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Physico-Chemical Parameters and Water Quality along Mutonga River in Tharaka Nithi County, Kenya.

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Abstract
Background*: Physico-chemical and biological components, shaped by environmental and anthropogenic dynamics affect water quality in different seasons.*
Materials and Methods*: Water samples were collected along the river in dry and wet seasons. Parameters investigated were pH, temperature, conductivity (EC), turbidity, total dissolved solids (TDS), total suspended solids (TSS), lead, iron, manganese, nitrates nd between seasons. Median of significant test results were compared based on Dwassand phosphates using standard procedures. Kruskal-Wallis test using Scientific Analysis System version 9.4 was employed to determine significant differences among sites a, Steel, Critchlow- Fligner multiple comparison (dscf-post-hoc) tests (α = 0.05).*
Results: The pH ranged from 5.67 to 6.15 in dry season and 6.48 to 7.74 in wet season, temperature from 13.50°C to 26.60°C (dry) and 16.30°C to 21.73°C (wet), EC from 0.10 to 0.60 µS/cm (dry) and 35.60 to 93.50 µS/cm (wet), turbidity 14.89 to 37.99 NTU (dry) and 64.47 to 1000 NTU (wet), TDS 29.33 to 224.00 mg/L (dry) and 17.0- 444.0 mg/L (wet). Significant (p<0.05) variations were noted in levels of lead (0.00 to 0.29 mg/l), iron (0.27 to 0.61 mg/l) and Nitrates (0.49 to 3.83 mg/l).
Conclusion: *Most parameters generally adhere to WHO permissible limits except for turbidity. The findings underscore the necessity for ongoing water quality monitoring and future investigations on other heavy metals, pesticide residues, and polycyclic aromatic hydrocarbons (PAHs) in soil samples from the adjoining farmlands.*
Key Word*: Physico-Chemical, Water-Quality, Mutonga River, Tharaka-Nithi, Kenya*

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I. Introduction:

Water is vital for all living beings and has a profound impact on our environment and our well-being. It supports the growth of plants, sustains animals, and is essential for human survival (Kithaka *et al.,* 2020). Surface water, including rivers, lakes, canals, ponds, and wells, as well as groundwater in shallow and deep aquifers, serves as the primary water sources (Masere *et al.,* 2012). Rivers, in particular, play a crucial role as freshwater ecosystems, providing essential water supplies for various agricultural, domestic, and industrial activities (Singh *et al.,* 2004; Pradhan *et al.,* 2009; Huq *et al.,* 2011). Unfortunately, water contamination has become a pressing global issue, endangering both organisms and human health (Kithaka *et al.,* 2020). Urbanization and inadequate effluent management policies have further intensified the pressure on water bodies, turning them into dumping and discharge points (Ifi *et al.,* 2019). Water pollution occurs as a result of the introduction of harmful substances that alter the physico-chemical and biological characteristics of water (Bartram, 2015). Due to water's innate solvent properties, it is highly susceptible to pollution. Anthropogenic activities, including urbanization, industrialization, agricultural activities, accidental chemical spills, dam construction, and natural processes like erosion and climatic conditions, significantly impact water quality by perturbing its physical, chemical, and microbial composition (Singh and Sao, 2015). This disruption of the natural equilibrium leads to the accumulation of toxic substances and pathogenic microorganisms, posing significant risks to both human health and aquatic ecosystems (Haseena *et al.,* 2017). Since it is crucial that access to clean and safe drinking water is important immediate action to address the continuous pollution that threatens our ecosystems and the future of our planet (Tarakegn and Truye, 2018). Understanding of water bodies necessitates a comprehensive assessment encompassing three fundamental components: physico-chemical properties, hydrology, and biology. The examination of chemical parameters, including pH, total suspended solids (TSS), nitrates, sulphates, dissolved oxygen, alkalinity, acidity, chlorides, fluorides, phosphates, metals, and various other elements, provides valuable insights into the compositional aspects of water. The assessment of physical parameters, such as color, odor, taste, temperature, and turbidity, facilitates the characterization of its sensory attributes (Ombaka *et al*., 2012).

Water pollution is widely recognized as a significant contributor to various hazards affecting both human health and ecosystems. Industrial and agricultural activities release pollutants into water sources, introducing metals such as arsenic, cadmium, and mercury, as well as synthetic organic compounds like pesticides and PCBs (Teck *et al.,* 2017; Sonja et *al.,* 2010). These substances, when present at high concentrations, pose toxicity risks to human beings. For instance, the consumption of water rich in nitrates can lead to a condition known as "blue baby" disease or methemoglobinemia, particularly affecting infants. Moreover, these pollutants have the potential to accumulate in groundwater, contaminate aquifers, and cause human poisoning (Bonareri *et al.,* 2017).

Excessive nutrient loading in water, often resulting from pollution, can lead to eutrophication and the formation of harmful algal blooms, posing a threat to aquatic biodiversity. Additionally, the presence of emerging pollutants such as pharmaceuticals and personal care products in water further intensifies the pressure on our water resources. The long-term effects of these emerging pollutants on human health and ecosystems are still not fully understood (Ezbakhe, 2018).

Another consequence of water pollution is the destruction of habitat for aquatic organisms, particularly small animals residing at the bottom of rivers, such as fish. Sediments, carried by water flow, can cause changes in river dynamics and adversely affect both aquatic life and human activities. Furthermore, river sediments act as sinks for heavy metals and nutrients like phosphates and nitrates. Various contaminants become attached to fine-grained sediments, including organic matter, clay, and silt particles. Notably, heavy metals can precipitate and adsorb onto sediments under conditions of high pH (Islam *et al.,* 2014).

