Assessment of Water Quality in Different Inlet and Outlet Canals of Kurunegala Lake, Sri Lanka

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***Abstract*: Kurunegala Lake is one of the major drinking water supplying tanks in Kurunegala, Sri Lanka. Water quality assessment is vital for the sustainable management of drinking water resources. This study evaluated the temporal variability of water quality in different inlets and outlet canals of Kurunegala Lake. Three major inlets and one outlet canals connected to Kurunegala were identified, and one sampling location was selected from each of these canals. Water samples data were collected from each selected location in a one-month interval for three years. Water quality parameters were determined in each water sample, such as pH, Electrical Conductivity (EC), Dissolved Oxygen Level (DO), Total Dissolved Solids (TDS), Nitrate-nitrogen (NO^{3-}-N), and Available Phosphorus (Av.P) concentrations. This study showed that pH, DO, NO^{3-}-N, and Av.P of some of the water samples tested were within permissible levels according to WHO & SLS drinking water standards, CEA act. The inlet and outlet canals showed a temporal and spatial variation in water quality parameters during the study period. The results conclude that there is an impact of surrounding land use on water pollution in inlet water canals connected to Kurunegala Lake. Therefore, a pollution management plan is required to prevent further pollution by conducting future research.**

***Keywords:* Land use, Drinking water, *Kurunegala Lake*, Pollution, Surface water quality**

I. INTRODUCTION

While about 70 % of the earth surface is covered by water, 97 % is in the oceans. A significant fraction of freshwater is stored as groundwater and frozen as polar ice; only 0.5% is available for human consumption (Baker & Aldridge, 2016). Water is continuously circulated between global reservoirs: the oceans, atmosphere, land surface, soils, plants, animals, etc. When the water drains from the land surface, it carries the residues from the land. Surface runoff is an essential source of non-point source pollution. Runoff from different land-use types may be enriched with different kinds of contaminants. For example, runoff from agricultural lands can be contaminated with nutrients and sediments. Likewise, runoff from highly developed urban areas may be enriched with rubber fragments, heavy metals, and sodium and sulfate from road deicers (Tong & Chen, 2002).

Water pollution is a common problem in the world. Surface water deterioration is a significant threat to the smooth functioning of ecosystems, including the health of human beings. Human civilization has initiated and successfully developed around lakes and rivers (Mithen, 2010). In Sri Lanka, most cities are located near large surface water bodies. Urban water bodies have developed a strong relationship with the city's economic, environmental, and socio-cultural aspects, which is vital in maintaining water quality for the sustainability of the system. Urban lakes can pollute water from various sources, including industrial discharges, mobile sources (e.g., cars/trucks), residential/commercial wastewater, trash, and polluted stormwater runoff from urban landscapes.

Kurunegala Lake is the primary source of drinking water supply to Kurunegala city and is one of the highly polluted major reservoirs in Kurunegala district, Sri Lanka. Some drainage canals open to the reservoir containing the surface runoff from different land uses in the Kurunegala lake catchment area that caused water pollution. Therefore, this study aimed to investigate the impact of surrounding land use on temporal and spatial variation of water quality in Kurunegala lake by examining the water quality and the relationship between surrounding land-use patterns and the water quality of Kurunegala Lake from January 2019 to December 2020.

II. MATERIALS AND METHODOLOGY

This study was conducted in *Kurunegala lake* in Kurunegala district, Sri Lanka, which belongs to the intermediate zone low-country (IL_1) agro-ecological zone, which receives an annual rainfall of around 1020mm.

Water samples were collected from four locations selected based on the land use. Fig. 1 shows a map of the Kurunegala Tank with the sampling points. The study was conducted from January 2019 to December 2020.

Fig 1: A map showing the Kurunegala tank and the sampling locations

Pre-cleaned polypropylene bottles rinsed with tank water were used to collect water samples. Collected water samples were immediately covered, labeled, and stored in a refrigerator for laboratory analyses. The obtained water samples were analyzed for various physicochemical parameters such as pH, Temperature, Turbidity, Electrical Conductivity (EC) (µS/cm), Dissolved Oxygen (DO) (mg/l), Chemical Oxygen Demand (COD) (mg/l), Biological Oxygen Demand (BOD) (mg/l), Nitrate-Nitrogen (NO_3^--N) (mg/l), Available Phosphorous (Av. P) (mg/l) and Hardness (mg/l).

