooms release toxins that further degrade water quality and pose health risks to both humans and aquatic organisms (UNEP, 2016).

Water pollution arises from both natural and human-induced factors. Natural contributors include floods, droughts, and animal waste, whereas human activities such as industrial discharge, agricultural runoff, and improper waste disposal significantly exacerbate contamination levels. For instance, flood events can cause the mixing of wastewater with natural water bodies, leading to the spread of pathogens and waterborne diseases. A study conducted by Margaret Mulholland, a biological oceanographer at Old Dominion University, and Alfonso Macias Tapia examined the effects of tidal flooding through the research initiative *Measure the Muck*. The study focused on the Lafayette River near Norfolk, Virginia, collecting water samples to assess pollution levels and their impact on local ecosystems.

Pesticide usage has been particularly prevalent in upper-middle-income countries such as Argentina, Brazil, South Africa, and Uruguay, as well as in lower-middle-income countries like Cameroon, Nicaragua, Pakistan, and Ukraine. Additionally, household waste, decomposable organic materials, and non-decomposable plastics often enter water sources, further degrading water quality. In 2015, approximately 41% of household wastewater worldwide was treated and recycled, while the remaining 11% was discharged directly into natural water bodies without proper treatment (UNEP, 2016). In many developing countries, inadequate sanitation infrastructure results in the informal disposal of sewage into rivers and lakes. This issue is especially prevalent in urban slums, where improper drainage systems lead to the accumulation of human waste, discarded pharmaceuticals, sanitary products, and food waste in water sources. As a result, many low- and middle-income countries face significant financial and logistical challenges in managing water pollution, as untreated wastewater continues to contaminate essential freshwater and marine resources (UNEP, 2016). Addressing these challenges requires the implementation of sustainable water management policies, improved sanitation infrastructure, and greater public awareness. Effective wastewater treatment, pollution control measures, and conservation efforts are crucial to ensuring the long-term sustainability of global water resources.

3. MATERIALS AND METHODS

To achieve the objectives of this study, which analyzes variations in water quality through temporal and spatial data analysis approaches, the following methods were employed. The Sri Lanka Land Development Corporation provided data related to water quality of water sources in the Colombo metropolitan region from the years 2012 and 2022 for this research. Additionally, to identify the pattern of population distribution in the metropolitan region of Colombo was collected by the Department of Census and Statistics. This research, conducted using primary and secondary data, falls under the category of quantitative research. To determine how changes in water quality have led to algal blooms in canals within the Colombo metropolitan wetlands, primary data was used. Images documenting the growth of algae in water bodies were acquired.

Water quality is assessed using various chemical and physical parameters, including pH, Ammonia, Dissolved Oxygen (DO), Phosphate, Turbidity, and Temperature. Annual changes for each parameter over the two years are illustrated through graphs generated with SPSS software, based on data from all variables collected for 2012 and 2022. Maps were created using the Spatial Analyst Tool of Interpolation; Invers Distance Waited (IDW) with ArcGIS Pro 3.2.3 software to identify changes in water quality between 2012 and 2022.

3.1 pH Value

pH is a measurement of the level of basic or acidic water. The range is from 0 to 14, with 7 being neutral. A pH value of less than 7 indicates acidity, whereas a pH value greater than 7 indicates base. The pH level of water is an essential indicator of water quality (US EPA, 2020).

3.2 Ammonia Concentration

In the context of water quality, ammonia is a nitrogen - based compound that can be toxic to aquatic life, especially at high concentrations. It is frequently regarded as a key marker of pollution from sources such as fertilizer runoff or animal waste, and its toxicity is highly dependent on the pH level of the water, with the un-ionized form (NH_3) being the most harmful to aquatic life (Hossain et al., 1970).

3.3 Dissolved oxygen (DO)

Dissolved Oxygen (DO) is an important indicator of water quality. It is critical to the survival of fish and other aquatic organisms. Winds oxygenate surface water, causing oxygen to dissolve. Aquatic plant photosynthesis also releases oxygen into the water (Omer, 2019).

3.4 Phosphate Concentration

In terms of water quality, "phosphate" refers to the amount of phosphorus present in water, which, when in excess, can significantly degrade water quality by causing excessive algae growth due to its role as a key nutrient for aquatic plants, resulting in issues such as low dissolved oxygen levels and potential fish kills; essentially, high phosphate levels contribute to a phenomenon known as eutrophication (Badamasi et al., 2019).

3.5 Turbidity

The term "turbidity of water quality" refers to a measurement of the water clarity, indicating the amount of suspended particles like silt, algae, or clay that scatter light passing through the water, making it appear cloudy or murky; A higher turbidity level means that the water is less clear and contains more suspended particles, which can be a significant indicator of water quality issues (Badamasi et al., 2019).

3.6 Temperature

"Water quality temperature" refers to a water body's measured temperature, which is an important factor in determining its overall quality as it directly impacts the solubility of dissolved oxygen, the rate of chemical reactions, and the types of aquatic life that can thrive within it; in essence, warmer water holds less dissolved oxygen and can support different organisms than colder water (Omer, 2019).

3.7 Study Area

In this study, the Colombo Metropolitan Wetlands area was selected as the focus of investigation. The Western Province, which has relatively high levels of development compared to other cities, acts as Sri Lanka's primary trade center. Furthermore, Colombo is the city in Sri Lanka with the highest concentration of wetlands Nishanthi & Ramachandran (2021). One can identify Colombo as a city built upon wetland regions. The wetlands of Colombo are framed by a wetland region. This area can be classified as an urban wetland Urban Development Authority Sri Lanka (2019).

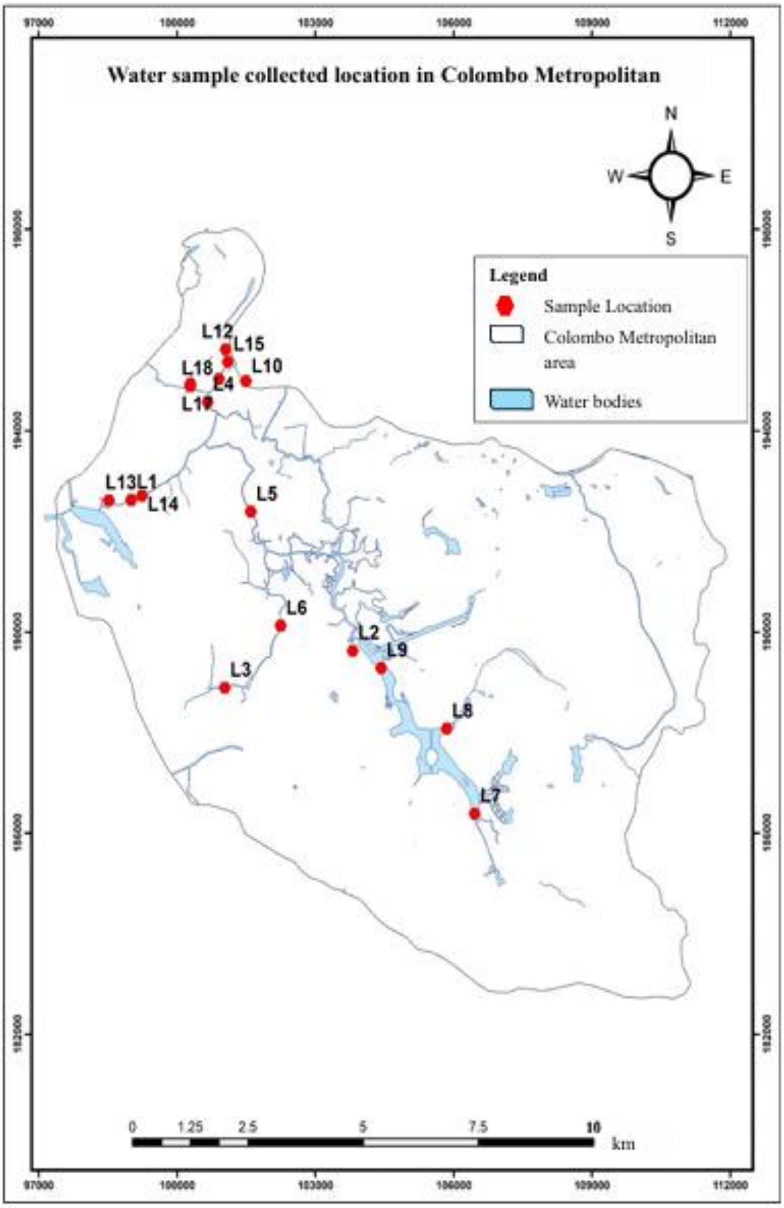


Figure 1: Water sample collected stations map

Source: Sri Lanka Land Development corporations,2012

A significant amount of pollution in the canals surrounding Colombo has caused a decline in water quality. Consequently, the quality of the water has deteriorated considerably. The city's population continues to expand, and many detrimental effects are already being observed.