Despite extensive research conducted on water sources in Kenya, there is a notable gap regarding the water quality along Mutonga River. This trans-boundary river, located between Meru and Tharaka-Nithi Counties, passed through areas with tea plantations, small-scale horticultural and tobacco farming, which potentially contributed to the release of heavy metals and nutrients into the river due to the use of farm chemicals and inorganic fertilizers. Moreover, the presence of stone cutting activities in the vicinity of the river, and that the river passes through semi-arid zones with different geological rocks are likely to bring additional chemical releases into the water since sediments act as sinks for heavy metals and nutrients like phosphates and nitrates, and various contaminants become attached to them, including organic matter, clay, and silt particles (Islam *et al.,* 2014).

II. Material and Methods

Study Area

Mutonga River traverses Tharaka – Nithi and Meru Counties, bordering Embu County to the south and Meru County to the south-west. Its geographical coordinates range from latitude 00°07' to 00°26' and longitudes 37°19' to 37°46' East (Jaetzold *et al.,* 2007). The river originates from Mount Kenya and flows eastwards, cutting through various climatic zones. Human activities are widespread along the Mutonga River, serving food production and income generation purposes. The study area (Figure 1) shows sampling points' locations. The riverbanks witness small-scale agriculture, featuring crops like kales, tomatoes, coffee, tea, maize, beans, and bananas (Hakizimana *et al.,* 2017). These crops necessitate the application of agricultural inputs like chemicals, fertilizers, and manure. Notably, quarrying activities for stone extraction occur along the river employing both manual labor and machinery. Furthermore, livestock rearing is prevalent, with animals being directly watered from the river in lower reaches (Jaetzold *et al.,* 2007).

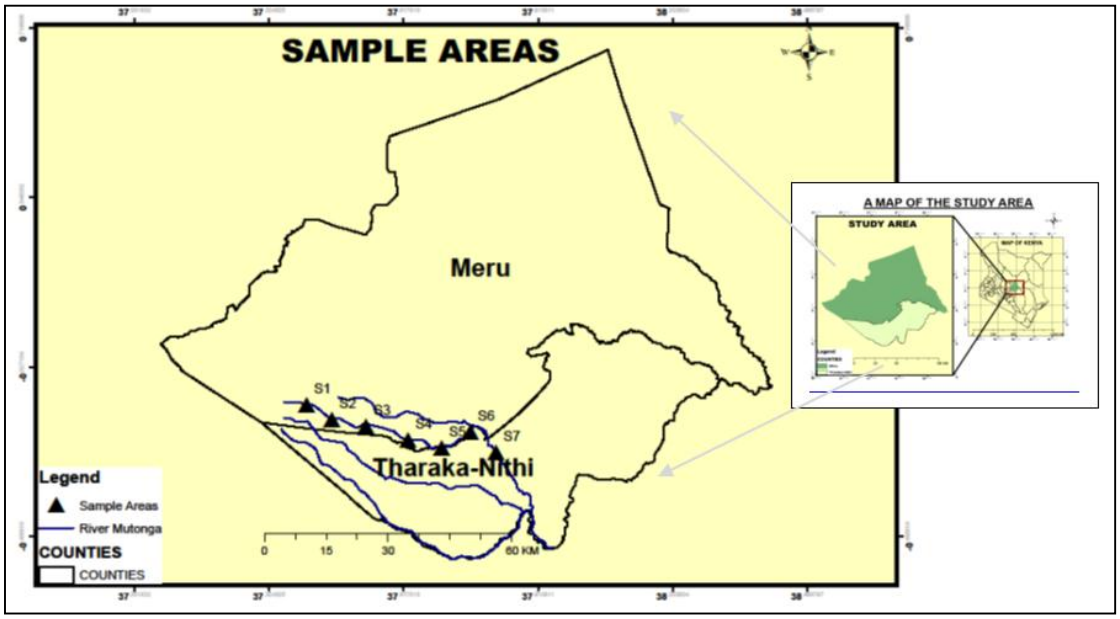

Figure 1: Location of Sampling Points. Source: http//mapsof.net/map/Kenya-topography
Where S1 (LS1) – Sampling point 1, S2 (LS2) – Sampling point 2, S3 (LS3) –Sampling point 3, S4 (LS4) - Sampling point 4, S5 (LS5) – Sampling point 5, S6 (LS6) – Sampling point 6 and S7(LS7) – Sampling point 7.

2.2 Sample collection and treatment

Sample collection was conducted consistently at designated points encompassing diverse areas of human activity. Water samples were obtained within specific windows: in early October for the dry season and late November the wet seasons. For the analysis of metals and anions, PET bottles were used for water sample collection as proposed by Ondoo *et al*. (2020).

2.3 Instrumentation, Chemicals and Method validation

The analysis of heavy metals was carried out using the atomic absorption spectrometer (AAS PG 900 by PG instruments ltd, UK), where specific operating wavelengths were employed: 217.0 nm for lead (Pb), 288.5 nm for cadmium (Cd), 248.3 nm for iron (Fe), and 279.5 nm for manganese (Mn), while the examination of anions involved the UV-VIS spectrometer (UV 1800A, Shimadzu), operating at distinctive wavelengths: 884.0 nm for phosphate (PO4-) and 220.0 nm for nitrate (NO3-) as per Ombaka *et al*. (2012). Standard chemicals essential for analyses were sourced from LOBA Chemical Ltd. in India.

Method validation encompassed recovery tests, wherein water samples were spiked with 2 mg/l solutions of target analytes and percentage recovery calculated using the formula outlined by Solano (2017).

% Recovery=(S-U)/A

Where S represents the concentration of the spiked sample, U is the concentration of the unspiked sample, and A is the concentration of the spiking standards, following the approach for calibration purposes, both AAS and UV-VIS methods utilized drawn calibration curves to determine analyte concentrations in water and sediment samples. Calibration for each heavy metals was established through serial dilution of 1000 mg/L commercial stock solutions, with varying dilution ranges depending on the metal's characteristics: cadmium spanned 0.1-0.5 mg/l, lead covered 0.5-8.0 mg/l, iron ranged from 0.5-10.0 mg/l, and manganese extended from 0.5-8.0 mg/l. In UV-VIS analysis used prepared stock solutions and dilutions ranged from 0.1-0.8 mg/l for phosphates and 0.2-10 mg/l for nitrates. A calibration curve was constructed to determine the concentration of nitrate ions (Samuel *et al*., 2017). The analysis included triplicate assessments of blank and standard solutions.

