Research in Ecology | Volume 07 | Issue 03 | September 2025

Research in Ecology
https://journals.bilpubgroup.com/index.php/re

ARTICLE

Physicochemical and Heavy Metal Characterization of River Kapingazi in Embu County, Kenya

Naomy Chepkirui Yego [1*], ***Charles Onyari Nyambane*** [1], ***Rebbecca Yegon*** [1], ***Shadrack Kiprotich*** [2]

[1] *Department of Water and Agricultural Resource Management, University of Embu, Embu P.O. Box 6-60100, Kenya*
[2] *Department of Agricultural Economics and Extension, University of Embu, Embu P.O. Box 6-60100, Kenya*

ABSTRACT

Surface water provides crucial support to the aquatic ecosystem and humans in numerous ways. However, its quality is paramount in determining its impact on the health of the aquatic ecosystem and humans. Currently, the malady of pollution arising from anthropogenic activities poses a significant threat to the quality of most rivers. The quality of water in the Kapingazi river in Embu County has received limited attention which is a concern that needs to be addressed. This study therefore, sought to investigate the status of water quality in river Kapingazi. The study analyzed 96 samples from four locations in a span of eight months which combined the dry and wet seasons of the year. Parameters measured in-situ included turbidity, pH, total dissolved solids (TDS), temperature, dissolved oxygen (DO) and electrical conductivity (EC) while ex-situ parameters were phosphates, nitrates and concentrations of heavy metals: iron and manganese. Results showed that Water Quality Index (WQI) during the drought period was74.05, suggesting that the water quality is only recommended for agricultural and industrial applications. During wet season, the water quality index was 89.67, reflecting a poor status, as more contaminants were likely introduced through surface runoff. Overall, the WQI averaged to 88.02. This study concludes that water in River Kapingazi is not suitable for human consumption; therefore, appropriate treatment is essential prior to its use. Similarly, the findings indicate that both rainy and drought periods significantly affect water quality, presenting challenges for its use for various purposes. It is recommended that the allocation of resources towards water treatment facilities and regulation of pollution sources should be enforced to ensure the safety of river water for diverse applications.

Keywords: Water Quality; Heavy Metals; River Kapingazi; Pollution; Physical & Chemical Parameters

*CORRESPONDING AUTHOR:
Naomy Chepkirui Yego, Department of Water and Agricultural Resource Management, University of Embu, Embu P.O. Box 6-60100, Kenya; Email: chepkiruinaomy2@gmail.com

ARTICLE INFO
Received: 5 May 2025 | Revised: 23 May 2025 | Accepted: 30 May 2025 | Published Online: 4 July 2025
DOI: https://doi.org/10.30564/re.v7i3.9873

CITATION
Yego, N.C., Nyambane, C.O., Yegon, R., et al., 2025. Physicochemical and Heavy Metal Characterization of River Kapingazi in Embu County, Kenya. Research in Ecology. 7(3): 104–114. DOI: https://doi.org/10.30564/re.v7i3.9873

1. Introduction

Freshwater resources are critical for survival and serve a variety of demands in households, agriculture, the economy, and industry [1,2]. However, there are increasing concerns about water security and quality. Such concerns emerge from the continuous pollution of water resources by anthropogenic, industrial, and agricultural sources which have become a serious environmental concern, requiring effective strategies for constant monitoring and enforcement of regulatory policies to sustain such ecosystems [3–8]. Poor management of agricultural runoff from pesticides and fertilizers, industrial chemical and heavy metal releases, and inappropriate home waste disposal has aggravated pollution in water sources [9].

Water pollution is a severe issue in Africa, attributed to lack of proper drainage and release of untreated waste in water ways [10,11]. Population expansion, rising urbanization, and climate change have exacerbated the growth of water scarcity, putting additional strain on already vulnerable water sources [12]. In Sub-Saharan Africa, the pollution situation is aggravated by widespread poverty, poor governance, and a lack of water control systems. Khan et al. [13] observed that 7% of individuals in urban and 27% of those in rural Sub-Saharan Africa use contaminated water sources. This implies that people acquire their drinking water from unguarded wells, streams, and rivers that may be contaminated with bacteria and pollutants from a variety of unmanaged sources.

Inadequate Water, Sanitation and Hygiene (WASH) has been cited as one of the cause of deaths in SSA, as reported by United Nation [14]. Water-related diseases disproportionately affect children under the age of five, contributing to high rates of infant mortality in SSA [15]. Efforts to improve water in SSA face obstacles such as a lack of finances, political concerns, and costly construction and maintenance expenses for water filtration systems [16]. It is evident from the fact that waste collection in SSA is among the lowest, thereby enhancing the likelihood of contaminating water resources [17]. Climate change further worsens the situation by increasing the frequency of extreme weather events such as droughts and floods, which cause water supply networks to fail and compromise water quality [18,19].