The water area of Colombo covers 7 km^2 and includes 3 km of adjacent coastline. A canal system of 53 km^2 and 0.78 km^2 of Beira Lake extend throughout the area Nishanthi & Ramachandran (2021). The Colombo Metropolitan area originates from Honblend, Honblend biotite, biotite gneiss, and granitic rocks found in the highland complex; meanwhile, Sri Lanka consists of Precambrian, Miocene, and Quaternary rocks. The Colombo metropolitan area is situated in the climate zone known as Tropical Rain Forest (Af). The minimum temperature is about 27°C, with an average temperature of approximately 29°C. On average, about 2500 mm of precipitation falls annually (Urban Development Authority Sri Lanka, 2019).

Table 1 : Water sampling locations

Location number	**Location name**	**X**	**Y**
L1	End point of St. Sebestian canal Outlet to Beira Lake	99004	192621
L2	Bridge on Kotte north canal	103812	189624
L3	Railway bridge on Torrington canal	101037	188889
L4	Weras Ganga on Borupana Road ferry crossing	103262	179920
L5	St.Sebestian canal bridge near Ingurukade junction	100662	194568
L6	Dematagoda canal, Kolonnawa bridge near the Petroleum Corporation	101600	192387
L7	Mahawatte canal, Kotte Road bridge, Rajagiriya	102247	190122
L8	Station No.01: Diyawanna Oya, kimbulawala Madiwela	106457	186384
L9	Station No.02 : Diyawanna Oya, Battaramulla south Pelawatte	105851	188073
L10	Station No.03 : Diyawanna Oya, Battaramulla north Diyawanna Oya outlet	104428	189281

L11	Kelaniya river close to new bridge upper stream to confluence of st.sebestian Canal	101495	194984
L12	Sebastian Canal north lock gate	100912	195027
L13	Kelani River close to Victoria Bridge downstream confluence of st.sebestian Canal	101056	195613
L14	Beira Lake just behind Pettah private bus stand	98520	192612
L15	St. Sebastian canal about 200m downstream from location no.02	99241	192707
L16	St.sebestian canal (north) outfall to kelani river	101100	195366
L17	Bloemendel, Branch earthen drain coming through garbage pile	100289	194931
L18	Bloemendel, Canal at the confluence of earthen drain of 27	100288	194885

Source: Sri Lanka Land Development Corporation, 2012.

4.RESULTS AND DISCUSSION

To assess water quality in the years of 2012 and 2022, the annual mean values of monthly data collected throughout each year were used to identify the nature of annual variations in different parameters. The analysis focused on both physical and chemical parameters, including pH value, ammonia concentration, dissolved oxygen in water, phosphate levels, turbidity, and temperature.

4.1 Temporal Analysis of Water Quality in Colombo Metropolitan Wetlands

4.1.1. pH Value

Figure 2. Among the 18 sampled water sources, the highest annual mean pH value recorded in 2012 was 7.16 at location L4 (near Verasgana Borupana Road Entrance). In the same year, the lowest annual pH value, 6.17, was observed at location L9 (Diyawanna Oya, Station No. 02: Diyawanna Oya, Battaramulla South Pelawatte). By 2022, the highest recorded annual mean pH value had increased to 7.52 at location L14 (Beira Lake, just behind the Pettah private bus stand), while the lowest annual mean Ph value was 6.72 at location L2 (Bridge on Kotte North Canal). A comparison of the pH ranges between the two years reveals a slight

variation. The difference between the highest annual mean pH values recorded in 2012 and 2022 is 0.36, whereas the difference between the lowest annual mean pH values is 0.55. Additionally, there is a noticeable variation in the pattern of annual pH fluctuations between 2012 and 2022.

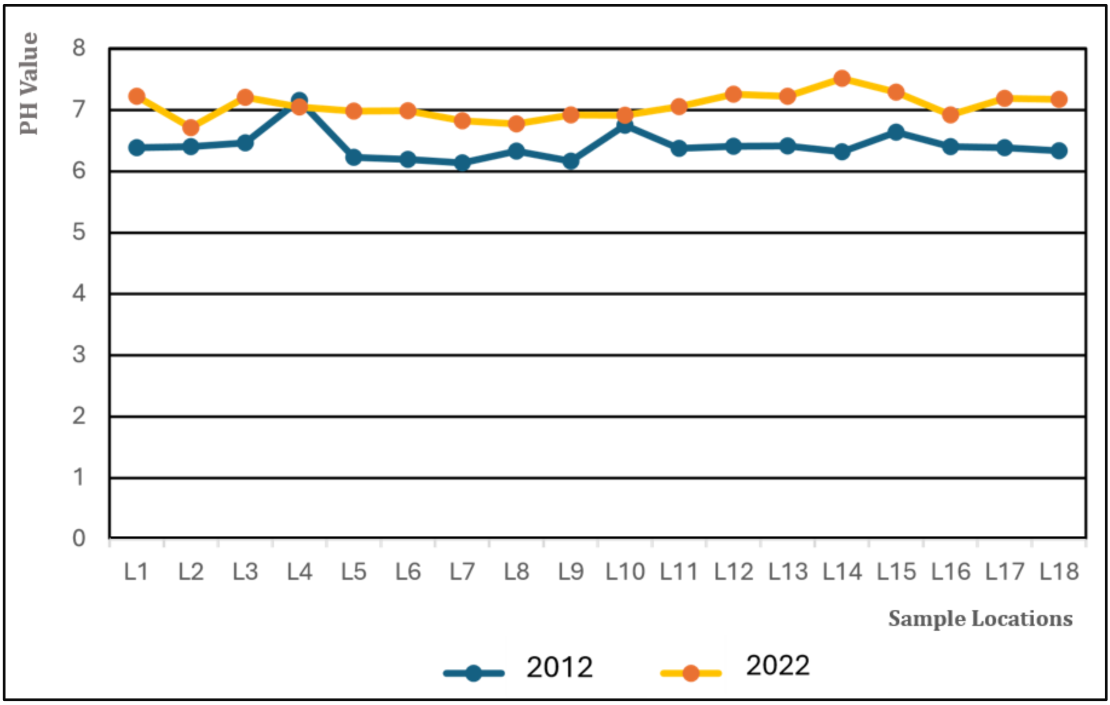


Figure 2: Variation of pH Value in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation, 2023.

4.1.2. Ammonia Concentration

According to the regulations of the Central Environmental Authority, the standard ammonia concentration in surface water should be 1.0 mg/L. Based on this standard, the analysis of the data reveals that the annual mean ammonia concentration in surface water within the Colombo urban wetland zone was higher in 2012 compared to 2022.