2.4 Analysis procedures

In-situ measurements of water temperature and pH were performed using a portable pH meter with temperature compensation set at 25ºC (APHA, 2010). The meter was calibrated using buffer solutions of pH 4.0, 7.0, and 10.0. Electrical conductivity was determined in the laboratory using a conductivity meter (HANNA EC 215), calibrated with distilled water and a 100 mg/l sodium chloride standard. Turbidity readings were obtained using a HANNA H193703 turbidity meter, calibrated with distilled water and a 100 NTU standard.

2.5 Sample preparation

For the analysis of nitrates, 50 ml of samples were prepared with the addition of 1 ml of one molar hydrochloric acid while in phosphates analysis, 50 ml of samples were prepared with 2 ml of ascorbic acid buffer. For metals in water samples were assessed using Atomic Absorption Spectrometry (AAS) procedures (Mwangi, 2013). Three hundred ml of the sample was mixed with concentrated nitric acid, heated, cooled, filtered, and diluted for analysis (Ondoo *et al.,* 2019).

Statistical analysis

Since the collected data for various physico-chemical water parameters did not follow a normal distribution, Kruskal-Wallis test, a non-parametric method was used to determine significant differences. To account for multiple comparisons, a Bonferroni adjustment was applied. The statistical analysis was conducted using Scientific Analysis System (SAS) version 9.4 where the medians from the significant test results were compared utilizing the Dwass-Steel-Critchlow-Fligner multiple comparison (post-hoc) tests at a significance level of alpha = 0.05.

Result: **Methods Validation**

The validation process involved the calibration of the analysis methods for iron and phosphates. Essential calibration parameters along with percentage recovery values were compiled in Table 1. All percentage recovery values fell within the acceptable range of 80-120%, affirming the reliability and accuracy of the employed methods (Mwangi, 2013).

Table 1: Method validation parameter results for metals and anions

Parameter	r^2	Regression line	% Recovery
Pb	0.99897	A=0.0100C+0.0017	99.55
Cd	0.98745	A=0.3994C- 0.0109	98.99
Fe	0.99925	A= 0.0259C-0.0009	116.20
Mn	0.77724	A =0.044C-0.0018	97.85
PO_4^-	0.99068	A=0.53465C+0.00734	97.68
NO_3^-	0.99728	A =0.05301C+0.01620	100.7

The r^2 values imply that in most calibration curves 98% of instrument responses correlated with concentration. Manganese r^2 value was below 97.85% and phosphate ions 97.68% due to possible matrix interferences.

3.2 Physical parameters in water

Water pH

The pH value serves as a gauge for the degree of acidity or alkalinity, with the pH value of 7 being ideal for potable water (WHO, 2011). Across sampling locations during the dry season, mean pH values ranged from 5.67 ± 0.00 to 6.15 ± 0.06, indicating a weakly acidic nature of the water (Table 2). Factors like quarrying activities, regional geology and the release of acidic carbon (IV) oxide from organic decomposition contribute to this trend (Bonareri *et al.,* 2017). During the wet season, pH levels ranged slightly higher, from 6.48 ± 0.03 to 7.74 ± 0.16. This increase was not statistically significant. Runoff during the wet season might introduce alkaline substances, neutralizing some hydrogen ions. This aligns with a similar study on Naka River by Ombaka *et al.,* (2012).

The World Health Organization (WHO) proposes a pH range of 6.5 to 8.5 for all water use all locations for human and animal consumption during the dry season. (WHO, 2011). Mean pH values increased along the river in both seasons with. The lowest values occurred downstream at LS6, attributed to intensive inorganic fertilizer use (Bonareri *et al*., 2017), while the higher values around LS2 upstream could be linked to quarrying (Musa *et al, 2009*). Significant differences in pH were observed among sampling locations during the dry season (p = 0.0051), highest at LS4 (*Median* = 6.11) and lowest at LS6 (*Median* = 5.67). No significance was found among locations during the wet season [(p = 0.128) Table 2]. Similar to findings were reported in Kpassa reservoir (Boukari *et al*., 2016). Water pH also significant ($p < 0.05$) varied between seasons (H (42) = 30.541, $p < .0001$) where wet season exhibited higher pH values (*Median* = 6.84) compared to the dry season [(*Median* = 5.92) Figure 1]. The results were consistent with the findings of Kaniz *et al*. (2014) in a study on Marbok estuary, Malasia.

Water temperature

Water temperature along River Mutonga significantly differed (p = 0.05) between seasons (H (42) = 3.2477, p = 0.0715). Interestingly, the dry season exhibited slightly higher water temperatures (*Median* = 20.09°C) than the

wet season (*Median* = 18.27°C). These results are in agreement with those of River Chania catchment (Kimani *et al*, 2016).

In the dry season, water temperatures ranged from 13.50 ± 0.10°C to 26.60 ± 0.10°C, while in the wet season, they ranged from 16.30 ± 0.10°C to 21.73 ± 0.55°C (Table 3.3). This temperature trend reflects the impacts of water level changes, since decreased water levels in the dry season reduce solubility and increase heat absorption, resulting in hotter water. Similar observations were made by Ombaka *et al.* (2012, 2013) in Ruguti and Naka Rivers and Ayenuddin *et al*. (2018) on the Padma River in Bangladesh. Cloudy conditions during the wet season limit solar radiation penetration, contributing to lower temperatures. High river temperatures are detrimental to aquatic life and interfere with water purification processes. As a highly non-linear parameter, temperature adheres to minimal standards for domestic use (Mbui *et al.,* 2016).

