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# Assessing the Seasonal Changes on Physicochemical Parameters and Major Nutrient Levels in Water and Sediments from Sulal River, Bureti Sub County, Kericho County, Kenya

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author SC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DAA and JOO managed the analyses of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

Sulal River is a victim of nutrient pollution as it crosses different small-scale tea farms in Bureti Sub County, Kericho County. A study was conducted to evaluate different physicochemical parameters and major chemical fertilizer's nutrients levels in water and sediments from Sulal River. In order to understand the degree of pollution in the river due to inflow of agricultural chemical fertilizer residue levels from its catchment, the samples were collected in the dry (February 2019) and wet seasons (November 2019). The ten chosen sampling sites stretched a length of 12 Km. Samples were analyzed for pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), sediment and water content (WC), nitrate-nitrogen ($NO_3$-N), phosphorous ($PO_3$-P) and potassium (K) using standard methods. Results were analyzed using IBM SPSS 20. The average results during dry and wet seasons in water samples for pH were 6.72±0.05 and 6.38±0.21, DO 6.78±0.59 and 9.58±0.64 mg/L, EC 174±5.02 and 205±20.14 µS /cm, TDS 92±4.59 and 120.70±19.57 mg/L,

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$NO_3$-N 0.58±0.21 and 1.19±0.22 mg/L, $PO_3$-P 0.00±0.00 and 0.13±0.84 mg/L and K 0.26±0.08 and 0.84±0.19 mg/L respectively. The average results during dry and wet seasons in sediment samples for pH were 6.62±0.20 and 6.75±0.17, EC, 67±6.66 and 52±10.19 µS /cm, WC 16.96±3.95 and 129.84±5.00%, $NO_3$-N 0.70±0.35 and 0.42±0.23 mg/kg, $PO_3$-P 0.49±0.25 and 1.14±0.40 mg/kg and K 1.53±0.45 and 2.86±0.31 mg/kg respectively. The levels of P in water during wet season and in sediments samples in both seasons were however, above the WHO (0.025 mg/L) and KEBS (0.030 mg/L) recommended limit for drinking and domestic use and WASREB (0.005 mg/L) level for the likelihood of eutrophication. Availability of excess phosphorus can accelerate eutrophication. The diversity of cancers has also been associated with drinking water containing phosphorous levels. The water from Sulal River may be used for irrigation purposes but not for drinking and domestic purposes. Significant seasonal variations were observed in all parameters analyzed except $NO_3$-N in sediments. This indicates that rainfall had a great effect on some soil physicochemical properties.

*Keywords: Water pollution; water nutrient; physicochemical parameters.*

## 1. INTRODUCTION

The quality of surface water is normally characterized by physical, chemical and biological parameters of water and sediments underlying [1]. These parameters vary widely depending on the season and the type of pollution [2,3] (Kerich and Fidelis, 2020). Rivers in many parts of the world are mostly affected by anthropogenic activities of point like industrial and domestic wastes and nonpoint including agricultural activities sources of pollution (Wu et al., 2018). These activities can introduce pollutants such as heavy metals, microorganisms, agricultural nutrients and other chemicals such as pesticides and persistent organic particulates (POPs) into water bodies [4]. Surface water pollution by nutrients is a concern because it is a threat to aquatic organisms, plants, humans, and climate [5]. Nutrients can be found in both water and the underlying sediments. Sediments can retain and transfer nutrients to water [6].

Nutrient pollutants of particular concern in surface water are nitrates and phosphates arising from farm waste and fertilizer runoff [7]. Accumulation of excess of these nutrients in water bodies causes eutrophication [8], a situation where nutrients accelerate algae growth. Drinking water contaminated with excess nutrients also causes chemical poisoning in humans and animals; nitrites can be converted to nitrates which interfere with how oxygen is transported in the blood by oxidizing the normal hemoglobin to methemoglobin, a condition called Methemoglobinemia [9]. A group which is potentially at high risk of nitrate poisoning is infants under three months of age and can be seen when babies turn “blue”. This “blue baby” condition is so serious that it can damage the brain of babies [10]. The diversity of cancers has also been associated with drinking water containing high nitrate and phosphorous levels [10,11].