Urban development, industrial growth, farming, chemical spills, dam construction, and natural phenomena such as erosion and climate change can all have a negative impact on surface water quality and quantity; however, it is unclear how these processes lead to water pollution [20]. River pollution not only damages the livelihoods and health of the people who live near the water and rely on it for drinking and farming, but it also endangers the entire aquatic ecosystems. Kenya is also experiencing growth in population and increased urbanization in rural areas, which has been intricately linked to high demand for water for industrial, domestic and farm use [12]. This highlights the importance of determining the status of water quality in rivers in order to provide policymakers with an informed basis for action. Extant studies have focused on aspects of litter decomposition [21], willingness to pay for services regarding river management [21] and assessing the role of biochar in the reduction of heavy metals [22]. Rarely, the literature relating to the study area has focused on water quality status of River Kapingazi. Therefore, this study seeks to determine the status of water quality based on physiochemical and heavy metal in River Kapingazi.

2. Materials and Methods

2.1. Study Area

The study was conducted at four sampling points (**Table 1**) of River Kapingazi, which flows south of Mt Kenya (**Figure 1**) and is a significant tributary of River Rupingazi, which in turn flows into River Tana, the Kenya's largest river [23]. Kapingazi River is located in the upper catchment region of the Tana River basin, where its water is used for drinking, domestic purposes, livestock and irrigation. It also acts as a source of livelihood in that majority of the residents along the River rely on income generating activities like car washing and water vending besides isolated fishing. Sampling point one was selected because it is close to Mt. Kenya forest and it was hypothesized that pollution at this site is low. This area is also a tea zone hence it hosts a vast plantation of tea and natural vegetation; and trees such as Eucalyptus and wattle are present along the river banks. Sampling point two is characterized by grazing along the river and it was hypothesized that level of pollution would likely to increase. This is evident from increased farming activities along the river forming a potential source of pollution. Sampling point 3 comprised of a natural vegetation, black beetles in the river. The mining industry, called Eagle One, situated near the river, and farming activities serve as the potential sources of pollution. Sampling point 4 which is in the furthest section of the downstream was hypothesized to have heightened levels of pollution. At this point, there is no natural vegetation and tree nursery, residential houses and restaurants formed the potential sources of pollution.

Table 1. Specific locations along River Kapingazi.

Sampling Campaign	Location	Latitude	Longitude
1	Kiriari	S 0 24 7	E 37 29 3
2	Kairuri	S 025 33	E 37 28 19
3	Kangaru	S 0 29 59	E 37 27 41
4	Muthatari	S 0 32 38	E 37 28 24