Statistically significant differences ($p < 0.05$) in temperature values were observed among all sampling locations during the dry season (H (21) = 19.816, p = 0.003). Similarly, temperatures significantly differed ($p < 0.05$) between some sampling locations during the wet season (H (21) = 18.718, p = 0.005), with the highest and lowest values at LS7 (*Median* = 21°C) and LS1 (16.90°C), respectively. This concurs with Kaniz *et al* (2014) where temperature levels were found to differ among the sampling sites during the dry and wet season.

Table 2: Water pH and temperature levels in different seasons and sampling locations along River Mutonga

Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal walis
		Water pH				
Dry	LS1	6.05±0.06	6.02^{ab}	6.01	6.12	
	LS2	5.7±0.01	5.7^{e}	5.69	5.71	
	LS3	6.05±0.06	6.05^{bc}	6.00	6.11	H = 18.484
	LS4	6.15±0.15	6.11^{a}	6.03	6.32	p = 0.0051
	LS5	5.92±0	5.92^{cd}	5.92	5.92	df= 6
	LS6	5.67±0	5.67^{e}	5.67	5.67	
	LS7	5.76±0.09	5.77^{de}	5.67	5.85	
Wet	LS1	6.48±0.16	6.45	6.34	6.65	
	LS2	7.10±0.29	6.94	6.93	7.44	
	LS3	6.71±0.34	6.89	6.32	6.92	H = 9.915
	LS4	6.84±0.01	6.84	6.83	6.84	p = 0.128
	LS5	6.65±0.18	6.55	6.54	6.86	Df = 6
	LS6	6.66±0.31	6.75	6.32	6.92	
	LS7	7.74±0.03	7.74	7.71	7.76	N = 3
	H =2.292			p = 0.891	Df= 6	
		Temperatures of water (°C)				
Dry	LS1	13.50±0.10	13.50^{a}	13.40	13.60	
	LS2	15.10±0.00	15.10^{b}	15.10	15.10	
	LS3	19.80±0.00	19.80^{c}	19.80	19.80	H =19.816
	LS4	20.07±0.06	20.10^{d}	20.00	20.10	p = 0.003
	LS5	20.47±0.06	20.50^{e}	20.40	20.50	df= 6
	LS6	25.00±0.00	25.00f	25.00	25.00	
	LS7	26.60±0.10	26.60^{g}	26.50	26.70	
Wet	LS1	17.00±0.10	17.00^{c}	16.90	17.10	
	LS2	16.30±0.10	16.30^{d}	16.20	16.40	
	LS3	18.40±0.10	18.40^{b}	18.30	18.50	H =18.718
	LS4	18.50±0.00	18.50^{b}	18.50	18.50	p = 0.005
	LS5	18.30±0.00	18.30^{b}	18.30	18.30	df = 6
	LS6	18.50±0.10	18.50^{b}	18.40	18.60	

LS7	20.73±0.55	21.00[a]	20.10	21.10	N = 3
H =31.297			$p < 0.0001$	df= 6	

where SD= standard deviation, N = Sample Size

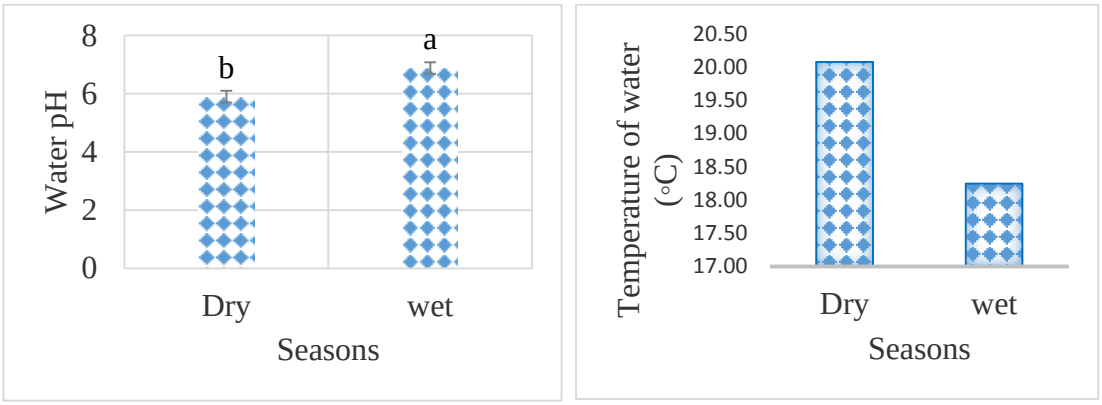

Figure 1: Variation of pH and temperature of water during the dry and wet season along River Mutonga in Kenya

Electrical conductivity

Electrical conductivity quantifies the ability of an aqueous solution to carry an electric current, contingent on the presence of ions, their concentration, mobility, and temperature. Inorganic compounds generally exhibit higher conductivity, while non-dissociating organic molecules conduct poorly. Water samples from Mutonga River exhibited electrical conductivity levels ranging from 0.10 to 0.60 µS/cm during the dry season and 35.60 to 93.50 µS/cm during the wet season (Table 3). These ranges compare with observations along Ruguti River and are below the WHO's prescribed guideline value for drinking water at 1,500 µS/cm (Ombaka *et al*., 2012). Elevated conductivity during the wet season could be attributed to surface runoff carrying dissolved minerals and increased ionization due to heightened water volume (Oduor *et al*., 2020). Sampling site 6 indicated the highest conductivity, possibly reflecting pollution from anthropogenic activities, sediment mineralization, or weathering (Ombaka *et al*., 2012). Significant spatial variations were observed in water conductivity during both dry (H (21) = 14.271, p = 0.027) and wet (H (21) = 18.957, p = 0.0042) seasons. Higher conductivity was noted at locations LS1 and LS7 during the dry season, and at LS6 during the wet season. Conversely, lower values were recorded at LS3 and LS5 during both seasons (Table 3). Wet season conductivity (Median = 43.9 µS/cm) surpassed dry season (Median = 0.3 µS/cm) which may be due to increased water volume and ion mobility.

