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Effects of Temporal Rainfall Variability on Water Quality of River Ruiru, Kiambu County, Kenya

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ABSTRACT

This paper assessed the effects of temporal rainfall variability on water quality of River Ruiru, Kiambu County. Findings from the study indicated that DO, TDS, thermal conductivity, total phosphorus and total nitrogen values were within World Health Organization (WHO) (2011) and National Environment Management Authority (NEMA) (2006) recommended values. The BOD values were found to be within NEMA (2006) limits in all sampling sites though above WHO (2011) limits both seasons except at Kwa Maiko where they were within the limit during the dry season. The pH and turbidity values were above WHO (2011)/ NEMA (2006) recommended values during dry and wet seasons except for Ruiru dam sampling site where they were within the limits during the dry season. The results for the total coliforms and E. *coli* indicated that River Ruiru was severely polluted. Moreover, the results indicated that pH, turbidity, DO, thermal conductivity and TDS had higher mean during wet season (M=8.40, M=79.00, M=51.20, M=87.00 and M=54.20) than in dry season (M=6.80, M=11.60, M=43.40, M=73.00, and M=45.40). The difference for these water quality parameters between dry and wet seasons was significant (P=0.003, P=0.034, P=0.005, P=0.013 and P=0.014).These findings will help in understanding the effects of temporal rainfall variability on water quality which is one component of the knowledge base required in applying the principles of integrated water resources management (IWRM) thus providing critical input to the decision making on water resources management and planning.

Keywords: River Ruiru, Temporal rainfall, Watershed, Water quality

INTRODUCTION

Water comprises over 70% of the earth's surface and therefore undoubtedly the most precious natural resource that exists on the planet without which life would be non-existent (Akali *et al.*, 2011). Water has a vital role in the global economy (WWAP, 2006; Baroni *et al.*, 2007) and is essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all (WHO, 1993; WHO, 1995).Climate-related river water quality issues have received considerable attention in recent years (Delpla *et al.*, 2009; Whitehead *et al.*, 2009). Particularly, changes in precipitation which leads to changes in water resources (IPCC, 2007). According to Bae (2007) water quality of rivers is affected by both point and non-point source pollutants and rainfall events play an important role as carriers of these pollutants. Consequently, changes of flow rate of rivers between rainy season and dry season could bring difficulties in maintaining a river's water quality (Lee *et al.*, 2005).

The Sustainable Development Goal (SDG) number six places emphasis on ensuring availability and sustainable management of water and sanitation for all (UNCSD, 2012). The social pillar of the Kenya vision 2030, aims to provide its citizens with a clean, secure and sustainable environment by the year 2030 (GOK, 2007). Moreover, the Government of Kenya (2010) also acknowledges that the environment is a heritage that must be managed sustainably. Indeed, part two of chapter five of the constitution provides for the management and conservation of the environment in order to *inter alia* conserve biological diversity and ensure that the right of all to a clean and secure environment is upheld.

River Ruiru watershed is an important water resource as it includes Ruiru 1 and the proposed Ruiru 2 dams important for inter-basin water transfer to Nairobi City County. This is due to the fact that the towns around the city of Nairobi that share water resources from the Aberdares are among the worst hit by water scarcity resulting from the ever increasing demand. The capacity of water resources in the headwater regions has been declining with time due to a number of factors including catchment degradation and reduced rainfall to recharge the sources (ESIA, 2014). River Ruiru is one of the major perennial tributaries of River Athi which provides water to the population in the vast semi-arid parts of Kenya for various purposes before discharging into the Indian Ocean. This study therefore assessed the effects of temporal rainfall variability on water quality of River Ruiru, Kiambu County.