Figure 3 shows, in 2012, the highest recorded annual mean ammonia concentration was 40.43 mg/L at location L17 (Bloemendhal Canal, Bloemendel Branch earthen drain passing through a garbage pile). The lowest annual mean ammonia concentration for the same year was 0.90 mg/L at location L1 (St. Sebastian Canal, the endpoint where the canal discharges into Beira Lake). By 2022, the highest recorded annual mean ammonia concentration had decreased to 20.40 mg/L at location L18 (Bloemendhal Canal, at the confluence of the earthen drain of 27). Meanwhile, the lowest annual mean ammonia concentration was recorded at location L11 (Sebastian Canal, near Kelaniya River close to the new bridge upstream of the confluence with St. Sebastian Canal), with a value of 1.16 mg/L. A slight increase of 0.26 mg/L in the lowest annual mean ammonia concentration was observed in 2022 compared to 2012. However, a notable reduction in the highest annual mean ammonia concentration indicates an overall decline in extreme ammonia levels over the decade. Increasing ammonium concentrations accelerate the spread of algae. Furthermore, Fish excrete ammonia, and increased ammonia concentration in water interferes with the excreation process of other aquatic organisums. Factors contributing to the increase in ammonium include industrial activities and rapid urbanization.

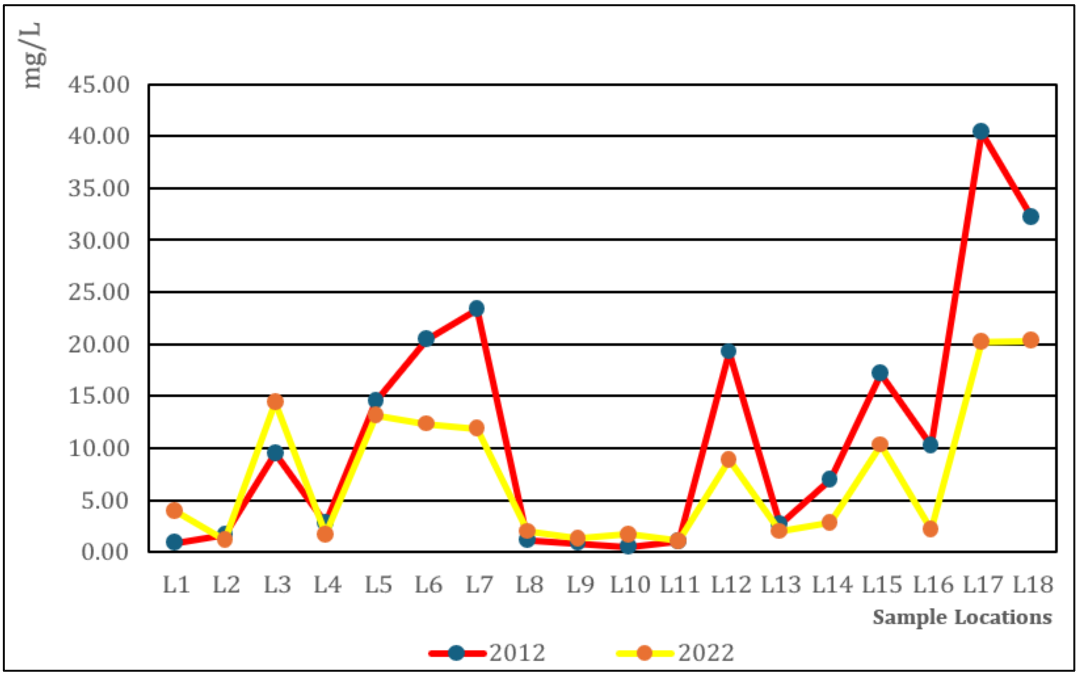


Figure 3: Variation of ammonia concentration in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023.

4.1.3. Dissolved Oxygen

Dissolved oxygen in water is a key parameter that determines the survival of aquatic organisms (Testa & Malkin, 2024). According to the Central Environmental Authority of Sri Lanka, the dissolved oxygen concentration in water should be maintained at 6 mg/L. If the dissolved oxygen concentration drops below 3 mg/L, it adversely affects the survival of aquatic life.

According to Figure 4, in 2012, the lowest annual mean dissolved oxygen concentration was recorded at location L6 (Dematagoda Canal, Kolonnawa Bridge near the Petroleum Corporation) with a value of 1 mg/L. In contrast, the highest dissolved oxygen concentration that year was observed at location L14 (Beira Lake, just behind the Pettah private bus stand) with a value of 14.85 mg/L. This significant variation in surface water oxygen levels between these two locations likely impacted aquatic life in the respective areas.

According to the Central Environmental Authority of Sri Lanka, the concentration of DO in water should be 6mg/L. Whenever this valu falls below 3mg/L, it disrupts the survival of aquatic organisms. The DO value of the water in places like Bira lake, Dematgoda Canals, Bulumandal Canal has decreased significantly. This is due to factors such as the collection of sewage, increased algae growth, and increased water temperature.

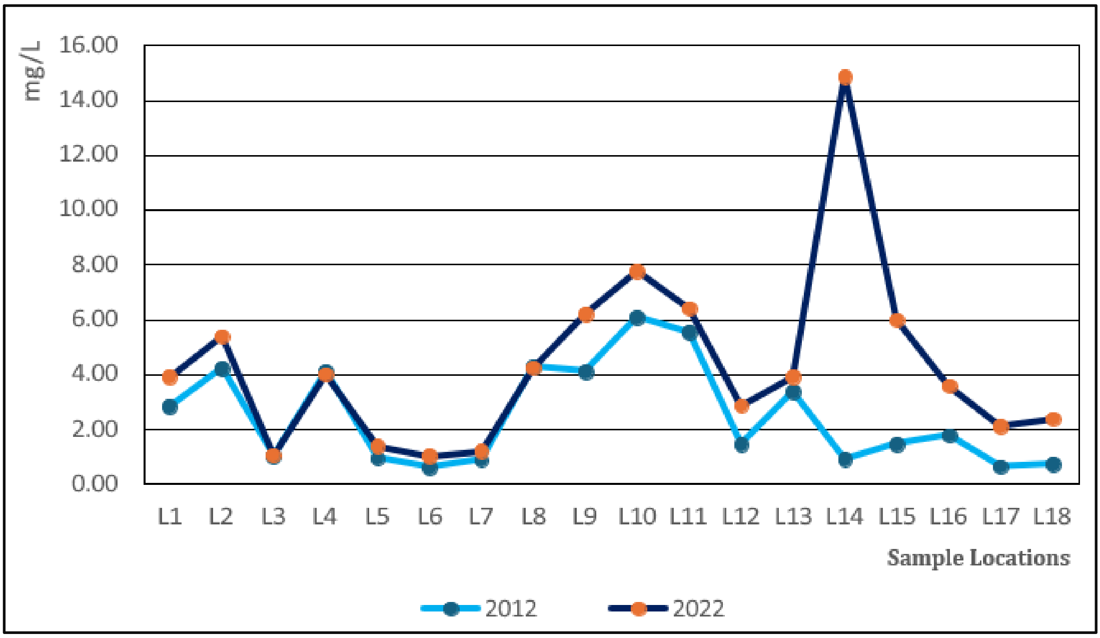


Figure 4: Variation of Dissolved Oxygen in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023.

For maintaining good water quality, dissolved oxygen levels should be above 3 mg/L The gazette – no 2148/20, (2019). However, in 2022, the lowest annual mean dissolved oxygen concentration was again recorded at location L6 (Dematagoda Canal, Kolonnawa Bridge near the Petroleum Corporation), but with a further decline to 0.60 mg/L. This indicates a severe deterioration in water quality, potentially posing a greater risk to aquatic ecosystems.

4.1.4. Phosphate Concentration

The phosphate concentration in water varies due to the presence of industries, urban slum housing, and agricultural activities in urban areas (Wang et al., 2023). The Central Environmental Authority has set the standard phosphate concentration for surface water at 0.7 mg/L.