Turbidity

Turbidity, indicating suspended particle presence, ranged from 14.89 ± 2.18 to 37.99 ± 0.84 NTU (dry) and 64.47 ± 4.57 to 1000 ± 0.67 NTU (wet). Elevated values were seen at LS6 (dry) and LS7 (wet). Differences in particle characteristics accounted for varying turbidity at sampling points (Ombaka *et al*., 2012). Higher turbidity in the wet season was likely due to increased runoff and suspended matter from surface, stream, and overland flow. Recorded turbidity levels surpassed WHO's 5 NTU recommendation, indicating water pollution. Significant spatial disparities emerged in water turbidity during the dry season (H (21) = 17.766, p = 0.0068). Highest turbidity was at LS6 (38.05 NTU), lowest at LS1 [(14.04 NTU), Table 3)]. Wet season turbidity (141 NTU) exceeded dry season (24.86 NTU) which again may be attributed to elevated water volume and suspended particle mobility (Kaniz *et al*., 2014; Oduor *et al*., 2020).

Table 3: Analysis of Water conductivity and turbidity in different sampling locations and seasons along River Mutonga in Kenya

		Conductivity of water (mS /cm)				Kruskal- wallis
Seasons	Location	Means±SD	Median	Minimum	Maximum	
Dry	LS1	0.43±0.15	0.40[ab]	0.30	0.60	
	LS2	0.30±0.10	0.30[ab]	0.20	0.40	
	LS3	0.13±0.06	0.10[cd]	0.10	0.20	H =14.271
	LS4	0.27±0.06	0.30[bc]	0.20	0.30	p = 0.027
	LS5	0.20±0.10	0.20[bd]	0.10	0.30	df= 6

	LS6	0.30±0.00	0.30[bd]	0.30	0.30	
	LS7	0.40±0.00	0.40[a]	0.40	0.40	
Wet	LS1	44.47±0.12	44.40[b]	44.40	44.60	
	LS2	43.87±0.06	43.90[c]	43.80	43.90	
	LS3	35.93±0.58	35.60[de]	35.60	36.60	*H* =18.957
	LS4	36.10±0.17	36.00[d]	36.00	36.30	*p* = 0.0042
	LS5	35.60±0.00	35.60[de]	35.60	35.60	*df* = 6
	LS6	93.50±0.10	93.50[a]	93.40	93.60	
	LS7	44.60±0.10	44.60[b]	44.50	44.70	N = 3
	H =7.2204			*p* = 0.3009	df= 6	
	Turbidity of water (NTU)					
Dry	LS1	14.89±2.18	14.04[d]	13.26	17.36	
	LS2	17.71±4.70	15.73[cd]	14.33	23.08	
	LS3	21.94±3.78	23.30[bc]	17.67	24.86	*H* =17.766
	LS4	25.60±3.09	26.58[bc]	22.14	28.08	*p* = 0.0068
	LS5	34.38±3.03	34.26[a]	31.42	37.47	df= 6
	LS6	37.99±0.84	38.05[a]	37.12	38.79	
	LS7	26.11±2.27	25.62[b]	24.13	28.58	
Wet	LS1	64.67±4.51	65.00[g]	60.00	69.00	
	LS2	75.33±3.06	76.00[f]	72.00	78.00	
	LS3	129.00±1.00	129.00[e]	128.00	130.00	*H* =19.7003
	LS4	325.00±0.00	325.00[b]	325.00	325.00	*p* = 0.0031
	LS5	141.00±3.00	141.00[d]	138.00	144.00	*df* = 6
	LS6	203.33±3.06	204.00[c]	200.00	206.00	
	LS7	1000.67±1.15	1000.00[a]	1000.00	1002.00	N = 3
	H =7.937			*p* = 0.243	df= 6	

where SD = standard deviation, N = Sample size

Total suspended solids (TSS)

TSS signifies pollution degree in water. It refers to the dry weight of non-dissolved solids in water (Bonareri *et al.,* 2017). The TSS mean values ranged from 38.33 ± 3.21 to 94.67 ± 5.14 mg/L (dry) and 100.33 ± 17.77 to 142.00 ± 25.33 mg/L (wet) along Mutonga River (Table 4). Elevated TSS at LS2 (dry) might result from nearby quarry activities introducing particles. Wet season's uniform particle distribution likely arose from water turbulence and higher flow rate (Oremo *et al.,* 2018). The TSS did not significantly differ among sampling locations in the dry season (H (21) = 6.6103, p = 0.3584), although location LS2 recorded slightly higher TSS (*Median* = 85 mg/L) while LS5 had lower [(*Median* = 37 mg/L) Table 4]. The TSS in water along River Mutonga differed significantly ($p < 0.05$) between the seasons (H (42) = 23.4629, $p < 0.0001$). However, there were no significant differences in TSS among the sites in both seasons. The TSS was higher during wet season (*Median*= 112 mg/L) as compared to dry season (*Median*= 57 mg/L). These results are similar to those observed on Rupingazi River in Embu, Kenya (Bonareri *et al*., 2017).

Total dissolved solids (TDS)

The TDS levels ranged from 29.33 ± 2.31 to 224.00 ± 0.01 mg/L (dry) and reached 444.0 ± 0.00 mg/L (wet) in Mutonga River (Table 3.3). Similarly high values were found in Nairobi River (Ondoo *et al.,* 2019), potentially due to multiple quarrying sites contributing particles. Despite high levels, TDS remained below WHO 2011 drinking standard (Bonareri *et al*., 2017). The TDS in wet season's increase may arise from surface runoff and domestic waste discharge (Bonareri *et al.,* 2017; Mbui *et al.,* 2016). Season had a significant difference (p < 2.05) on the TDS values recorded (H (21) = 9.5077, p = 0.002) during wet season. Wet season had higher values of TDS (*Median* = 248mg/L) compared to dry season (*Median* = 61mg/L). The TDS fluctuated across locations and seasons due to varied surrounding conditions such as runoff from agricultural land, geology of the area and quarrying activities (Mbui *et al.,* 2016).