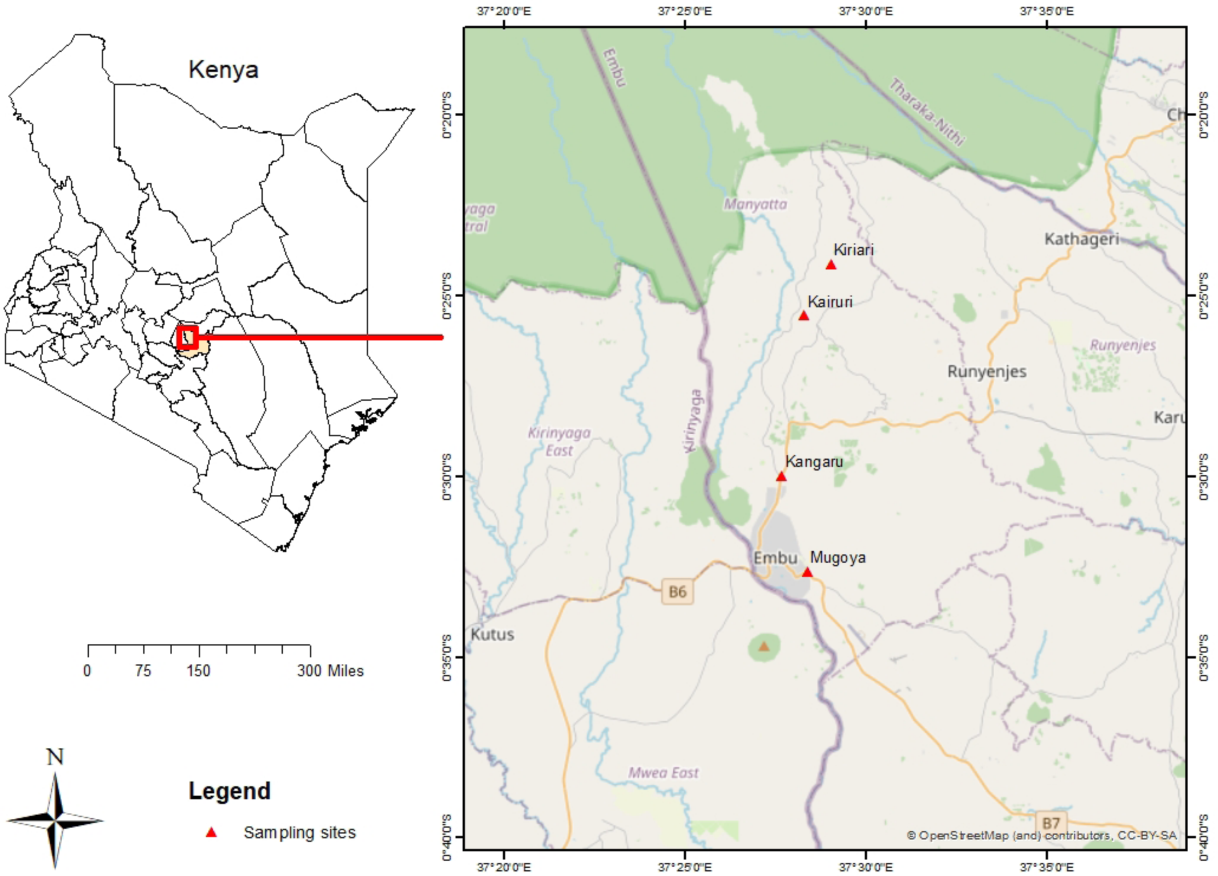

Figure 1. Map of the study area.

2.2. Sampling Procedure

Samples used in this study were collected for a period of 8 months, form March to October 2024. Every sampling was conducted once a month at all four sampling points in triplicate, totaling 96 samples. Plastic bottles with a capacity of 250 milliliters were used to collect water samples. The bottles were cleaned and rinsed twice with 1-2 milliliters of 2% hydrochloric acid, developed specifically for industrial use. The water samples were collected securely, while cautiously avoiding sampling aeration, and properly labeled. The water samples were transported carefully to the Water Resource Chemistry laboratory, where they were kept for the purpose of conducting both chemical and physical analysis. It was determined that the samples were obtained from the river at intervals of approximately 1km. Accuracy and precision of the analytical data was ensured through running the samples in triplicate analyses and a quality control chart was maintained to monitor the analyses. Digestion for heavy metal analysis involved measuring 100 ml of the sample and adding 5 to 20 mls of concentrated HCL depending on the level of turbidity, then evaporating the sample mixture to reduce the sample to 40 ml, transferring into the 50 mL conical flask and topping up to the mark with 1 percent nitric acid. Physical parameters were measured using calibrated portable multi-parameter analyzer H19829 HANNA made in USA, while traces of heavy metals were analyzed using Atomic Spectrophotometer machine SHIMADZU AA-7000 made in Italy. Nutrients were measured using UV 1800PC (SPECORD 200 PLUS made in Germany.

2.3. Procedure of Measuring Water Quality Parameters—Determination of Water Quality Index

This investigation aimed to evaluate the appropriateness of utilizing Kapingazi River water for household applications by employing the Water Quality Index (WQI). The study adopted techniques of evaluating WQI from existing studies related to this research [19,24,25]. The technique selected requires that the study parameters be assigned weight values (Wu) according to their importance in water quality. A Likert scale of 1–5 is used to assign values to the parameters, while 1 means the lowest health impact and 5 represents a highly detrimental health impact as far as water quality consumed is concerned. Weight values (Wu) are then used to calculate relative weightage values as shown in Equation (1).

$$Wr = \frac{W_u}{\sum W_u} \tag{1}$$

The next procedure is computation of quality rating (Q_i) for each selected parameter as shown in Equation (2).

$$Q_i = \frac{V_a - V_i}{S_i - V_i} x100 \tag{2}$$

Where, Q_i is the rate of quality of the selected i^{th} water quality parameter, S_i is the standard value of each parameter provided by World Health Organization (WHO), V_a is the observed value of the selected i^{th} water quality parameter obtained from laboratory analysis while V_i it the ideal value of the selected i^{th} water quality parameter. It has been observed that V_i for pH is 7, while for the rest of the parameters, it is 0.

The product of W_r and Q_i yields the parameter sub-indexes (PI_s), which are calculated as shown in Equation (3).

$$PI_s = W_r Q_i \tag{3}$$

The resultant PI_s are summed up to yield WQI as shown in Equation (4). The WQI is then compared with the Water Quality Status (WQS) provided in **Table 1** in order to understand the quality of water in the River Kapingazi.

$$WQI = \sum PI_s \tag{4}$$

3. Results

Table 2 contains WQS adopted from the previous study [26]. It corresponding to a set of categories of WQIs and recommended use of each category.

Table 3 presents standard international (SI) units, standard values, ideal values including the reference agencies for the selected water quality parameters.

Table 2. Classification of water quality index.

WQI	WQS	Recommended Use
0-25	Excellent	Domestic, farm and industry
26-50	Good	Domestic, farm and industry
51-75	Poor	Farming and industry
76-100	Very poor	Farming
Above 100	Unsafe for drinking	Treat before use

Table 3. Standards of water quality parameters.