Table 1 shows the standard methods used to analyze the physicochemical parameters of the obtained water samples.

Table 1: The water quality parameters tested and the test methods

Parameters	Test methods
pH	pH Meter
Electrical Conductivity (EC) (µS/cm)	Portable Multipara Meter
Turbidity	Nephelometric Method
Temperature	Portable Multipara Meter
Dissolved Oxygen (DO) (mg/l)	Azide Modification
Chemical Oxygen Demand COD (mg/l)	Open Reflux Method
Biological Oxygen Demand (BOD) (mg/l)	5-Day BOD Test
Cl^- (mg/l)	Argentometric Methods
Hardness (mg/l)	EDTA Titrimetric Method
NO_3^- as N (mg/l)	Ultra-volte Spectrophotometer Screening Methods
PO_4^{-3} as P (mg/l)	Ascorbic Acid Method

(Federation, 1999)

Data Analysis

The world health organization released drinking water quality standards (WHO) and continually produced guidance on managing drinking water quality since 1958 when it published the international standard for drinking water. Further, Sri Lanka Standards (SLS) Institution and Central Environment Authority (CEA) have also prescribed drinking and ambient water quality standards. Analyzed water quality data were compared with the WHO and SLS drinking water standards & CEA guidelines for ambient water quality standards. Ambient water quality is a set of numerical concentration limits of physical, chemical, and biological parameters urged to support and maintain designated water use. The parameters have different degrees of impact on human health & other environmental systems. For example, a water body can be categorized into beneficial water uses such as drinking, bathing or contact recreation, fisheries, aquatic organism, irrigation, and agriculture based on the concentration of physicochemical and biological parameters. Central Environmental Authority has prepared Ambient water quality standards and according to that, a water body can be categorized into six categories with recommended values shown in Table 2.

Category A - Water that requires Simple treatment for drinking
Category B - Bathing and contact recreational water
Category C - Water suitable for aquatic life
Category D - Water source that requires to undergo a general treatment process for drinking
Category E - Water suitable for irrigation and agricultural activities
Category F - The water with minimum quality but does not fall into categories A to E

Table 2: Ambient Water Quality Standards (CEA, 2019)

	No	Parameter	Unit	Category A	Category B	Category C	Category D	Category E	Category F
General	1	Electrical conductivity	µS/cm, max	-	-	-	-	700	-
	2	Turbidity	NTU max	5	-	-	-	-	-
	3	Total hardness (as $CaCO_3$)	mg/l	250-600	-	-	-	-	-
	4	pH	-	6.0-8.5	6.0-9.0	6.0-8.5	6.0-9.0	6.0-8.5	5.5-9.0
	5	DO at 25^{0}C	mg/l mini	6	5	5	4	3	3
	6	BOD_5 at 20 25^{0}C	mg/l max	3	4	4	5	12	15
	7	COD	mg/l max	10	10	15	30	-	40
Nutrient	8	NO_3^- - N	mg/l max	10	10	10	10	-	10
	9	PO_4^- - P	mg/l max	0.7	0.7	0.4	0.7	-	-
Other	10	Cl^-	mg/l max	250	-	-	250	600	-

Source - (CEA, 2019)

The results were graphically represented using Microsoft Excel software.

III. RESULTS AND DISCUSSION

Water Quality Characteristics

Water quality describes chemical, physical and biological characteristics of water in respect of its intended use. It is a principal cause of water scarcity, reducing the amount of fresh water available for potable, agricultural, and industrial use. At any point in the landscape, the water quality reflects the combined effects of many processes along water pathways. Water quality is affected by various natural and human influences, time, and location. Anthropogenic activities like discharging domestic, industrial, urban, and other effluents into the surface water bodies and overapplication of agrochemicals into the agricultural lands adversely affect the surface water quality. Hence, this study was essential to analyze the impacts of surrounding land use on water pollution in inlet water canals connected to *Kurunegala Lake.*

pH

pH is an essential parameter in evaluating drinking water's acidic or alkaline nature (Meride and Ayenew, 2016). The pH range is from 0 to 14, in which a pH value of 7 is neutral, less than acidic, and greater than 7 represents alkalinity. According to the results, pH values of all the measured water samples were within the recommended levels for drinking and irrigation (6 – 8.5) prescribed by SLS, WHO, and CEA throughout the sampling period.