Table 4: Analysis of TSS and TDS in different sampling locations and seasons along River Mutonga in Kenya

Seasons	Location	Total suspended solid of water (mg/L) Means±SD	Median	Minimum	Maximum	Kruskal-Wallis
Dry	LS1	71.33±12.90	75.00	57.00	82.00	
	LS2	94.67±55.14	85.00	45.00	154.00	
	LS3	38.33±3.21	37.00	36.00	42.00	*H* =6.6103
	LS4	56.00±12.77	59.00	42.00	67.00	*p* = 0.3584
	LS5	47.00±9.54	48.00	37.00	56.00	df= 6
	LS6	52.33±46.18	57.00	4.00	96.00	
	LS7	66.67±49.12	93.00	10.00	97.00	
Wet	LS1	112.67±25.40	98.00	98.00	142.00	
	LS2	100.33±17.67	109.00	80.00	112.00	
	LS3	103.67±6.66	102.00	98.00	111.00	*H* =8.7153
	LS4	105.33±25.54	107.00	79.00	130.00	*p* = 0.1902
	LS5	142.33±38.53	144.00	103.00	180.00	df = 6
	LS6	142.00±25.53	136.00	120.00	170.00	
	LS7	132.00±19.97	122.00	119.00	155.00	N = 3
	H =2.6006			*p* = 0.857	df= 6	
		Total dissolved solid in water (mg/L)				
Dry	LS1	206.33±2.08	207.00ab	204.00	208.00	
	LS2	224.0±291.01	60.00ab	52.00	560.00	
	LS3	152.00±1.0	152.00ab	151.00	153.00	*H* =15.1976
	LS4	60.0±1.00	60.00ab	59.00	61.00	*p* = 0.0188
	LS5	29.33±2.31	28.00b	28.00	32.00	df= 6
	LS6	59.67±0.58	60.00c	59.00	60.00	
	LS7	125.33±0.58	125.00b	125.00	126.00	
Wet	LS1	247.33±1.15	248.00b	246.00	248.00	
	LS2	142.0±2.0	142.00bc	140.00	144.00	
	LS3	264.0±4.0	264.00ab	260.00	268.00	*H* =19.3498
	LS4	266.0±4.0	266.00ab	262.00	270.00	*p* = 0.0036
	LS5	444.0±287.52	278.00a	278.00	776.00	df = 6
	LS6	17.0±1.0	17.00c	16.00	18.00	
	LS7	229.67±1.53	230.00b	228.00	231.00	N = 3
	H =13.3501			*p* = 0.0378	df= 6	
	where SD = standard deviation, N = Sample size					

3.3: Chemical parameters in water

Lead

Lead levels exhibited variability, ranging from below detection limit to 0.29 ± 0.031 mg/l in dry season and 0.03 ± 0.001 to 0.22 ± 0.02mg/l in the wet season (Table 5). Seasonal differences were significant, consistent with other studies on Kenyan rivers (Mbui *et al.*, 2016; Ombaka *et al.*, 2012). During the dry season, significant differences in Pb levels were observed among sampling locations along River Mutonga (H (21) = 18.6103, p = 0.0049), in agreement with Mwangi (2013). Notably, higher Pb levels were recorded at location LS6 (*Median* = 0.27 mg/l), possibly attributed to geological factors and inorganic fertilizer use in small-scale agricultural activities. Locations LS1, LS2, and LS5 registered Pb levels below detection limits (BDL) (Table 5) (Ombaka *et al.*, 2012). In the wet season, significant differences in Pb values were observed among sampling locations (H (21) = 16.9331, p = 0.0095), with location LS7 exhibiting higher Pb values (*Median* = 0.22 mg/l) and LS1 lower values (Median = 0.01 mg/l) (Table 5). The effect of season on Pb values was not significant (*H* (21) = 0.0518, *p* = 0.82) during the wet season, which is in agreement with what Minhaz *et al.* (2019) reported. Nonetheless, dry season exhibited slightly higher Pb levels (*Median* = 0.12 mg/l) compared to wet season (*Median* = 0.09 mg/l) (Minhaz *et al.*, 2019).

Iron

Iron levels exhibited variability, spanning from 0.27 ± 0.02 to 0.61 ± 0.01 mg/l during the dry season and reaching 2.20 ± 0.03 to 7.65 ± 0.13 mg/l in the wet season (Table 5). This trend aligns with findings from other river studies and is attributed to iron-rich soils and rocks along the river (Mwanzia *et al.,* 2019). Multiple quarry sites, containing stones with unknown composition but suspected high iron content, could contribute to these observations. Notably, higher levels were observed in the wet season, potentially due to surface runoff transporting iron-rich soil particles into the water and increased solubility of iron compounds (Ombaka *et al.,* 2012; Wasike, 2017). Fe values significantly differed among sampling locations in water along River Mutonga during the dry season (H (21) = 14.1569, p = 0.0279). Location LS4 registered higher Fe values (*Median* = 0.58 mg/l), whereas LS1 exhibited lower values [(*Median* = 0.28 mg/l) Table 5]. In the wet season, Fe values showed no significant difference among sampling locations (H (21) = 17.9048, p = 0.0065). Nevertheless, location LS5 recorded higher Fe values (*Median* = 7.7 mg/l), while LS3 displayed slightly lower Fe values [(*Median* = 2.19 mg/l) Table 5]. Season had a significant effect ($p < 0.05$) on Fe values in water (H (21) = 30.7724, $p < 0.0001$) during the wet season. The values of Fe were higher in the wet season (*Median* = 3.04 mg/l) compared to the dry season (Median = 0.57 mg/l).This can be attributed to geology of the region, discharge from sediments as well as deposition of iron rich soil in the water. This trend aligns with findings from the Nzhelela River (Joshua *et al.,* 2017).