Variable	Unit	Standard Value	Ideal Value	Reference Agency
Turbidity	N-T-U	5	0	WHO
Temperature	° C	20		WHO

Table 3. *Cont.*

Variable	Unit	Standard Value	Ideal Value	Reference Agency
pH	pH scale	8.5	7	WHO
Dissolved Oxygen (DO)	mg/l	5	14.6	WHO
Total Dissolved Solids (TDS)	mg/l	1000	0	WHO
Electric Conductivity	µS/cm	250	0	WHO
Iron	mg/l	0.3	0	WHO
Manganese	mg/l	100	0	WHO
Nitrates	$mgNO_3/l$	50	0	WHO
Phosphates	mg/l	30	0	WHO

3.1. Distribution of Water Quality Parameters

Results in **Table 4** illustrate the distribution of parameters across the 96 samples that were collected in the study. A study reported that TDS, EC, DO and turbidity were significant indicators of pollution [27]. Similarly, TDS, temperature, phosphate and turbidity as well as manganese were found to be significant contributors to pollution, and as a result, they cause poor water quality [28,29]. The findings reveal that turbidity ranged from a minimum of 2.60 NTU to a maximum of 135 NTU and this variation was likely influenced by factors such as rainfall, erosion, and runoff. The need to conserve the riverine ecosystem through local environmental regulations and policies is essential to maintain an acceptable level of turbidity in the River Kapingazi if it has to continue providing its traditional services and goods. The temperature fluctuated from 17.02 °C to 22.20 °C, indicating seasonal variations and potential impacts from thermal pollution linked to nearby activities such as farming. The pH varied from a neutral 7.00 to a highly alkaline 10.30, suggesting potential chemical influences or geological variations affecting the water's alkalinity.

Table 4. Statistics showing distribution of water quality parameters.

Parameter	Wet Season Min	Wet Season Max	Dry Season Min	Dry Season Max
pH	7.48	9.5	7	10.3
EC	12	88	7	72
DO	1.36	2.56	1.42	2.37
TDS	6	44	6	36
Turbidity	3.2	79.3	2.6	135
Temperature	18.11	22.2	17.02	21.48
Iron	0.1	6	0.1	0.8
Manganese	0.13	1.24	0.5	1.48
Nitrate	0	4.5	0	3.99
Phosphates	0	2.51	0	2.08

Dissolved Oxygen levels varied from 1.360 to 2.56 mg/L, indicating a relatively low concentration. This is significant, as oxygen levels are crucial for aquatic life and may suggest potential organic pollution. The range of TDS observed was between 6.00 mg/L and 44.00 mg/L, indicating the variability in dissolved mineral content, which may arise from natural sources or human activities. The observed range of Electric Conductivity spanned from 7.000 µS/cm to 88.000 µS/cm, indicating fluctuations in ion concentration and possible variations in salinity among different locations. The concentration of iron varied significantly in the samples, ranging from 0.100 to 6.00 mg/l. Elevated levels of this metal may be attributed to factors such as industrial waste discharges, natural mineral deposits, or the corrosion of pipelines. The observed Manganese levels varied between 0.1278 mg/L and 1.480 mg/L, indicating potential natural mineral leaching or changes resulting from human activities. The Nitrates concentration varied between 0.000 and 4.500 mg/L, indicating potential localized runoff from agricultural activities or wastewater discharge in specific regions. The phosphate concentration exhibited a range from 0.000 to 2.047 mg/L. Elevated values may be associated with agricultural fertilizers, detergents, and industrial effluent.

3.2. Statistical Analysis of Water Quality Parameters

The results in **Table 5** present the statistical analysis of selected water quality parameters in form of means and standard deviation during the dry, wet and entire season. From the findings turbidity levels recorded during the dry season were 32.09 NTU, which is higher than the wet season's 25.35 NTU, resulting in an overall mean of 28.72 NTU. The elevated turbidity observed during the dry season may be due to diminished water flow, potentially leading to the accumulation of suspended particles. This significant variability in water clarity, likely influenced by factors such as rainfall, erosion, and runoff during the wet season. Similar seasonal variation of turbidity was also observed in Lakes [30]. The overall mean temperature across both seasons was 19.56 °C. The observed variation corresponds with the fluctuations in seasonal ambient temperature and precipitation levels [31]. The pH levels averaged in moderate alkaline ranges during both seasons, with the wet season exhibiting a slightly elevated average of 8.34, in contrast to the dry season's average of 8.08. The mean pH of 8.21 indicates minimal seasonal variation in water pH levels. The findings correlate well with those of Osifeso et al. [32], who found that water in River Ogun situated in Nigeria was alkaline. However, Dey et al. [33] reported that pH is lower during the dry season and higher during the wet season, and this difference can be attributed to the underlying geology, soils upstream, human activities that include use of fertilizers and dumping. The DO exhibited only minor variation across seasons, although values were somewhat lower during the dry season. The overall mean of dissolved oxygen (DO) was recorded at 1.85 mg/L, with observed values ranging from 1.81 mg/L during the dry season to 1.89 mg/L in the wet season. Notably, During the wet season, faster streamflow leads to increased dissolution of O_2 due to turbulent flow, in contrast to the laminar flow observed during the dry season. Again during dry season, slow rate allows more utilization of O_2 by the benthic organisms (micro- and maro-). This suggests a generally low availability of oxygen, potentially linked to the decomposition of organic matter and the stagnation of water. The findings of Saturday et al. [34] indicated seasonal variation in DO in River Bunyonyi.