Electrical Conductivity (EC)

The ability of water to carry an electrical current is measured by its conductivity (Kavindra, 2020). This is proportional to the ion concentration in the water. Dissolved salts and inorganic elements such as alkalis, chlorides, sulfides, and carbonate compounds provide conductive ions to the water. Electrolytes are chemical compounds that dissolve into ions. Electrolytes break into positively charged (cation) and negatively charged (anion) particles when they dissolve in water. The concentrations of each positive and negative charge remain equal as the dissolved compounds split in water. The conductivity of water increases with the number of ions present. Although adding ions to water increases the EC, the water remains electrically neutral. Significant variations in conductivity (typically rises) may indicate that a discharge or other source of disturbance has lowered the relative state or health of the water body and its biota. Human disturbance generally increases the number of dissolved solids entering waterways, resulting in higher conductivity. Other indications may be hindered or altered in water basins with increased conductivity.

Fig. 2 shows the variation of electrical conductivity (EC) in each inlet and outlet canal during the three years. According to the results, measured EC values of all the water samples are below 700 µS/cm, and can be recommended for irrigation and agriculture purposes.

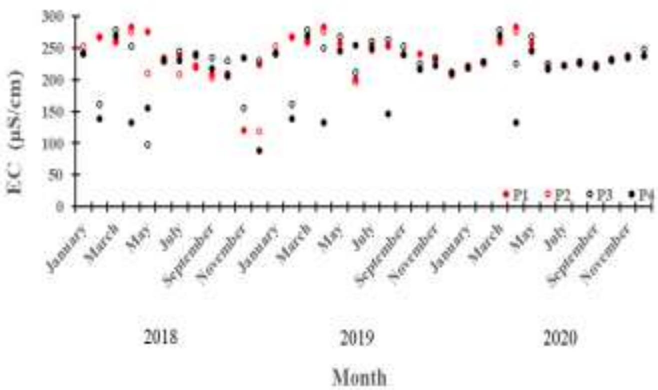

Fig 2: Measured Electrical Conductivity (EC) (µS/cm) of water samples obtained from each inlet and outlet canal during the three years.

Temperature

Temperature changes occur in water bodies as a result of natural climatic oscillations. Seasonally and in some aquatic bodies, across 24-hour intervals, these fluctuations occur (Nigel *et al*., 2015). Latitude, altitude, season, time of the day, air circulation, cloud cover, and the flow and depth of the water body are the factors influencing the temperature of surface waters. Temperature, in turn, affects the physical, chemical, and biological activities in water bodies and the concentration of various variables. The solubility of gases in water, such as O_2, CO_2, N_2, CH_4, and others, decreases with the increasing temperature. Aquatic species' metabolic rates are similarly affected by temperature, and in warm seas, respiration rates increase, resulting in higher oxygen consumption and organic matter decomposition. When nutritional conditions are favorable, growth rates increase (most notably for bacteria and phytoplankton, which treble their populations in short durations), resulting in increased water turbidity, macrophyte growth, and algal growth blooms. Surface waters of tropical regions are generally between 0 and 30 degrees Celsius, while hot springs can reach 40 degrees Celsius or higher. These temperatures vary periodically, with a minimum in the winter or during wet times and a maximum in the summer or dry periods, especially in shallow waters. The water temperature in the Kurunegala lake ranged from 27.4 °C to 34.1 °C throughout the study period. The water temperature during April, May, and June of the three years (2010, 2013, 2016, 2019) are higher, and November and December are also recorded as low water temperatures. This is determined by Sri Jayawardenapura Kotte weather

Water temperature determines the pH value, chemical reaction, dissolved oxygen, biological oxygen demand (BOD), solubility, palatability, smell, conductivity, and water viscosity. The water temperature in the Kotte Canal ranges from 26.5 °C to 32.4 °C. The temperatures in April, May, and June of the calendar years (2018, 2019, and 2020) were higher, and November and December were lower than the mean values. The surrounding weather conditions mainly determine this variation.