Figure 5. Focusing on phosphate concentration in surface water within the Colombo urban wetland zone, the lowest annual phosphate concentration in 2012 was recorded at location L10 (Diyawanna Oya, Station No.03: Diyawanna Oya, Battaramulla North Diyawanna Oya Outlet) with a value of 0.22 mg/L. In contrast, the highest phosphate concentration that year was 3.35 mg/L, observed at location L18 (Bloemendhal Canal, at the confluence of the earthen drain of 27)

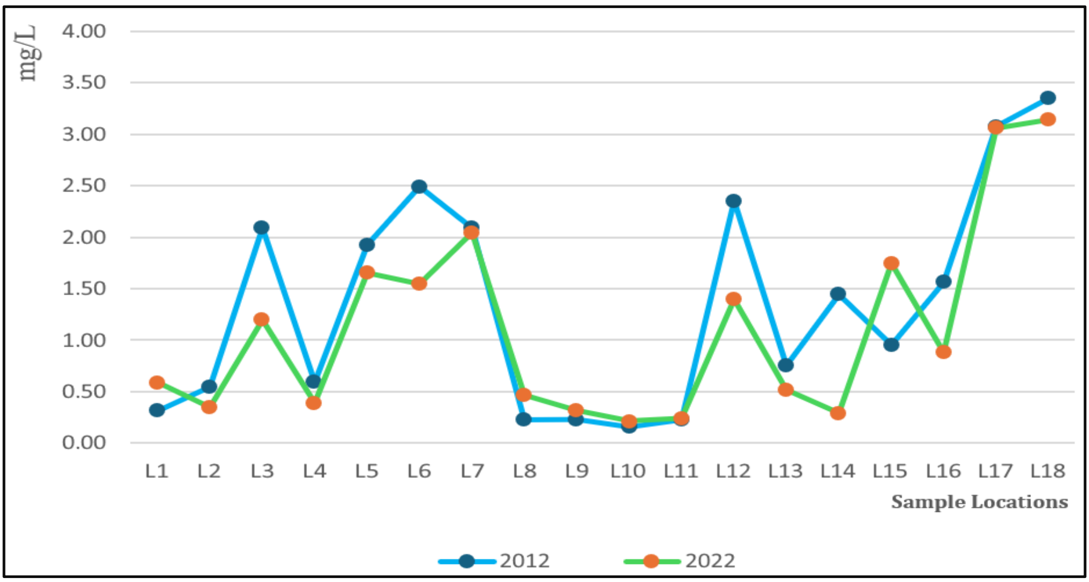


Figure 5 -Variation of Phosphate concentration in 2012 and 2022.

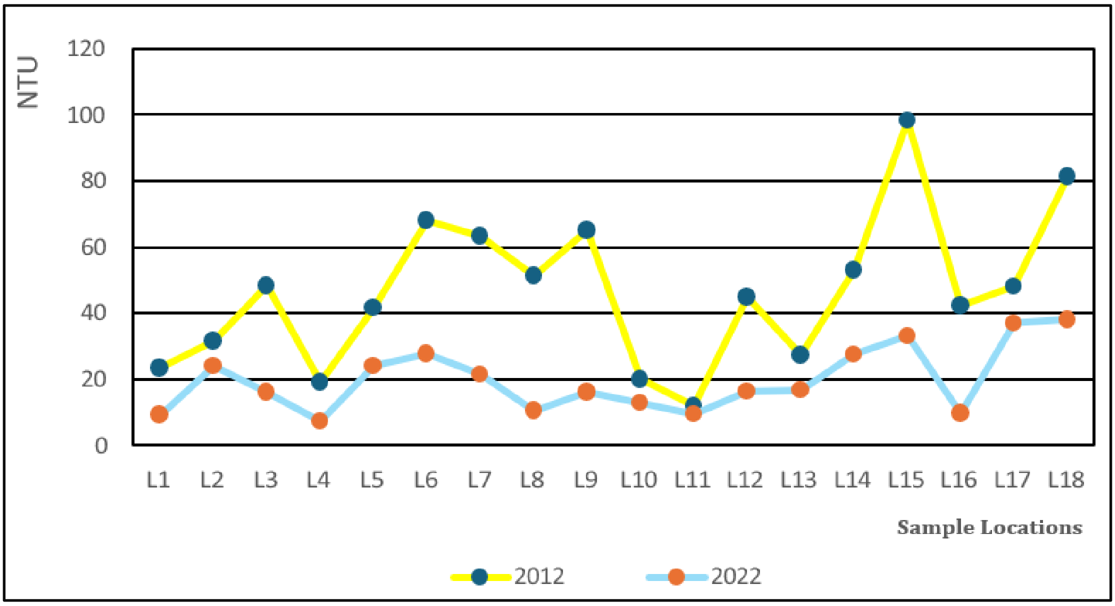
Source - Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation – 2023

In 2022, the lowest annual mean phosphate concentration remained unchanged at location L10 (Diyawanna Oya, Station No.03: Diyawanna Oya, Battaramulla North Diyawanna Oya Outlet) with a value of 0.22 mg/L. However, the highest recorded phosphate concentration for that year was 3.15 mg/L at location L1 (St. Sebastian Canal, the endpoint where St. Sebastian Canal discharges into Beira Lake).

Generally, when phosphate concentrations exceed 0.7 mg/L, algae growth increases (Guo et al., 2023), leading to a decline in dissolved oxygen levels. This, in turn, negatively impacts the survival of aquatic organisms by disrupting the ecological balance of the water system.

4.1.5. Turbidity

Observations of water sources in the Colombo urban wetland zone indicate that turbidity levels remain poor across all monitored water sources. According to the Central Environmental Authority, the turbidity level in water should be maintained at 5 NTU.



Figer 6 -Variation of turbidity in 2012 and 2022

Source - Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation – 2023

Figure 6. When comparing turbidity levels in 2012 and 2022, both years recorded values exceeding 5 NTU. However, a decrease in overall turbidity was observed in 2022 compared to 2012. In 2012, the highest annual mean turbidity was recorded at location L18 (Bloemendhal Canal, at the confluence of the earthen drain of 27) with a value of 81.50 NTU, while the lowest turbidity was recorded at location L11 (Diyawanna Oya) with a value of 12.08 NTU.

By 2022, the highest annual mean turbidity was again observed at location L18 (Bloemendhal Canal), but with a reduced value of 38.28 NTU. The lowest annual mean turbidity in 2022 was recorded at location L4 (Torrington Canal) with a value of 7.52 NTU. This indicates an overall decline in turbidity levels in 2022 compared to 2012. The difference between the highest annual mean turbidity levels in 2012 and 2022 is 43.22 NTU, reflecting a significant reduction in turbidity over the decade. The discharge of sewage, industrial easte, municipal waste, and household waste from urban slums into water sources significantly degrades water quality.

4.1.6. Temperature

The temperature of a water body is a crucial factor influencing its chemical and biological characteristics. The recommended water temperature for aquatic life typically ranges from 25°C to 30°C. Exceeding this range can negatively impact aquatic organisms,by oxygen levels and increased stress on ecosystems (Sanz-Latorre et al., 2024).