MATERIALS AND METHODS

The study area description

River Ruiru originates from Kikuyu plateau and drains to the south eastern slopes of the Aberdare ranges in Kiambu County. It is hydrologically located within the Athi Basin 3BC sub-basin administered from upper Athi Water Resource Authority (WRA) in Kiambu. It is the major river in River Ruiru watershed with its main tributaries being Makuyu, Gatamaiyu and Komothai (ESIA, 2014). It is located in a medium rainfall potential area of Athi Basin with moderate and reliable rainfall. The area has two distinct rainy seasons: The long rains are experienced in March-April-May (MAM) while short rains are experienced in October and November. Rainfall pattern in the watershed has changed in the recent past with years recording less than the mean annual rainfall becoming more frequent. Temporal rainfall variability over the years varies between 590mm to 1390mm (CIDP, 2018). The mean temperature is 26°C with temperature ranging from 17.1°C in the upper highlands to 34°C in the lower midlands and shows an increasing trend in the recent past. July and August are the months during which the lowest temperatures are experienced while January, February and March are the hottest months (ESIA, 2014).

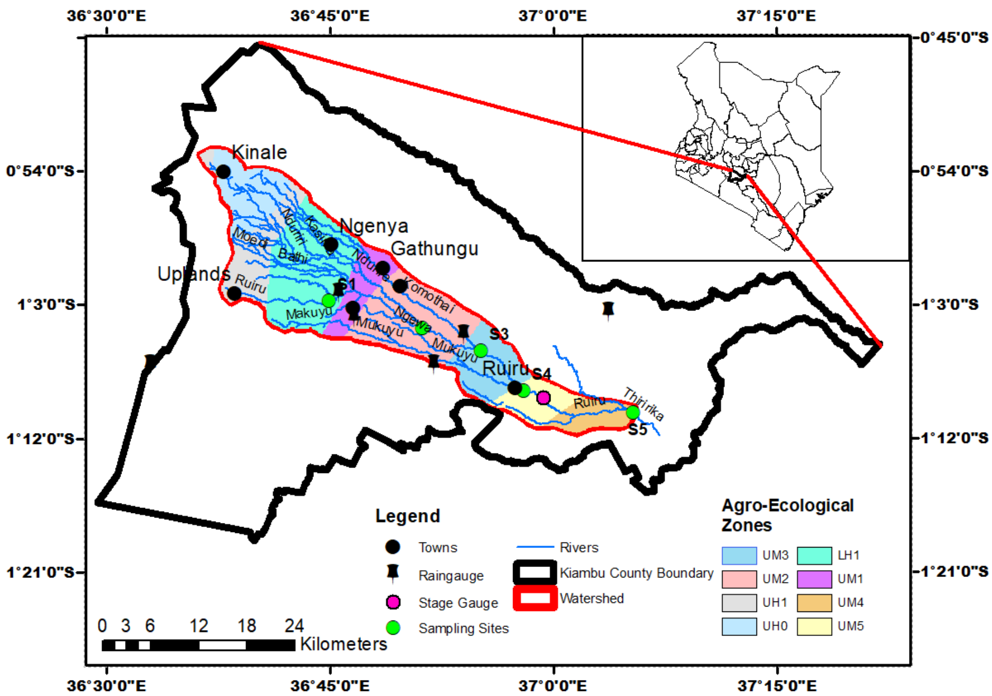

Figure 1: River Ruiru Watershed

Water sample collection

According to Patil *et al.* (2012) the selection of water quality assessment parameters depends on the needs and objectives of the assessment. This study considered water quality parameters that affect drinking water standards as per WHO (2011) and NEMA (2006) standards. Water quality samples for thermal conductivity, pH, temperature, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), total nitrogen, total phosphorus, total coliforms and *Escherichia coli (E. coli)* were collected in the field during the dry season in January and February 2018 and wet season in April and May 2018. Water sample collection was done in duplicates and three times for each season.

The collected water samples were subjected to the standard procedures for testing physico-chemical and biological water quality for drinking purposes in the field and in the laboratory according to APHA (1996). The water samples for laboratory analysis were immediately placed in a lightproof insulated box containing ice packs with water to ensure rapid cooling. The samples were transported to the Central Water Testing Laboratories in Nairobi for analysis and quantification. They were refrigerated at temperature of 4°C while waiting for analysis. The time between sample collection and analysis never exceeded 6 hours and 24 hours was considered as the absolute maximum.