Turbidity

Turbidity in drinking water is undesirable because it makes the water appear unappealing. It has the potential to raise the cost of water treatment for a variety of purposes. The particulates might be a haven for hazardous germs, shielding them from disinfection. Suspended debris can clog or injure fish gills, lowering disease resistance, lowering growth rates, interfering with egg and larval maturation, and diminishing the efficiency of fish capture methods. Heavy metals include mercury, chromium, lead, and cadmium, and numerous harmful organic pollutants like Poly Chlorinated Biphenyls (PCBs), Polycyclic Aromatic Hydrocarbons (PAHs), and pesticides adsorb the suspended particles (Xuejiao *et al*., 2017). The turbidity and clarity of water are controlled by the type and concentration of suspended materials (Robert and Smith, 2007). Silt, clay, fine organic and inorganic matter particles, soluble organic compounds, plankton, and other microscopic organisms make up suspended matter. Although the suspended matter is generally recognized as the proportion that will not pass through a 0.45 m pore diameter filter, such particles range in size from around 10 nm to 0.1 mm. The particles' scattering and absorption of incident light cause turbidity, transparency, and the limit of water's visibility. Seasonal variations in biological activity in the water column and surface runoff carrying soil particles can affect both. Hourly turbidity changes can also be caused by heavy rain.

The turbidity of the inlet and outlet canals during the three years ranged from 13.53 to 22.43 NTU. Moreover, there was no significant difference between these values. According to the CEA standards, for category A, the maximum value of the turbidity was 5 NTU. All the measured turbidity values were higher than the recommended level. The main reason for higher turbidity might be the algal growth in the lake water.

Hardness

The hardness of natural waters depends mainly on dissolved calcium and magnesium salts. Calcium may dissolve readily from carbonate rocks and limestones or be leached from soils. The total content of these salts is known as general hardness, which can be further classified into carbonate hardness and non-carbonate hardness. However, dissolved Mg^{2+} concentration is lower than Ca^{2+} in the groundwater. Other sources include industrial and municipal discharges (Sharma & Rout, 2011). River water hardness varies seasonally, with the highest values occurring during low flow conditions and the lowest values occurring during floods.

On the other hand, the hardness of groundwater is less changeable. Specific criteria for water hardness in connection to water use are mainly based on the qualities of the cations that make up the hardness. According to the results, the Kurunegala lake hardness ranges from 61 – 120 mg/l and can be categorized as moderately hard water. Table 3 shows a classification of water based on the total hardness.

Table 3: The Table of Total Hardness, Water Classification (Durfor & Becker, 1964)

Water classification	**Total hardness concentration as mg/L as $CaCO_3$**
Soft water	0-60 mg/L as $CaCO_3$
Moderately hard	61-120 mg/L as $CaCO_3$
Hard water	121-180 mg/L as $CaCO_3$
Very hard	>180 mg/L as $CaCO_3$

Dissolved Oxygen (DO)

Water temperature, the number of dissolved salts present in the water (salinity), and atmospheric pressure influence the dissolved Oxygen concentration in water. Higher water temperatures cause increased molecular vibrations. Essentially, the amount of space between water molecules is reduced, causing to lower DO concentration. As the salinity rises, water's capacity to contain DO decreases. During the daytime, aquatic plants and algae photosynthesis cause to increase in the DO in water bodies. When photosynthesis is not functioning during the night, these same organisms absorb DO through respiration. Most aquatic plants and animals cannot survive for long in water with dissolved oxygen of less than 5 mg/L. Lower oxygen in water can kill fish and other aquatic organisms (Patel and Washi, 2015). About 4 mg/L of minimum DO should be in the water for living organisms. The low level of DO concentration in water is a sign of contamination and is an essential factor in determining water quality, pollution control, and treatment process.

According to the results of this study, DO concentration in inlets and outlet canals during the studied three years varied from 6.79 to10.15 mg/l, within the recommended level for drinking and irrigation.