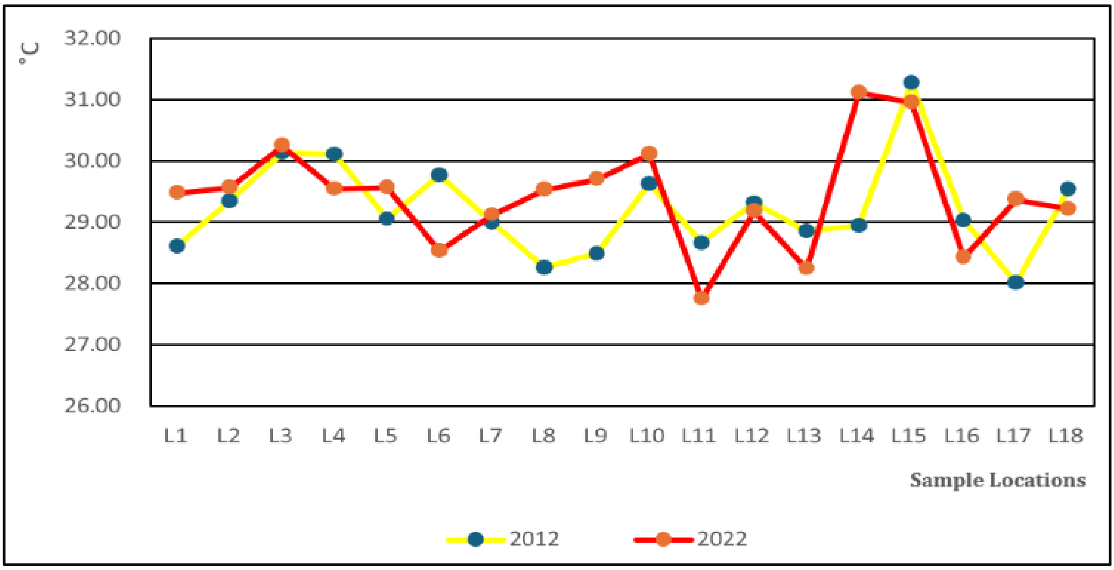


Figure 7 Variation of temperature in 2012 and 2022

Source - Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023

The increase in the concentration of organic and inorganic substances in water has contributed to a rise in retained water temperature. According to Figure 7, water temperatures in the wetlands of the Colombo urban area remain notably high. In 2012, the highest recorded annual average water temperature was 31.28°C, observed near location L15 (St. Sebastian Canal). The lowest annual average temperature that year was 28.02°C, recorded near location L17 (Bloemendhal Canal). By 2022, the highest recorded annual average water temperature was 31.13°C, reported at both location L15 (St. Sebastian Canal, about 200m downstream from location No. 02) and location L14 (Beira Lake). The lowest annual average temperature in 2022 was 27.77°C, recorded near location L11 (St. Sebastian Canal). With increasing water temperatures, a significant rise in algae growth has been observed in the wetlands associated with the Colombo urban area, potentially affecting water quality and aquatic ecosystems.

4.2 Spatial Analysis of Water Quality in Colombo Metropolitan Wetlands

4.2.1 pH Value

The spatial distribution of pH values in the Colombo urban area, ranging from minimum to maximum, is illustrated through a map (Figure, 8). In 2012, pH values remained below 7, indicating an overall acidic nature, though no instances of extreme acidity were recorded.

By 2022, minimum pH values ranged between 6.72 and 6.88 in locations such as Dematagoda Canal, Mahawatta Canal, Station No. 02 – Diyawanna Oya, and Battaramulla. Compared to 2012, these areas exhibited pH values closer to neutral (pH 7), suggesting an improvement in water quality.

In 2012, pH levels fluctuated between 6.26 and 6.62 in areas including Station No. 02 – Diyawanna Oya, Battaramulla, Station No. 03 – Diyawanna Oya, Dematagoda Canal, St. Sebastian Canal (Igurukade Junction), Kelani River (near Victoria Bridge), Torrington Canal, and Bloemendhal Canal (Bloemendhal Branch earthen drain passing through a garbage pile and the confluence of the earthen drain of 27). These values indicated acidic water characteristics in these locations. Additionally, slightly higher pH values ranging from 6.62 to 6.74 were recorded in areas such as St. Sebastian Canal (outlet to Beira Lake), St. Sebastian Canal near Kelani River (about 200m downstream from location No. 02), and Beira Lake, indicating a mildly acidic nature. As of 2022,pH values in water sources such as St. Sebastian Canal (north lock gate), Sebastian Canal near the New Kelani Bridge (Kelani River upstream, close to the confluence of

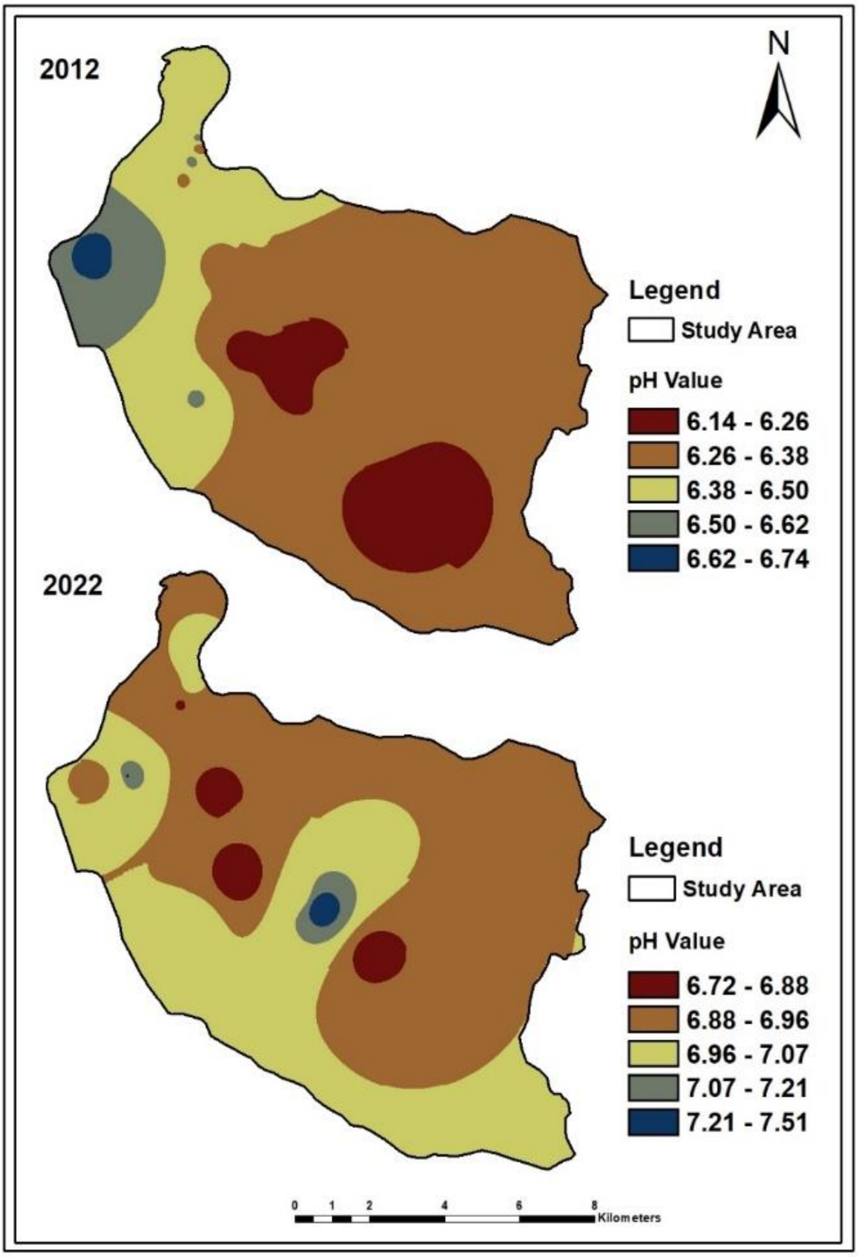


Figure 8: Spatial distribution of pH value in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023

St. Sebastian Canal), Sebastian Canal near Victoria Bridge (Kelani River downstream, near the confluence of St. Sebastian Canal), Beira Lake (just behind Pettah private bus stand), and Torrington Canal (railway bridge on Torrington Canal) were found to be close to neutral (pH 7), with no significant deterioration in water quality. However, an increase in alkalinity was observed in Sebastian Canal and Kotte North Canal, with the maximum recorded pH value reaching 7.51.