Table 5: Analysis of *lead and* Iron in different sampling locations and seasons along River Mutonga in Kenya

		Values of *Pb* (mg/l)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal Wallis
	LS1	BDL	0.00^{c}	0.00	0.00	
	LS2	BDL	0.00^{c}	0.00	0.00	
	LS3	0.14±0.02	0.14^{b}	0.11	0.16	H =18.6103
Dry	LS4	0.16±0	0.16^{b}	0.16	0.16	p = 0.0049
	LS5	BDL	0.00^{c}	0.00	0.00	df= 6
	LS6	0.29±0.03	0.27^{a}	0.27	0.32	
	LS7	0.14±0.02	0.13^{b}	0.12	0.16	
	LS1	0.03±0.00	0.03^{c}	0.03	0.03	
	LS2	0.04±0.01	0.04^{c}	0.03	0.05	
	LS3	0.12±0.06	0.15^{b}	0.05	0.16	H =16.9331
Wet	LS4	0.09±0.01	0.09^{b}	0.08	0.10	p = 0.0095
	LS5	0.09±0.00	0.09^{b}	0.09	0.10	df = 6
	LS6	0.10±0.01	0.10^{b}	0.09	0.11	
	LS7	0.22±0.02	0.22^{a}	0.19	0.24	N = 3
	H =29.9612			p <.0001	df= 6	
	Values of Fe (mg/l)					
	LS1	0.27±0.02	0.28^{c}	0.26	0.29	
	LS2	0.37±0.01	0.37^{bc}	0.36	0.38	
Dry	LS3	0.47±0.20	0.57^{ab}	0.24	0.61	H =14.1569
	LS4	0.61±0.01	0.61^{a}	0.59	0.62	p = 0.0279
	LS5	0.59±0.02	0.58^{a}	0.58	0.61	df= 6
	LS6	0.56±0.01	0.57^{a}	0.54	0.57	
	LS7	0.56±0.03	0.57^{a}	0.53	0.60	
	LS1	2.37±0.05	2.39^{d}	2.32	2.41	
	LS2	2.98±0.08	2.99^{c}	2.90	3.05	
Wet	LS3	2.20±0.03	2.19^{d}	2.18	2.23	H =17.9048
	LS4	5.94±0.08	5.91^{b}	5.89	6.03	p = 0.0065
	LS5	7.65±0.13	7.70^{a}	7.50	7.74	df = 6
	LS6	6.11±0.13	6.09^{b}	6.00	6.26	
	LS7	2.40±0.55	2.10^{d}	2.06	3.04	N = 3
	H =6.1472			p = 0.4069	Df= 6	

where Std= standard deviation, N = Sample size, BDL = Below detection levels (BDL was assumed to be zero for the purpose of analysis), SD = standard deviation, N = Sample size

Manganese

In the dry season, manganese levels were below the detection limit in all water samples. However, during the wet season, the element displayed a mean range of 0.05 ± 0.002 to 2.22 ± 0.06 mg/l (Table 6). This rise can be attributed to several factors, including the transport of manganese through surface runoff from agricultural

areas, dissolution from geological rocks with uncertain composition, and release from sediments, alongside the impact of quarrying activities along the river (Damaris et al., 2016; Saeed et al., 2014; Brian et al., 2011). During the wet season, the Mn values significantly differed ($p < 0.05$) among the sampling locations along River Mutonga (H (21) = 18.303, $p = 0.0055$). LS7 recorded higher values of Mn with a Median of 2.25 mg/l, likely due to accumulation as the river flows and the geological characteristics of the area (Omwoma *et al*., 2011). Conversely, LS3 exhibited lower Mn values with a Median of 0.01 mg/l No analysis was performed on the Mn data from the dry season since its levels were below detectable limits in water samples from all seven locations (Table 6).

Table 6: Variation of Mn in Water in sampling locations in wet Season

		Values of Mn (mg/l)				
	Location	Means	Median	Minimum	Maximum	Kruskal Wallis
	LS1	0.05±0.00	0.05^{c}	0.05	0.05	
	LS2	0.08±0.01	0.07^{bc}	0.07	0.08	
Wet	LS3	0.11±0.01	$0,10^{b}$	0.10	0.11	H(21) =18.303
	LS4	0.11±0.00	0.11^{b}	0.11	0.11	$p = 0.0055$
	LS5	0.08±0.06	0.11^{b}	0.01	0.11	Df = 6
	LS6	0.14±0.01	0.14^{b}	0.04	0.15	
	LS7	2.23±0.06	2.25^{a}	2.16	2,28	

where Std= standard deviation, N = Sample size =3, values followed by similar letters were not significantly different

Levels of Nitrates

Nitrates in the water are influenced by surface runoff from agricultural areas, carrying nitrates from fertilizers like Calcium Ammonium Nitrate (CAN) and organic matter. This contributes to higher nitrate levels during the wet season (range 2.36 ± 0.00 – 4.01 ± 0.00 mg/l) in comparison to the dry season [(range 0.49 ± 0.00 - 3.83 ± 0.00 mg/l) Table 7]. During the dry season, the NO_3^- values significantly differed ($p < 0.05$) among the sampling locations along River Mutonga (H (21) = 19.6747, $p = 0.0032$) (Ayennudin *et al*, 2018) (LS6 exhibited higher NO_3^- levels with a *Median* of 3.83 mg/l, while LS7 showed lower NO_3^- levels [(Median 0.49 mg/l) Table 7]. This variation might be attributed to fertilizers used in small-scale irrigation activities in LS6 (Bonareri *et al.,* 2017). A significant ($p < 0.05$) difference in NO_3^- values in water was observed among the sampling locations during the wet season (H (21) = 19.6619, $p = 0.0032$) (Ezzat *et al.,* 2012) (LS7 displayed higher NO_3^- values (Median = 3.96 mg/l), whereas LS1 had lower NO_3^- values [Median = 2.36 mg/l (Table 6)]. The wet season had a significant ($p < 0.05$) impact on NO_3^- values in the water (H (21) = 21.549, $p < 0.0001$) (Ayennudin *et al*., 2018). NO_3^- values were higher during the wet season (*Median* = 3.59 mg/l) compared to the dry season (*Median* = 1.19 mg/l). This could be due to surface runoff from agricultural land (Bonareri *et al*., 2017).