Biological Oxygen Demand (BOD_5)

Biochemical Oxygen Demand (BOD) is widely used to characterize the organic pollution of water bodies. It is determined by estimating the amount of oxygen required by aerobic microorganisms for degrading organic matter in wastewater (Singh & Verma, 2013). BOD is the amount of oxygen required for the aerobic microorganisms in the water or wastewater sample to oxidize the organic matter to a stable inorganic form (Kimstach, 1996).

Temperature, pH, the presence of specific types of bacteria, and organic & inorganic materials in the water are the factors influencing the rate of oxygen consumption in a stream. The amount of dissolved oxygen in a lake is directly related to BOD. The higher the BOD, the faster the oxygen in the lake is lost, i. e. higher types of aquatic life have less oxygen available to them. Higher BOD has the same effect as lower DO in that aquatic organisms become stressed, suffocate and die. Leaves and woody debris, dead plants and animals, animal manure, wastewater treatment plants, and food-processing plants are also sources of BOD, as in urban stormwater runoff.

According to the results, the BOD concentration values of the obtained water samples varied from 2.41 to 5.16 mg/l. Further, there was no significant difference in the BOD concentrations of inlets and outlets. According to the Ambient Water Quality Standards prescribed by CEA, the maximum values were recommended to protect against anticipated adverse effects on human health or welfare, wildlife, or the environment, with a margin of safety. Unpolluted waters typically have BOD values of 2 mg/1 or less, whereas those receiving wastewater may have levels up to 10 mg/1 or more, particularly near the wastewater discharge point (Kimstach, 1996). According to the results, *Kurunegala lake* water was not polluted. However, it is proven that a particular type of polluted material might have mixed with lake water. BOD values increased with time due to the influence of human activities. In 2020, BOD values were lower because of the restricted human activities during the covid – 19 pandemic situations on the island. Further, BOD values in point 3 were recorded higher than in other points, indicating a possible contamination source.

Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) measures the oxygen equivalent of the organic matter in a water sample that is subjected to be oxidized by a strong chemical oxidant, such as dichromate (Kimstach, 1996). Fig. 2 illustrates the measured Chemical Oxygen Demand (COD) (mg/l) of water samples obtained from each inlet and outlet canal during the three years. According to the results, the COD concentration of the water samples varied from 13.3 to 28.3 mg/l. The results showed that COD concentrations of all the inlets and outlets were not significantly different. However, according to the CEA act, the water COD level is higher than the recommended level.

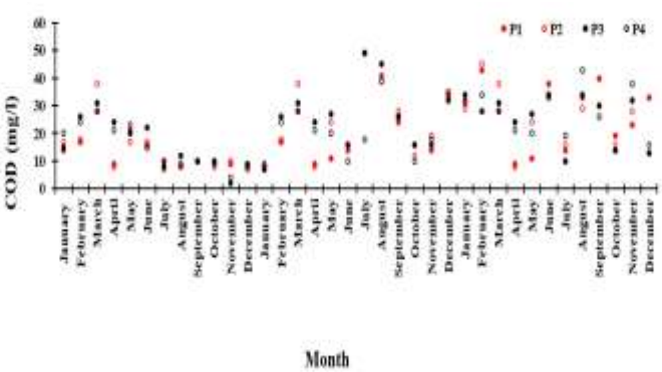

Fig. 3: Measured Chemical Oxygen Demand (COD) (mg/l) of water samples obtained from each inlet and outlet canal during the three years

Nitrate – Nitrogen (NO_3^- - N)

Elevated levels of nutrients, especially Nitrogen and Phopherous in surface water bodies, cause acceleration of eutrophication resulting in oxygen deprivation and fish death. NO_3^--N in the water originates from septic, livestock, manure piles, or fertilizers contaminants. Fig. 3 illustrates the change of NO_3^- concentration with time. The NO_3^- -N concentration of the water samples obtained from the inlet and outlet canals of the *Kurunegala lake* during the three years ranged from 1.20 to 1.80 mg/l. All the measured values are lower than the maximum permissible level of 10 mg/l for drinking and thus suitable for irrigation and agriculture (WHO, 1984) .