Water quality samples were taken from five sampling sites; at Ruiru dam-downstream (S1), Kwa Maiko (S2), Jacaranda coffee research centre (S3), Ruiru town-downstream (S4), Ruiru sewerage treatment plant-downstream (S5) as shown in Figure I. These were representative of different land use and land cover based on different agro-ecological zones and settlement patterns within the study area. An extensive field survey was performed using GPS GARMIN 64s equipment to obtain accurate GPS coordinates for mapping water sampling sites.

Data Analysis

The obtained mean values for each water quality parameter were compared with the standard values set by WHO (2011) and the local standards set by NEMA (2006). A paired sample t-test was performed to compare the effects of temporal rainfall variability on water quality during dry and wet seasons. A repeated measured t-test was performed to determine any significant difference of water quality parameters during dry and wet seasons. During the analysis, 95% level of significance was used as the critical point ($p<0.05$).

RESULTS AND DISCUSSIONS

The results of the study in Tables 1 and 2 indicated that River Ruiru had high turbidity values both in dry and wet seasons except for the area around Ruiru dam sampling site whose values were within the limits during the dry season. Turbidity levels exceeded the allowable WHO (2011)/NEMA (2006) levels at Kwa Maiko, Jacaranda Coffee Research Centre, Ruiru town and the area downstream the sewerage plant. The pH was also higher than WHO (2011)/NEMA (2006) recommended values in all the sampling sites during the wet season while within limit at Ruiru dam sampling site only during the dry season. The BOD values were found to be within NEMA (2006) limits in all sampling sites though above WHO (2011) limits both seasons except at Kwa Maiko where they were within the limit during the dry season. The results for the total coliforms and *E. coli* indicated that River Ruiru was highly polluted. Their levels were very high and above WHO (2011)/NEMA (2006) values in all the sampling sites. Total coliforms were high during dry season while *E. coli* were high during the wet season. The TSS values exceeded the allowable WHO (2011)/NEMA (2006) limits at the area downstream sewerage treatment plant during the wet season. The DO, TDS, thermal conductivity, total phosphorus and total nitrogen levels were within WHO (2011)/NEMA (2006) recommended values in both seasons.

The results indicated that pH, turbidity, DO, thermal conductivity and TDS had a higher mean values during wet season than in dry season. The findings also indicated that the difference between dry and wet season was significant. This implies that temporal rainfall variability significantly affects the pH, turbidity, DO, thermal conductivity and TDS of River Ruiru. Similarly, a study on spatial and temporal variations of water quality observed seasonal difference in the physico-chemical composition of water during dry and wet season (Fan *et al.*, 2012; Tlili-Zrelli *et al.*, 2018). Ojok *et al.* (2017) observed that colour, turbidity, TSS, TDS, pH, BOD and DO were higher in rainy season as a result of erosion discharge of domestic and industrial waste. Razelan *et al.* (2018) in their study noted that during the wet season, the water was impaired by the non-point sources which originated from the upstream of the water while the point sources were dominating the pollution of the Segamat River during the dry season.

The results also showed that River Ruiru had high turbidity both during the dry and wet season except for the site at Ruiru dam whose turbidity values were within WHO (2011)/NEMA (2006) limits. The pH was also above WHO (2011)/NEMA (2006) recommendations during the wet season except for Ruiru dam sampling site. This could have been attributed to human activities such as agriculture, car wash and laundry activities taking place along the river except for the area around Ruiru dam which was within a forest zone. High BOD values at Jacaranda and downstream Ruiru treatment plant could be attributed to domestic effluent into the river, organic waste and use of chemical fertilizers. On the contrary, Mbui *et al.* (2016) observed that BOD was slightly higher in dry season compared to wet season due to dilution of water during wet season and sedimentation process during the dry season. In addition, they observed that the values of BOD for both seasons were below NEMA limit for effluent discharge into natural water courses and above the WHO limit for drinking water. The DO profile may also be attributed to the relatively higher BOD levels during the dry season compared to the wet season. The higher the BOD level, the more rapidly oxygen is depleted resulting to low DO levels.