Table 5. Statistical analysis of the parameters in seasons.

Variable	Wet Season Means ± SD	Dry Season Means ± SD	Combined Means ± SD
Turbidity	25.35 ± 21.05	32.09 ± 37.48	28.72 ± 30.43
Temperature	20.46 ± 1.25	18.66 ± 1.24	19.56 ± 1.54
PH	8.34 ± 0.59	8.08 ± 0.82	8.21 ± 0.72
Dissolved Oxygen (DO)	1.89 ± 0.31	1.81 ± 0.29	1.85 ± 0.30
Total Dissolved Solids (TDS)	17.13 ± 10.45	14.88 ± 9.08	16.00 ± 9.81
Electric Conductivity	33.39 ± 21.34	29.31 ± 18.49	31.35 ± 19.97
Iron	0.51 ± 0.83	0.37 ± 0.18	0.44 ± 0.60
Manganese	0.62 ± 0.29	0.94 ± 0.30	0.78 ± 0.33
Nitrates	1.37 ± 1.04	1.37 ± 1.11	1.37 ± 1.07
Phosphates	0.72 ± 0.56	0.47 ± 0.56	0.59 ± 0.57

The total dissolved solids (TDS) exhibited a higher concentration during the wet season, recorded at 17.13 mg/L, compared to the dry season, which showed a lower concentration of 14.88 mg/L. The overall mean TDS across both seasons was calculated to be 16.00 mg/L. The rise in TDS levels during the wet season can be attributed to surface runoff that transports dissolved substances into water bodies. The electric conductivity exhibited higher values during the wet season at 33.39 µS/cm and lower values in the dry season at 29.31 µS/cm, resulting in a combined mean of 31.35 µS/cm. The variations in conductivity may be associated with seasonal water inflow, enhanced from the runoff, which delivers differing quantities of dissolved ions. Iron concentrations exhibited a slight increase during the wet season, measuring 0.51mg/L, compared to the dry season, which recorded 0.37 mg/L. The overall mean concentration was 0.44 mg/L. The rise observed during the wet season could be attributed to surface runoff that brings in iron-rich sediments [35]. Manganese concentrations were higher during the dry season, measuring 0.94 mg/L, in comparison to the wet season, which recorded levels of 0.62 mg/L. The overall mean concentration was 0.78 mg/L. The observed phenomenon could be attributed to the reduced dilution effects during the dry season, which consequently leads to an increase in manganese concentration. The results contradict those of Chai et al. [28] who found that the concentration of manganese was higher during the wet season in Fen River. The nitrates concentration remained consistent across both seasons, recorded at 1.37 mg/L, indicating a negligible seasonal fluctuation in nitrogen-related pollution. The NO_3^{-1} from agricultural practices may have been rapidly absorbed by plants due to high nutrient demand and its ease of dissolution, in addition to its volatility, making it less available. The phosphate concentration exhibited a higher value during the wet season, recorded at 0.72 mg/L, compared to the dry season, which measured 0.47 mg/L. The overall average is 0.59 mg/L. This suggests that the runoff containing fertilizers from agricultural fields and other sources elevates phosphate concentrations during the wet season. Unlike nitrates, phosphates are less soluble, giving them a longer residence time, and are thus more prone to runoff loss that finds itself in surface water bodies like rivers. Even though the phosphorous and nitrates showed relative stability, the findings of Hou et al. [36] revealed that its concentration was higher during summer and spring seasons compared to autumn season.

3.3. Correlation of Selected Water Quality Parameters

Results in **Table 6** illustrate the existing relationship among the different water quality parameters in the River Kapingazi. Results indicate that there was a strong positive correlation between EC and TDS , significant at the 1% level. This indicates that elevated levels of total dissolved solids in water lead to an increased electrical conductivity, which is expected since both serve as indicators of the mineral content in water. The EC also revealed significant relationship with turbidity and temperature. Similarly, potential of hydrogen (pH) showed significant negative association with EC, TDS, Turbidity, manganese and nitrates. Dissolved oxygen had significant relationship which was positive with temperature and negative with manganese. Positive significant relationship was observed between TDS and temperature as well as turbidity. Manganese and nitrate also displayed positive relationship with turbidity.

Table 6. Matrix of correlations of water quality parameters.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) pH	1.000									
(2) EC	-0.519*	1.000								
(3) DO	-0.100	0.256	1.000							
(4) TDS	-0.494*	0.994*	0.278	1.000						
(5) Turbidity	-0.460*	0.389*	-0.308	0.379*	1.000					
(6) Temperature	0.065	0.458*	0.490*	0.468*	-0.056	1.000				
(7) Iron	-0.192	0.245	0.085	0.243	0.256	0.183	1.000			
(8) Manganese	-0.483*	0.057	-0.330*	0.022	0.581*	-0.443	0.151	1.000		
(9) Nitrates	-0.345*	0.226	-0.094	0.231	0.477*	-0.042	0.141	0.140	1.000	
(10) Phosphates	0.167	0.153	0.180	0.129	-0.204	0.168	0.014	-0.188	-0.169	1.000

3.4. Water Quality Index of River Kapingazi

Table 7 profiles the weightage values (Wu), relative weights (Wr), rates of quality (Qr) and also the sub-indexes (PIs) for the two seasons and for the combined period. Using ten parameters, the water quality index obtained was 88.02137 for the combined seasons, 74.04511 for the dry season and 89.66551 for the wet season. This shows that the WQI for the River Kapingazi ranged from 74.04511 to 89.66551.