This rise in alkalinity in these two water bodies represents an approximately tenfold increase compared to previous levels. Additionally, heavy metal concentrations were notably high in these sources. A comparison of pH values between 2012 and 2022 indicates a transition from acidic to more alkaline conditions in the water bodies of the Colombo urban area, reflecting a significant shift in water chemistry over the decade.

4.2.2. Phosphate Concentration

In 2012, phosphate concentrations were observed in several locations, including the bridge on Kotte North Canal, Station No. 02 – Diyawanna Oya (Kimbulawala, Madiwela), Station No. 03 – Diyawanna Oya (Battaramulla South, Pelawatte), Diyawanna Oya (Battaramulla North, Diyawanna Oya outlet), Beira Lake (just behind Pettah private bus stand), and St. Sebastian Canal (Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal).

By 2022, Beira Lake (just behind Pettah private bus stand) and St. Sebastian Canal (Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal) were newly identified as areas with the lowest phosphate concentrations, ranging from 0.22 mg/L to 0.80 mg/L.

In 2012, phosphate concentrations ranged between 0.78 mg/L and 1.41 mg/L. By 2022, the concentration range was slightly changed, measuring between 0.80 mg/L and 1.38 mg/L across various locations such as Torrington Canal (railway bridge on Torrington Canal), St. Sebastian Canal (north outfall to Kelani River and about 200m downstream from location No. 02), Mahawatta Canal (Kotte Road Bridge, Rajagiriya), Dematagoda Canal (Kolonnawa Bridge near the Petroleum Corporation), and St. Sebastian Canal (near Ingurukade Junction).

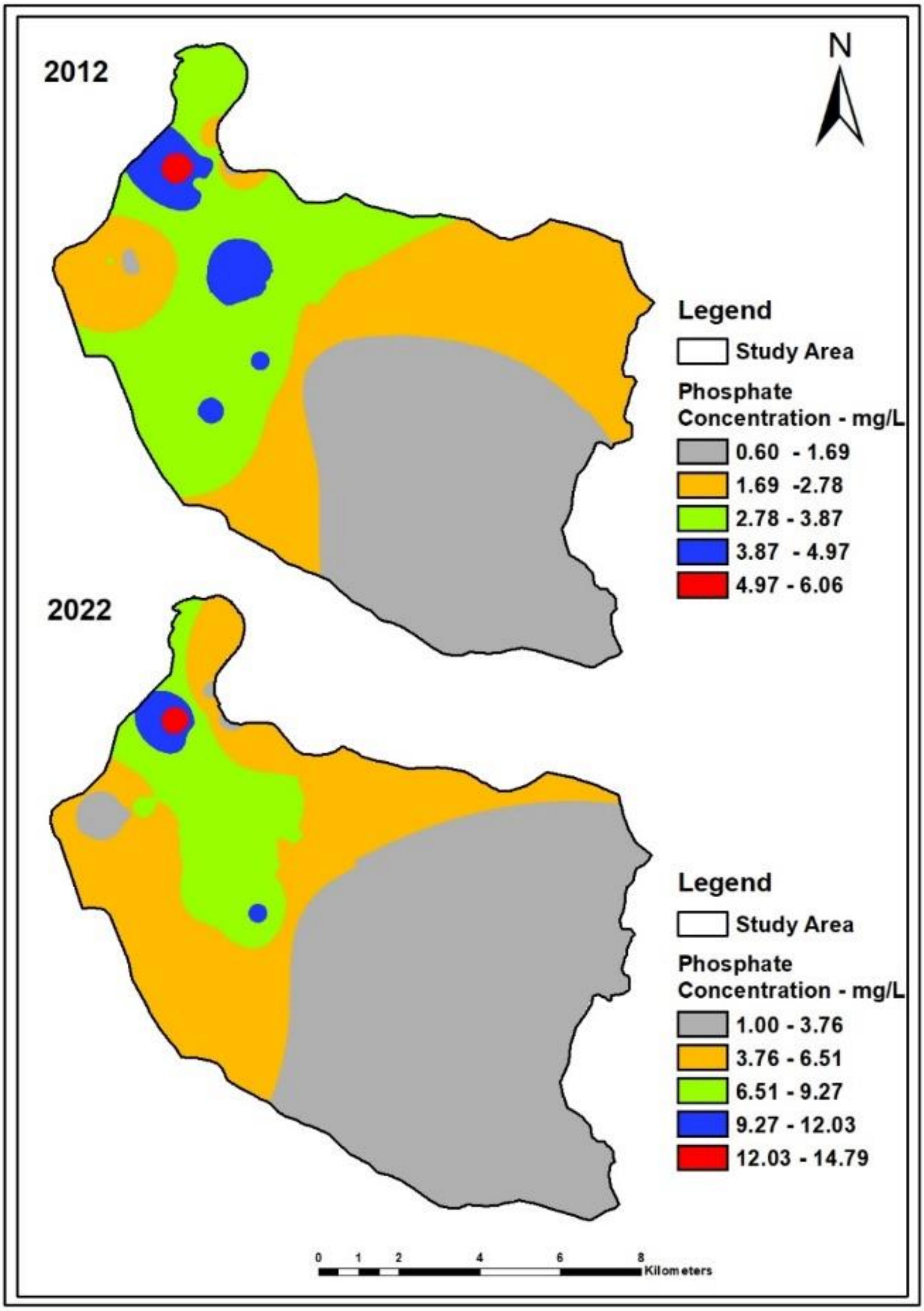


Figure 9: Spatial distribution of phosphate concentration in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023

In both 2012 and 2022, the areas surrounding Bloemendhal Canal (Bloemendhal Branch earthen drain passing through a garbage pile and Bloemendhal Canal at the confluence of the earthen drain of 27) were consistently identified as regions with high phosphate concentrations.

4.2.3. Dissolved Oxygen

Dissolved oxygen levels in water play a crucial role in supporting aquatic life within an ecosystem. Ideally, the oxygen concentration in water should be maintained at around 6 mg/L. In the mapped area, regions with high dissolved oxygen demand are shows in light green, while areas with significantly low dissolved oxygen concentrations are depicted in dark blue.

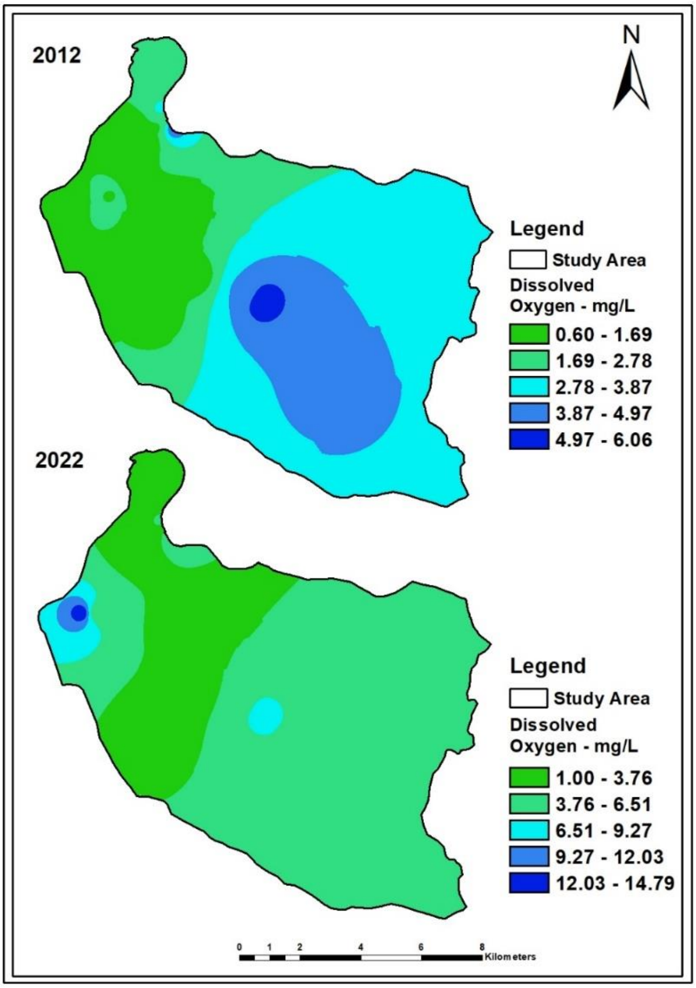


Figure 10: Spatial distribution of dissolved oxygen in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation – 2023

In 2012, Diyawanna Oya (Station No. 03: Diyawanna Oya, Battaramulla North Diyawanna Oya outlet) and the areas surrounding Beira Lake (just behind Pettah private bus stand) exhibited relatively high dissolved oxygen concentrations, ranging from 4.97 mg/L to 6.06 mg/L. By 2022, dissolved oxygen levels in the areas around Beira Lake had significantly increased, reaching a range of 12.03 mg/L to 14.79 mg/L.