The TSS values were above WHO (2011)/NEMA (2006) recommended values at the site downstream Ruiru sewerage treatment plant during wet season. This could have been attributed to the construction of the sewerage plant which was taking place in the area. Total coliforms and *Escherichia Coli* were very high and above WHO (2011)/NEMA (2006) recommended values which could have been attributed to discharge of raw sewerage from industries and wastes washed from agricultural, residential and urban areas. The increase in water pollution in River Ruiru may also have been contributed to increased surface runoff from agricultural lands and storm water from the built-up areas. This is because of the fact that surface runoff is a carrier of other components such as sediments, nutrients, pesticides, bacteria and agricultural wastes that undesirably affect water quality.

The level of total coliforms and *E. coli* in River Ruiru is contrary to WHO (2003) drinking water guidelines in which the minimum microbiological quality of water was set as an absence of faecal indicator bacteria such as

Escherichia Coli and *Salmonella typhi.* UNICEF (2008) concluded that when the faecal coliform counts are high over 200 colonies/100ml of a water sample in a water body, there is a great chance that disease causing organisms are present. Similarly, Tornevi *et al.* (2014) in their study which aimed to determine how daily rainfall causes variation in indicators of pathogen loads observed that rainfall was associated with exponential increases in concentrations of indicator bacteria while the effect on turbidity attenuated with very heavy rainfall. Manyatshe *et al.* (2016) observed elevated concentration of parameters were mainly predominant in wet season, which may be due to washout of contaminants from polluting sources into surface water.

However, findings of this study indicated that DO, TDS, total phosphorus and total nitrogen levels were within WHO (2011)/NEMA (2006) guidelines. The trend for TDS values was similar to that of observed thermal conductivity. This is expected since most dissolve solids in water are ionic species which tend to increase thermal conductivity. Ontumbi (2015) also found that the water quality parameters with high quantities included *E. coli*, turbidity and TSS while pH, nitrates and phosphorus were within WHO/NEMA standards. Rostani *et al.* (2018) also concluded that some water quality parameters such as turbidity and total phosphorus would increase, whereas other parameters would decrease or show no appreciable change under the projected increase of precipitation under the medium climate change scenario for the river basin.

Table 1: Mean water quality parameter values for the dry season

Sampling sites	pH	Turb. (NTU)	Temp. (℃)	DO (mg/l)	EC (µs/cm)	TDS (mg/l)	BOD (mg/l)	TSS (mg/l)	TN (mg/l)	TP (mg/l)	TC (mg/l)	E. *Coli* (mg/l)
Ruiru dam $1^0$02S, $36^0$45E	6.0	3.5	25.8	17.5	61	37.82	4	10	0.0003	0.19	69100	238
Kwa Maiko $1^0$04S, $36^0$51E	6.7	7.5	21.7	45.6	53.7	33.29	3	20	0.001	0.14	79150	980
Jacaranda $1^0$06S, $36^0$54E	7.0	20.7	21.5	50.8	60.5	37.51	12	20	0.001	0.35	96000	196
Ruiru town $1^0$09S, $36^0$58E	6.9	13.5	22.1	52.5	88	54.56	5	20	0.001	0.33	10110	649
Downstream sewerage plant $1^0$10S, $37^0$02E	7.3	11.3	22.5	50.0	102	63.24	7	20	0.001	0.54	17330	1046

Table 2 Mean water quality parameter values for the wet season

Sampling site	pH	Turb. (NTU)	Temp. (^{0}C)	DO (mg/l)	EC (µs/cm)	TDS (mg/l)	BOD (mg/l)	TSS (mg/l)	TN (mg/l)	TP (mg/l)	TC (mg/l)	E. *Coli* (mg/l)
Ruiru dam $1^0$02S, $36^0$45E	7.8	0	22.4	22.2	71	44.02	4	10	0.0003	0.58	24200	10800
Kwa Maiko $1^0$04S, $36^0$51E	8.8	74	20.6	55.0	64	39.68	7	14	0.001	0.42	242000	141400
Jacaranda $1^0$06S, $36^0$54E	8.0	76	20.2	56.0	67	41.54	6	20	0.001	0.58	2420000	687000
Ruiru town $1^0$09S, $36^0$58E	7.9	115	22.0	63.0	106	65.54	8	20	0.001	0.65	24200000	15530000
Downstream sewerage plant $1^0$10S, $37^0$02E	8.6	130	23.0	60.0	127	78.74	14	60	0.001	1.16	2420	1986