Table 7. Computation of water quality index for combined, dry and wet seasons.

Variable	Wu	Wr	Combined Seasons		Dry Season		Wet Season	
			Qr	PI	Qr	PI	Qr	PI
pH	4	0.114286	80.7000	9.222857	72.0000	8.228571	89.300	10.20571
EC	3	0.085714	12.5400	1.074857	11.7240	1.004914	13.356	1.1448
Turbidity	3	0.085714	574.4400	49.23771	23.6000	2.022857	37.800	3.24
DO	5	0.142857	37.0200	5.288571	297.6000	42.51429	342.60	48.94286
TDS	3	0.085714	1.6000	0.137143	3.2090	0.275057	2.5350	0.217286
Temperature	2	0.057143	97.8000	5.588571	93.3000	5.331429	102.30	5.845714
Iron	4	0.114286	147.5667	16.86476	123.3333	14.09524	170.00	19.42857
Manganese	3	0.085714	0.78000	0.066857	0.9400	0.080571	0.6200	0.053143
Nitrates	4	0.114286	2.74200	0.313371	2.7400	0.313143	2.7400	0.313143
Phosphates	4	0.114286	1.98333	0.226667	1.56667	0.179048	2.4000	0.274286
WQI				88.02137		74.04511		89.66551

3.5. Status of Water Quality in River Kapingazi

Results in **Table 8** present the findings on the water quality status of the River Kapingazi based on the study selected parameters. Findings show that during the dry season, an overall Water Quality Index (WQI) of 74.045 was recorded, categorizing the condition as poor. In the wet season, the WQI recorded a value of 89.666, categorizing it as very poor. The integrated WQI for both seasons was determined to be 88.021, indicating that the classification was very poor.

Table 8. Status of water quality in River Kapingazi.

Season	WQI	WQS	Recommended Use
Dry season	74.045	Poor	Farming and industry
Wet season	89.666	Very poor	Farming
Combined	88.021	Very poor	Farming

4. Discussion

The findings of the study suggest that the only suitable use for this water is agriculture and specific industrial applications, however, it remains unsuitable for direct human consumption. The limited availability of water during this season results in an increased concentration of pollutants. This may represent a potential factor contributing to the diminished quality. In relation to the wet season, it is clear that surface runoff during the rainy season still introduces more contaminants, leading to a continued deterioration in water quality. Given the current circumstances, the only recommended application of water during this season is for agricultural purposes, due to potentially elevated contamination levels rendering it unsuitable for industrial or domestic use. This results correspond well with the findings of Aduwo & Adenyi [37] who reported that the water quality index of water in Lake Baringo was not suitable for human consumption as its standard surpassed the recommendation of WHO. However, the findings contrast with those of Saturday et al. [34] who found that the water quality of River Bunyonyi on overall was good. Similarly, 30% of the urban rivers examined in East Africa were found to be of good quality [38]. Further, the findings of Aduwo and Adenyi [39] indicated that the water of Research Farm Lake was safe for use in all other purposes except drinking. The water requires comprehensive treatment prior to being suitable for drinking, as its overall quality does not adequately meet the standards for consumption. Seasonal variation offers a clear illustration of how environmental elements, including precipitation and runoff, influence the overall dynamics of water quality. To improve water quality, Zou et al. [19] proposes that sewage treatment should be implemented. It is necessary to enforce treatment on water before use and also impose strict management practices to enhance water quality [40,41]. Maulud et al. [42] suggests that sources of pollution should be controlled to ensure that water quality in rivers is maintained.

5. Conclusion

This study aimed to determine the status of WQI in the River Kapingazi using the physicochemical properties of TDS, pH, EC, temperature, turbidity, iron, manganese, Nitrates and Phosphates. These parameters showed both positive and negative correlations across the dry and wet seasons, reflecting their dependence and influence from changes in the catchment of the river, leading to varying degrees of water pollution. According to the computations made from the two seasons, the WQI was very high indicating that water was not safe for domestic consumption. The recommended use during the dry season is irrigation and industrial use, and only agricultural use during the wet season. The higher index can be largely attributed to surface run off, poor drainage of irrigation systems, and undeniable reckless disposal of waste by humans including disposal of untreated effluents from nearby industries. To improve water quality, this study recommends a robust follow up on policies governing riparian area along the river banks including sensitizing the various users who depend on it for sustenance. The necessary management of the water catchment area should be instituted to improve drainage system and reduce runoff. It is also recommended that stakeholder involvement should be sufficiently done to ensure that policies such as establishment of buffer zones and effluent treatment under the existing institutional framework is embraced inclusively. To support the conclusions of this study, it can be recommended that more samples be taken from different water points with additional parameters.