Levels of phosphates

Phosphate levels displayed a range of 0.247 ± 0.00 to 0.818 ± 0.001 mg/l during the dry season and 0.421 ± 0.115 to 4.27 ± 0.058 mg/l during the wet season (Table 7). Notably, levels were higher in the wet season, attributed to surface runoff from agricultural areas carrying dissolved phosphate fertilizers and detergents into the river, along with accelerated organic matter decomposition (Bonareri *et al*., 2017). In the dry season, significant differences ($p < 0.05$) in PO_4^{3-} values among sampling locations along River Mutonga were observed [(H (21) = 19.9209, $p = 0.0029$) Fella *et al*., 2018]. Location LS2 had significantly higher values of PO_4^{3-} (*Median* = 0.03 mg/l), whereas LS7 had significantly lower values [(*Median* = 0.004 mg/l) Table 7]. This could be related to small-scale agricultural practices involving the use of farmyard manure and inorganic fertilizers (Boukari *et al.,* 2016). During the wet season, a significant ($p < 0.05$) difference in PO_4^{3-} values among sampling locations was evident (H (21) = 19.921, $p = 0.0029$), aligning with results of Ayennudin *et al* (2018). Location LS7 had higher values of PO_4^{3-} (*Median* = 0.23 mg/l), while LS2 exhibited lower values (*Median* = 0.002 mg/l) (Table 7). The elevated levels in LS7 could be attributed to surface runoff and detergent discharge from direct riverbank laundry activities (Boukari *et al.,* 2016). Season had no significant ($p > 0.05$) effect on PO_4^{3-} values in water (H (21) = 1.4639, $p = 0.2263$) during the wet season due to continuous fertilizer and detergent use in both seasons. However, slightly higher values of PO_4^{3-} were observed during the wet season (*Median* = 0.03 mg/l) compared to the dry season may be due to surface runoff and detergents from laundry [(Median = 0.02 mg/l) (Kimani *et al,* 2016)].

Table 7: Levels of Nitrates and Phosphates in different sampling locations and seasons along River Mutonga in Kenya

		Values of NO_3^- (mg/l)				
Dry	LS1	1.33 ±0.00	1.33[c]	1.33	1.33	
	LS2	1.13±0.00	1.13[f]	1.13	1.13	
	LS3	1.20±0.01	1.19[d]	1.19	1.21	H =19.6747
	LS4	1.43±0.00	1.44[b]	1.43	1.44	*p* = 0.0032
	LS5	1.15±0.00	1.15[e]	1.15	1.15	df= 6
	LS6	3.83±0.00	3.83[a]	3.82	3.83	
	LS7	0.49±0.00	0.49[g]	0.49	0.49	
Wet	LS1	2.36±0.0	2.36[g]	2.36	2.37	
	LS2	2.59±0.0	2.59[f]	2.59	2.59	
	LS3	3.20±0.0	3.20[e]	3.20	3.21	H =19.6619
	LS4	3.59±0.0	3.59d	3.58	3.59	*p* = 0.0032
	LS5	4.01±0.0	4.01[a]	4.01	4.01	df = 6
	LS6	3.83±0.0	3.83[c]	3.83	3.84	
	LS7	3.97±0.03	3.96[b]	3.95	4.00	
	H =9.6916			*p* = 0.1383	df= 6	N = 3
		Values of PO_4^{3-}(mg/l)				
Dry	LS1	0.023±0.0	0.023[b]	0.023	0.023	
	LS2	0.03±0.0	0.030[a]	0.030	0.030	
	LS3	0.019±0.0	0.019[c]	0.019	0.019	H =19.9209
	LS4	0.013±0.0	0.015[f]	0.015	0.015	*p* = 0.0029
	LS5	0.015±0.0	0.02[e]	0.02	0.02	Df= 6
	LS6	0.017±0.0	0.017[d]	0.017	0.017	
	LS7	0.004±0.0	0.004[g]	0.004	0.005	
Wet	LS1	0.003±0.0	0.003[e]	0.003	0.003	
	LS2	0.002±0.0	0.002[g]	0.002	0.002	
	LS3	0.014±0.0	0.014[f]	0.014	0.014	H =19.9209
	LS4	0.088±0.0	0.088[b]	0.088	0.088	*p* = 0.0029
	LS5	0.038±0.0	0.038[c]	0.037	0.038	Df = 6
	LS6	0.031±0.0	0.031[d]	0.031	0.031	
	LS7	0.230±0.0	0.230[a]	0.229	0.230	N = 3
	H =5.7092			*P*= 0.4565	Df= 6	

where SD = standard deviation, N = Sample size

III. Conclusion

The findings reveal significant variations in most physical parameters between seasons, except for TSS. Notably, pH, temperature, EC, turbidity, and TDS showed significant differences among sampling sites during the dry season, but not in the wet season. Regarding chemical parameters, lead and iron values exhibited significant site and seasonal differences, with higher levels in the wet season. Manganese levels were undetected during the dry season. Nitrate levels varied significantly between sites and seasons, with higher values in the wet season. Similarly, phosphate levels differed among sites but not between seasons. Turbidity levels exceed WHO allowed limit (5 NTU). This indicates that the water may be polluted due to high levels of turbidity.

Conflict of interest

The authors wish to declare that there are no conflicts of interest associated with this publication. The authors have not received support of any kind from anyone that may influence the outcome.

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