In contrast, the lowest dissolved oxygen concentrations in 2012 were recorded in locations such as Beira Lake (just behind Pettah private bus stand), St. Sebastian Canal (Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal), Torrington Canal (railway bridge on Torrington Canal), St. Sebastian Canal – Kelani River (about 200m downstream from location No. 02), Mahawatta Canal (Kotte Road Bridge, Rajagiriya), Dematagoda Canal (Kolonnawa Bridge near the Petroleum Corporation), St. Sebastian Canal (near Ingurukade Junction), and Bloemendhal Canal (Bloemendhal Branch earthen drain passing through a garbage pile).

By 2022, except for these locations, the lowest dissolved oxygen concentration was still observed in the areas surrounding St. Sebastian Canal (north outfall to Kelani River), indicating persistent low oxygen levels in that region.

4.2.4. Turbidity

Focusing on the spatial distribution of turbidity in the Colombo urban area, a decreasing trend in turbidity levels was observed in 2022 compared to 2012.

In 2012, the areas with the lowest turbidity were Diyawanna Oya (Station No. 03: Diyawanna Oya, Battaramulla North Diyawanna Oya outlet), St. Sebastian Canal (Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal), and St. Sebastian Canal (Kelani River, close to Victoria Bridge downstream from the confluence of St. Sebastian Canal). The turbidity values in these areas ranged from 14.77 NTU to 31.40 NTU.

By 2022, turbidity levels had further decreased, ranging from 9.47 NTU to 15.18 NTU. The areas with the lowest turbidity included Diyawanna Oya (Station No. 02: Diyawanna Oya, Battaramulla South, Pelawatte), St. Sebastian Canal (near the lower New Kelani Bridge and Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal), and St. Sebastian Canal (north outfall to Kelani River).

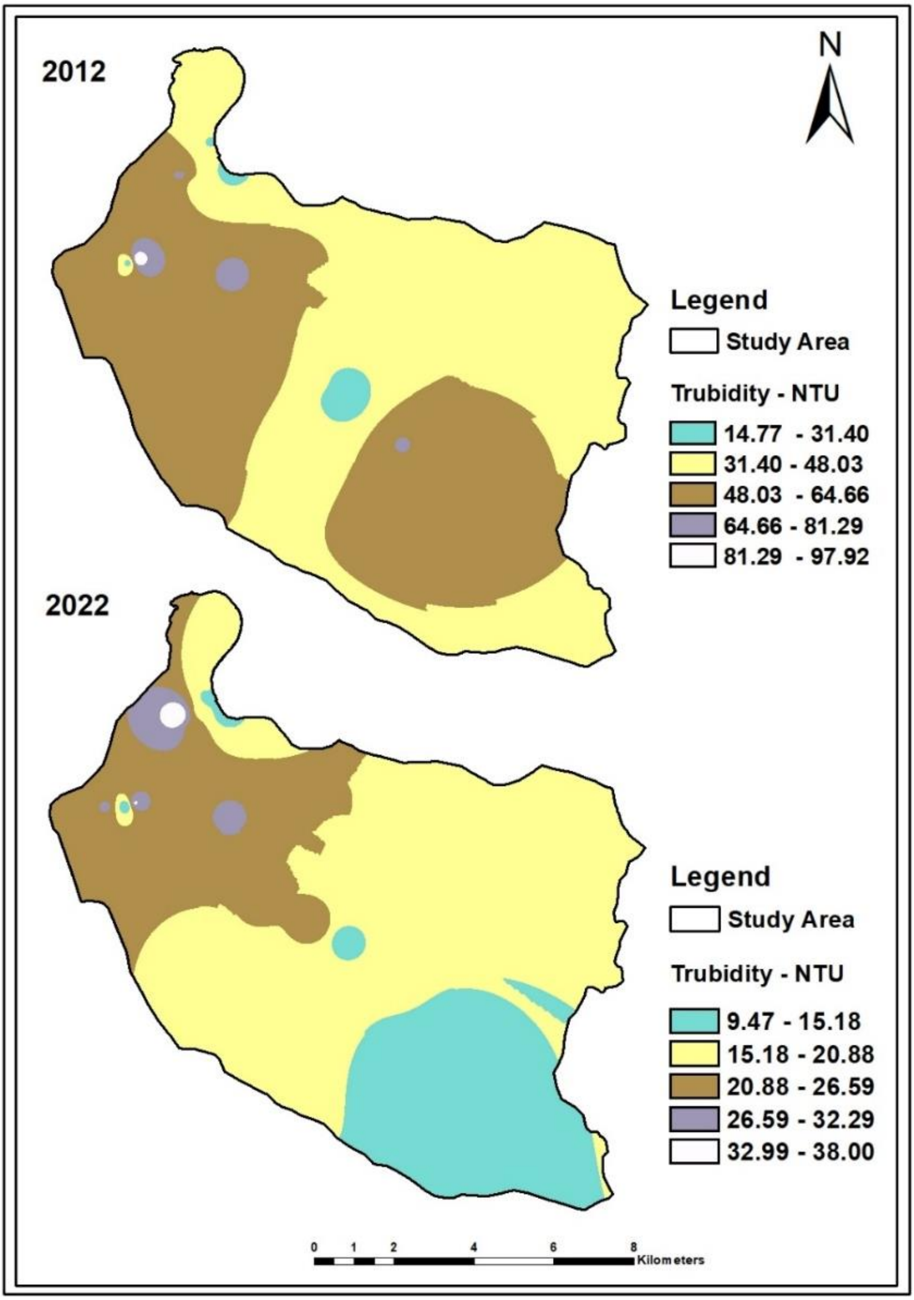


Figure 11: Spatial distribution of turbidity in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation - 2023

By 2022, turbidity levels had further decreased, ranging from 9.47 NTU to 15.18 NTU. The areas with the lowest turbidity included Diyawanna Oya (Station No. 02: Diyawanna Oya, Battaramulla South, Pelawatte), St. Sebastian Canal (near the lower New Kelani Bridge and Kelani River, close to the new bridge upstream from the confluence of St. Sebastian Canal), and St. Sebastian Canal (north outfall to Kelani River).

In 2012, high turbidity values were observed in St. Sebastian Canal (about 200m downstream from location No. 02), whereas in 2022, the highest turbidity levels were recorded in areas surrounding Bloemendhal Canal (Bloemendhal Branch earthen drain passing through a garbage pile).
According to the mapped data, Colombo's urban water bodies had significantly high turbidity levels in 2012, resulting in lower water visibility. By 2022, although turbidity values had decreased compared to 2012, water visibility had not improved significantly, suggesting that other factors may still be affecting water clarity.

4.2.6. Temperature

Temperature is a fundamental physical property of water, influencing various other water quality parameters (Sundaray, 2012). When water temperature exceeds 24°C, dissolved oxygen concentrations tend to decrease, affecting aquatic ecosystems.