Authors Contribution

N.C.Y. collected and analyzed data and drafted the original manuscript. C.O.N. was responsible for review and editing. R.Y. was responsible for review and editing. S.K. conducted data analysis, review and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research did not receive any financial support.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability

Research data will be available from the corresponding author upon request.

Acknowledgements

The authors acknowledge the National Commission for Science Technology and Innovation NACOSTI for granting the research permit, and the Key stakeholders from NEMA, Ministry of Agriculture Livestock and Fisheries, Water Resource Authority and EWASCO in Embu County.

Conflict of interests

The authors declare no conflict of interest.

References

[1] Xiang, X., Li, Q., Khan, S., et al., 2021. Urban water resource management for sustainable environment planning using artificial intelligence techniques. Environmental Impact Assessment Review. 86, 106515.

[2] Yang, D., Yang, Y., Xia, J., 2021. Hydrological cycle and water resources in a changing world: A review. Geography and Sustainability. 2(2), 115–122.

[3] El-Batrawy, O.A., Ibrahim, M.S., Fakhry, H., et al., 2018. Anthropogenic impacts on water quality of River Nile and marine environment, Rosetta Branch using geospatial analyses. Journal of Environmental Science. 47, 89–101.

[4] Gupta, S., Gupta, S.K., 2021. A critical review on water quality index tool: genesis evolution, and future directions. Ecological Informatics. 63, 101299.

[5] Mahlathi, C., Siyakatshana, N., Chirwa, E., 2016. Water quality modelling and optimisation of wastewater treatment network using mixed integer programming. Water SA. 42(4), 650–657.

[6] Nagy-Kovács, Z., Davidesz, J., Czihat-Mártonné, K., et al., 2019. Water quality changes during riverbank filtration in Budapest. Water. 11, 302.

[7] Sandhu, C., Grischek, T., Börnick, H., et al., 2019. A water quality appraisal of some existing and potential riverbank filtration sites in India. Water. 11, 215.

[8] Mogane, L.K., Masebe, T., Msagati, T.A., et al., 2023. Water quality index models for lotic and lentic ecosystems – A systematic review. Environmental Monitoring and Assessment. 195(8), 926.

[9] Akhtar, N., Syakir Ishak, M.I., Bhawani, S.A., et al., 2021. Various natural and anthropogenic factors responsible for water quality degradation: A review. Water. 13(19), 2660.

[10] Isukuru, E.J., Opha, J.O., Isaiah, O.W., et al., 2024. Nigeria's water crisis: Abundant water, polluted reality. Cleaner Water. 2, 100026.

[11] Nkatha, K., 2024. Water woes: 13 undeniable facts about Africa's water. Greenpeace. Available from: https://www.greenpeace.org/africa/en/blog/55086/water-woes-13-undeniable-facts-about-africas-water-scarcity/ (cited 8 April 2025).

[12] Mulwa, F., Li, Z., Fangninou, F.F., 2021. Water scarcity in Kenya: current status, challenges and future solutions. Open Access Library Journal. 8(1), 1–15.

[13] Khan, S., Guan, Y., Khan, F., et al., 2020. A comprehensive index for measuring water security in an urbanizing world: the case of Pakistan's capital. Water. 12(1), 166.

[14] United Nations, 2023. Global Report on Sanitation and Wastewater Management in Cities and Human Settlements.

[15] Gaffan, N., Kpozehouen, A., Degbey, C., et al., 2023. Effects of household access to water, sanitation, and hygiene services on under-five mortality in Sub-Saharan Africa. Frontiers in Public Health. 11, 1136299.

[16] Hlongwa, N., Nkomo, S.P.L., Desai, S.A., 2024. Barriers to water, sanitation, and hygiene in Sub-Saharan Africa: a mini review. Journal of Water Sanitation and Hygiene for Development. 14(7), 497–510.

[17] Tariq, A., Mushtaq, A., 2023. Untreated wastewater reasons and causes: a review of most affected areas and cities. International Journal of Chemical and Biochemical Sciences. 23(1), 121–143.

[18] Fabian, P.S., Kwon, H.H., Vithanage, M., et al., 2023. Modelling, challenges and strategies for understanding impacts of climate extremes (droughts and floods) on water quality in Asia: a review. Environmental Research. 225, 115617.

[19] Zou, X.Y., Peng, X.Y., Zhao, X.X., et al., 2023. The impact of extreme weather events on water quality: International evidence. Natural Hazards. 115(1), 1–21.

[20] Zhang, Y., Zhao, Z., Zhu, J., et al., 2024. The dynamic patterns of critical ecological areas in the Yellow River Basin are driven primarily by climate factors but threatened by human activities. Journal of Environmental Management. 371, 123282.