According to the results, most of the measured NO_3^- -N concentrations in the *Kurunegala lake* water were not exceeding 2.0 mg/l. Although the values in point 3 were slightly higher than in the other three points, there was no significant difference between the values. Point 3 is located around the residential area. Most of the paddy fields, poultry farms, and small-scale cattle farms within the urban limits are located in this area. Wastewater generated from these sources may be causing the higher N level in lake water.

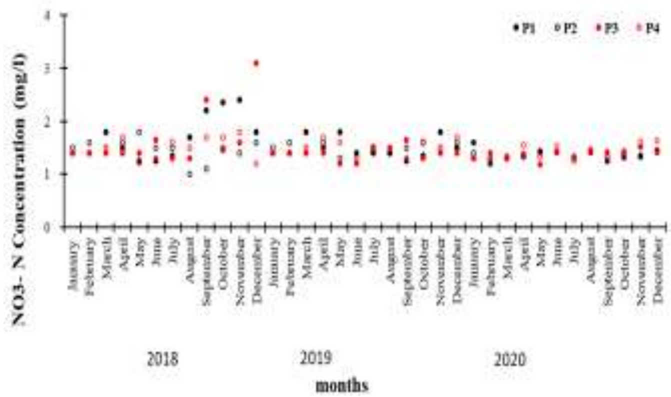

Fig.4: Measured Nitrate-nitrogen concentration (NO^{3-} - N) (mg/l) of water samples obtained from each inlet and outlet canal during the three years

Available phosphorus

Phosphate generally enters the water from phosphorus-rich bedrock, human and animal waste, including laundry, cleaning, industrial effluents, and fertilizer runoff (Sikder *et al*., 2013).It is one of the significant macronutrients responsible for eutrophication in surface water bodies. Typically, phosphates concentration in the environment is low, making it the limiting nutrient for aquatic plant growth. Higher phosphate levels can be due to anthropogenic sources such as septic systems, fertilizer runoff, improperly treated wastewater, and bank erosion. The permissible range of phosphorous phosphate concentration in irrigation water is 0 to 2 mg/l (FAO, 1985). The critical phosphorus concentration value for eutrophication occurrence is 0.08 mg/l (USEN, 1976). CEA act has two ranges for several categories. These are categories A, B, D – 0.7 mg/l, and C – 0.4 mg/l. In this study, the available phosphorous concentrations in most water samples varied within recommended levels. The measured available phosphate concentration of the inlets and outlet canals below 0.01 mg/l during all three years.

Cl^-

Chloride is found naturally in groundwater, streams and lakes, but excessive chloride concentrations in freshwater (about 250 mg/L or higher) may indicate wastewater contamination. Surface water can contain chlorides from various sources, including chloride-containing rock, agricultural runoff and wastewater. Chloride ions (Cl^-) in drinking water have no adverse health effects. However, higher quantities can give most individuals an unpleasant salty taste. Chlorides are rarely toxic to humans. Lower levels of chlorides are required for normal cell activities in animal and plant life. According to the results, the chloride concentration of the inlet and outlet canals during the three-year study period ranged from 74.63 to 100.58 mg/L.

IV. CONCLUSION AND SUGGESTIONS

This study evaluated the temporal variability of water quality in different inlets and outlet canals of *Kurunegala Lake*. During the study period, the inlet and outlet canals observed a temporal variation of water quality parameters. This study showed that pH, DO, NO^{3-}-N, and Available P of some of the water samples tested were higher, and other water quality parameters were within permissible levels according to WHO drinking water standards. Higher Available N and Available P were observed in all soil samples compared to the reference values in the literature. However, the discharge of waste matter from nearby hotels and residential areas into canals directly connected to the lake also might contribute to the higher pollution in the *Kurunegala Lake*. The results conclude that impacts of surrounding land use on water pollution in inlet water canals connected to *Kurunegala Lake* are higher.

V. RECOMMENDATION

Comprehensive management plan should be implemented to prevent further pollution by conducting future research. The main recommendation to improve the quality of water in the drainage canals connected to the *Kurunegala Lake* is to reduce pollution at the source by increasing the discharge water quality in industries by introducing cleaner production techniques, preventing solid waste from being dumped into the canals and regularly removing solid waste from the canals and manage urban runoff.

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