In 2012, lower water temperatures were recorded in Diyawanna Oya (Battaramulla North Diyawanna Oya outlet), Diyawanna Oya (Battaramulla South, Pelawatte), and areas surrounding St. Sebastian Canal (north outfall to Kelani River), with values ranging from 28.0°C to 28.6°C. By 2022, water temperatures in the range of 27.8°C to 28.51°C were recorded around St. Sebastian Canal and St. Sebastian Canal near the Kelani River (close to Victoria Bridge, downstream from the confluence of St. Sebastian Canal).

In both 2012 and 2022, water temperatures ranged from 28°C to 30°C in the mapped area, represented by a gradient from light yellow to red. In 2012, the highest water temperatures were observed in Beira Lake (just behind Pettah private bus stand) and Torrington Canal (railway bridge on Torrington Canal). By 2022, elevated temperatures were recorded in areas around Beira Lake, St. Sebastian Canal (about 200m downstream from location No. 02 and at the outlet to Beira Lake), Torrington Canal (railway bridge on Torrington Canal), and Diyawanna Oya (Battaramulla North Diyawanna Oya outlet).

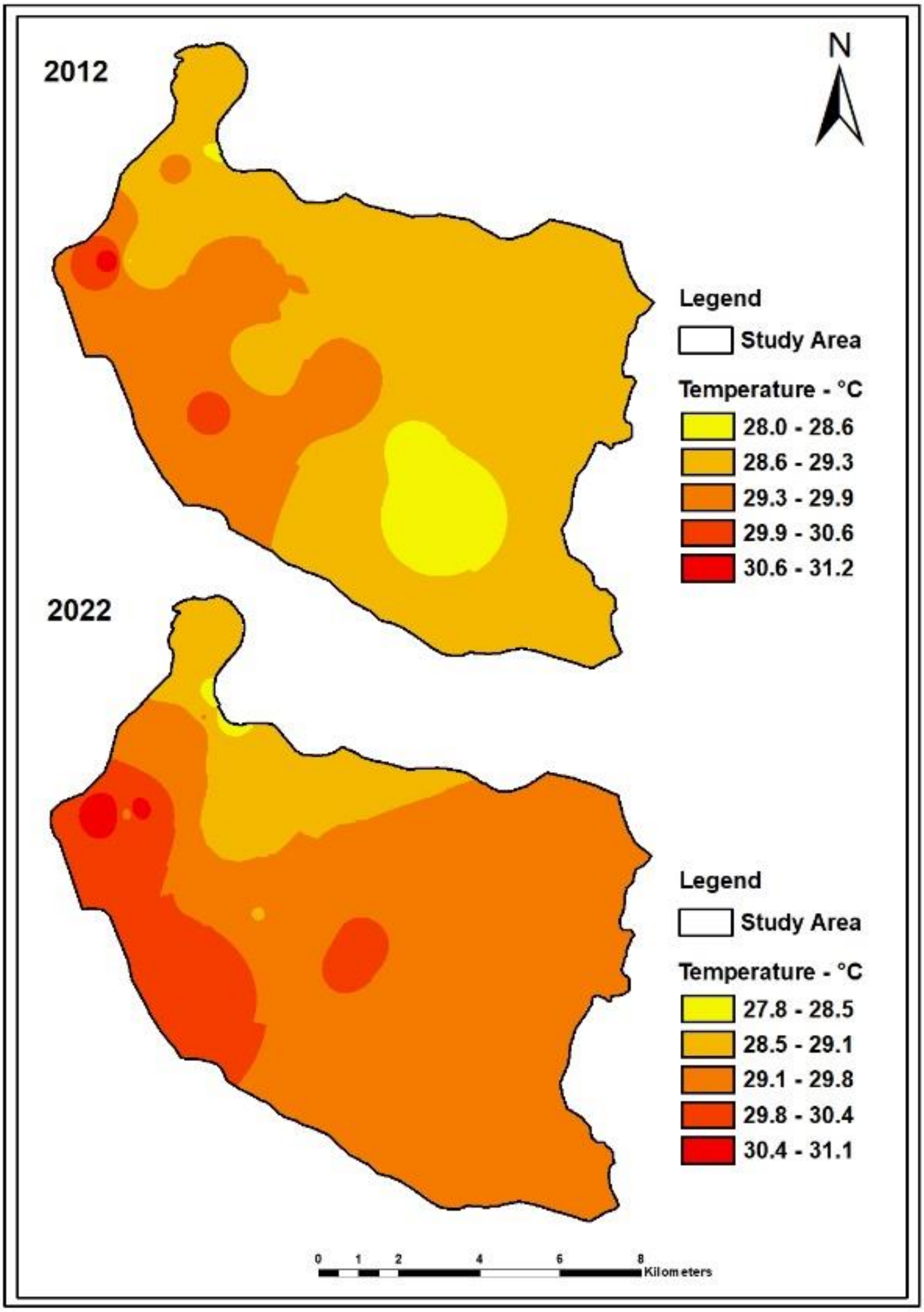


Figure 12: Spatial distribution of temperature in 2012 and 2022

Source: Prepared by the authors (2024), using data from the Sri Lanka Land Development Corporation – 2023

5.Conclusion

The results of this study indicate that the overall water quality in the urban wetlands of the CMA remains significantly degraded, both spatially and temporally. Data analysis confirms that water from all water quality sampled s is unsuitable for consumption or safe use. The primary contributors to water pollution in these wetlands include industrialization, urbanization, and domestic activities. However, a temporary decrease in including pH, ammonia, dissolved oxygen (DO), phosphate, turbidity levels observed in 2022 compared to 2012 suggests that reduced industrial activities during the COVID-19 pandemic may have led to a short-term improvement in water clarity.A notable increase in phosphate concentration and water temperature has resulted in excessive algal growth, particularly in areas surrounding the Diyawanna Oya. Additionally, rising levels of phosphate and temperature have accelerated eutrophication, leading to a significant proliferation of blue-green algae, primarily observed in the Beira Lake region. As the eutrophication process advances, the algae exhibit a red-brown coloration, a condition extensively documented in the Parliament Lake area of Sri Jayewardenepura Kotte.

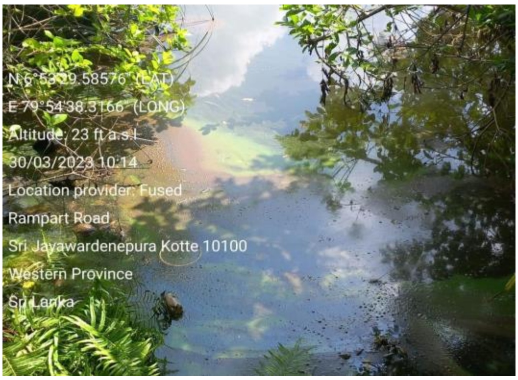


Figure 13: Proliferation of Red-Brown Algal Blooms and Aquatic Vegetation on Water Surface

Source: Field data, 2023

The excessive growth and subsequent decomposition of algae have also increased carbon dioxide emissions in the water, adversely affecting the stability of aquatic ecosystems. Field observations have noted the widespread presence of invasive plant species, such as Japan Jabara and Salvinia, which create dense surface mats that restrict water movement and reduce dissolved oxygen levels.

This situation has markedly intensified the prevalence of hypoxic conditions in urban water bodies. Furthermore, the degradation of water quality has accelerated the breakdown of phytoplankton, converting nitrogen into nitrates and phosphorus into phosphates. This nutrient displacement disrupts aquatic ecosystems, further increasing the risk of hypoxic conditions in Colombo's urban water bodies. The findings of this study provide compelling evidence that without immediate intervention and sustainable water management strategies, the trend toward severe hypoxia will persist, posing a significant threat to urban aquatic ecosystems and biodiversity.

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