[21] Ireri, B.K., Makenzi, P.M., Makindi, S.M., et al., 2024. Provisioning of water ecosystem services in the Kapingazi River Basin in Kenya: can prospects of willingness to pay improve water quality and quantity? Water International. 49(3–4), 410–416.

[22] Njoroge, M., Mwangi, E., Wandili, S., 2024. Utilization of bamboo biochar as an adsorbent in the removal of heavy metals from wastewater stabilization ponds effluent in Embu Town, Kenya. African Journal of Science, Technology and Social Sciences. 3(2), 9–18.

[23] Balana, B., Yatich, T., Mäkelä, M., 2011. A conjoint analysis of landholder preferences for reward-based land-management contracts in Kapingazi watershed,

Eastern Mt. Kenya. Journal of Environmental Management. 92, 2634–2646.

[24] Al-Ani, I.A., 2019. Mathematical computation of water quality index for the assessment of Al-Hilla River ecosystem. International Journal of Civil Engineering and Technology. 10(1), 1862–1869.

[25] Srinivas, P., Kumar, G.P., Prasad, A.S., et al., 2011. Generation of groundwater quality index map – A case study. Civil and Environmental Research. 1(2), 9.

[26] Wekesa, A.M., Otieno, C., 2022. Assessment of groundwater quality using water quality index from selected springs in Manga Subcounty, Nyamira County, Kenya. Scientific World Journal. 2022(1), 3498394.

[27] Rahman, A., Jahanara, I., Jolly, Y.N., 2021. Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh. Water Science and Engineering. 14(2), 139–148.

[28] Chai, N., Yi, X., Xiao, J., et al., 2021. Spatial–temporal variations, sources, water quality and health risk assessment of trace elements in the Fen River. Science of the Total Environment. 757, 143882.

[29] Oputu, O.U., Akharame, M.O., 2024. Assessment of surface water quality within Cape Town, South Africa using NSF water quality index. International Journal of Energy and Water Resources. 8(4), 493–505.

[30] Mishra, K., Choudhary, B., Fitzsimmons, K.E., 2024. Predicting and evaluating seasonal water turbidity in Lake Balkhash, Kazakhstan, using remote sensing and GIS. Frontiers in Environmental Science. 12, 1371759.

[31] Marisi, D.P., Suprihatin, S., Hariyadi, S., et al., 2025. The impacts of land use and cover change on water quality of watershed basin. Global Journal of Environmental Science and Management. 27(11), 1019.

[32] Osifeso, O.O., Umoren, O.D., Akinbola, M.G., et al., 2025. Heavy metals (HMs) concentration in two sections of Ogun River, Abeokuta, Ogun State, Nigeria. World News of Natural Sciences. 60, 115–125.

[33] Dey, S., Botta, S., Kallam, R., et al., 2021. Seasonal variation in water quality parameters of Gudlavalleru Engineering College pond. Current Research in Green and Sustainable Chemistry. 4, 100058.

[34] Saturday, A., Lyimo, T.J., Machiwa, J., et al., 2021. Spatial–temporal variations in physicochemical water quality parameters of Lake Bunyonyi, Southwestern Uganda. SN Applied Sciences. 3(7), 684.

[35] Haghighizadeh, A., Rajabi, O., Nezarat, A., et al., 2024. Comprehensive analysis of heavy metal soil contamination in mining environments: impacts, monitoring techniques, and remediation strategies. Arabian Journal of Chemistry. 105777.

[36] Hou, W., Wang, H., Zheng, Y., et al., 2022. Seasonal variation characteristics of water quality in the Sunxi River Watershed, Three Gorges Reservoir Area. PeerJ. 10, e14233.

[37] Walumona, J.R., Odoli, C.O., Raburu, P., et al., 2021. Spatio–temporal variations in selected water quality parameters and trophic status of Lake Baringo, Kenya. Lakes & Reservoirs: Research & Management. 26(3), e12367.

[38] Chen, S.S., Kimirei, I.A., Yu, C., et al., 2022. Assessment of urban river water pollution with urbanization in East Africa. Environmental Science and Pollution Research. 29(27), 40812–40825.

[39] Aduwo, A.I., Adeniyi, I.F., 2019. The physico-chemical water quality of the Obafemi Awolowo University teaching and research farm lake, OAU campus, Ile-Ife, Southwest, Nigeria. Journal of Envi-ronmental Protection. 10(7), 881.

[40] Subramanian, A., Baskar, S., 2022. Water quality assessment of Noyyal River using water quality index (WQI) and multivariate statistical techniques. Water Science. 36(1).

[41] Ram, A., Tiwari, S.K., Pandey, H.K., et al., 2021. Groundwater quality assessment using water quality index (WQI) under GIS framework. Applied Water Sciences. 11, 1–20.

[42] Abdul Maulud, K.N., Fitri, A., Wan Mohtar, W.H.M., et al., 2021. A study of spatial and water quality index during dry and rainy seasons at Kelantan River Basin, Peninsular Malaysia. Arabian Journal of Geosciences. 14, 1–19.