**Turb.-turbidity, Temp.-temperature, DO-dissolved oxygen, EC-electrical conductivity, TDS-Total dissolved solids, BOD-biological oxygen demand, TSS-Total suspended solids, TN-total nitrogen, TP-total phosphorus, TC-total coliforms, *E.coli-Escherichia Coli*

Results in Table 3 indicated that the mean of pH of water sampled from the river during the wet season was higher (M=8.40, SD= 0.548) than the sample obtained during the dry season (M=6.80, SD=0.447). A repeated measured t-test shows that the observed difference was significant, t(4)=6.532, P=0.003. Similar observations were made with regard to turbidity, DO, thermal conductivity and TDS, the mean of the water quality parameters during the wet season recording a higher mean (M=79.00, SD=50.43; M=51.20, SD=16.63; M=87.00, SD=28.05 and M=54.20, SD=17.38) compared to their corresponding qualities during the dry season (M=11.60, SD=6.43; M=43.40, SD=14.38; M=73.00, SD=20.86 and M=45.40, SD=12.90). A repeated measured t-test show the observed difference was significant (4)=3.17, P=0.034; t(4)=5.60, P=0.005; t(4)=4.24, P=0.013 and t(4)=4.13, P=0.014.

Table 3: Relationship between water quality during dry and wet Seasons

Pair	Variables	Mean	SD	T	Df	Sig.
1	pH1	6.800	0.447	-6.532	4	.003
	pH2	8.400	0.548			
2	Turbidity1	11.600	6.427	-3.169	4	.034
	Turbidity2	79.000	50.428			
3	Temperature1	22.800	1.789	1.395	4	.235
	Temperature2	21.600	1.1402			
4	DO1	43.400	14.3805	-5.600	4	.005
	DO2	51.200	16.6343			
5	Conductivity1	73.000	14.3805	-4.240	4	.013
	Conductivity2	87.000	28.045			
6	TDS1	45.400	12.896	-4.130	4	.014
	TDS2	54.200	17.384			
7	BOD1	6.200	3.564	-0.726	4	.508
	BOD2	7.800	3.768			
8	TSS1	18.000	4.472	-0.811	4	.463
	TSS2	24.800	5.454			
9	Total nitrogen1	0.400	0.346	-1.126	4	.065
	Total nitrogen2	0.200	0.346			
10	Total phosphorus1	0.200	0.447	-2.449	4	.070
	Total phosphorus2	0.800	0.447			
11	Total coliforms 1	54338.000	38389.394	-1.124	4	.324
	Total coliforms 2	5377724.000	10570666.706			
12	*E.Coli*1	621.80	399.250	-1.068	4	.346
	*E.Coli*2	3274237.20	6856927.835			

1-Dry season, 2-Wet season

Contrary to the current study, Makwe and Chup (2013) in a study on seasonal variations in physico-chemical properties of groundwater around Karu abattoir observed that all the parameters have higher concentration in the dry season. However, most of the parameters in this study had their mean values within the WHO standards in both seasons except for TSS, *E. coli* and faecal *streptococci* which were higher than guideline provisions. Similarly, Saifulla *et al.* (2012) while investigating some water quality parameters of Buriaganga River observed higher BOD, EC and TDS in dry season compared to wet season.

CONCLUSION

The findings from this study indicated that temporal rainfall variability significantly affects the pH, turbidity, DO, thermal conductivity and TDS of River Ruiru. This study will help in the efforts of pursuing integrated water resource management.

RECOMMENDATIONS

This study recommends for a strategic plan for water quality management by the county government based on priorities that reflect an understanding of economic and social costs of impaired water. Specific mechanisms for providing drinking water monitoring capabilities at the community level should be established. These include supporting and strengthening the participation of local communities for improved water resource management. There is need for a regulatory framework that includes a combination of appropriate water quality objectives and effluent control.

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