Studies on the effect of fertilizers’ nutrients on water quality has been reported on rivers situated within tea farming areas. Research done by Maghanga et al. [12] in different rivers passing through the tea plantations of Eastern Produce Kenya Limited found out that fertilizer application led to rise in nitrate levels in surface water. Studies on relatively small rivers within small-scale tea farms is rather limited although rivers in those areas may be affected by elevated levels of chemical nutrients from tea farms. The Sulal River, a small river in Bureti Sub County, is a victim of nutrient pollution as it crosses small scale tea farms. The river supplies water for domestic purposes, livestock and irrigation. However, very little is known about the quality of its waters in terms of health and well-being of the users, and also its likelihood of eutrophication. There is also no work on seasonal variation in physicochemical parameters and nutrient load in Sulal River. The objective of this study was therefore to assess the levels of physicochemical parameters and nutrient load in water and sediments in Sulal River in dry and wet seasons.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Study Area

The Sulal River, located in Bureti Sub County, Kericho County lies between Latitude 0°39'14"S and Longitude 35°10'41"E and crosses small scale tea farms. It has a catchment area of 25 $km^2$ and total length of 12 km from its source, Kapkatet to an area where it joins Kipsonoi River which drains southward through Bomet County into Sondu-Miriu River Fig. 1 and enters Lake Victoria through Winam Gulf [13]. The river is important because it supplies water for domestic, livestock and irrigation purposes. It is a permanent river that is prone to floods during heavy wet season and serves a population of approximately 4000 households in Bureti Sub County (GoK, 2019).

## 2.1 Equipment and Apparatus

UV-VIS Spectrophotometer (MR Spectronic 1001 PLUS), flame photometer (EEL 100), analytical balance (C054-E032Q Shimadzu), pH-EC-TDS meter (HANNA 9812), mechanical orbital shaker, extraction bottle with stopper, laboratory glassware and sampling bottles and bags.

## 2.2 Sampling Sites Selection

Water and sediment sampling sites on Sulal River were selected basing on the position of the river: upstream, midstream and downstream. Thus, 10 sampling sites in Fig. 1 were chosen and are described in Table 1.

## 2.3 Samples Collection

The water and sediment samples were collected from the selected sampling sites Fig. 1 and transported to the laboratory for analysis using standard methods for examination of water and wastewater APHA/AWWA/WPCF [14]. Samples were collected in February and November 2019 presenting dry and wet seasons respectively. The water samples were collected from the selected ten sampling sites in the morning hours to facilitate the transportation time from the field to the laboratory. Sample were collected using a 1-liter clean plastic containers by grab method at a depth of approximately 30 cm below the water surface, the containers were capped tightly to avoid leakage and contamination, each was labeled and packed in polyurethane cooler boxes. Utmost care was taken to avoid bubbling of air in water samples during the collection period. 1000 g of sediment samples were scooped with a stainless spoon from a depth of 0–10 cm, from each of the points where the water samples were collected, mixed on a sterilized aluminum foil to form a composite sample. Sample from each site was wrapped in sterilized aluminum foil, labeled and packed in a plastic container with a lid and store in a polyurethane cooler box for transportation to the University of Nairobi, Faculty of Agriculture, Department of Soil Chemistry laboratory for analysis.

## 2.4 Preparation of Samples for Analysis

In the laboratory, samples of water were filtered using No. 42 What man filter paper. Sediment samples were dried using an oven at 105°C for 24 hours, pebbles, stones and plant materials were removed from the dried samples, a roller was used to break down the large masses of the particles and then sieved using a 2.0 mm mesh. All samples were stored in a refrigerator using clean labelled plastic bottles to be used in subsequent analysis.

## 2.5 Sample Analysis

Water samples were analyzed for pH, dissolved oxygen (DO), total dissolve solids (TDS), electrical conductivity (EC), nitrogen (N), phosphorous (P) and potassium (K) while sediment samples were analyzed for pH, electrical conductivity (EC), water content (WC), nitrogen (N), phosphorous (P) and potassium (K). pH, EC and TDS were determined using HANNA 9812 combined meter while sediment water content (WC) was determined by weighing samples before and after oven-drying at 105°C for 15 hours. DO was determined following the Winkler Method. Nitrogen, as nitrate-nitrogen ($NO_3$–N) and phosphorous, as phosphate-phosphorous ($PO_4$-P) were analyzed calorimetrically using Salicylic acid and Olsen methods respectively. Potassium was determined using flame photometer. Each analysis was performed in triplicate, and the mean value was taken.

## 2.6 Data Analysis

Statistical program for social scientists (IBM SPSS Version 20) was used to obtain the mean and standard deviation, paired sample t-test for comparison of the means between seasons and Bivariate Pearson's correlation between any two parameters. Differences were regarded to be significant at 95% confidence limit.

# 3. RESULTS AND DISCUSSIONS

## 3.1 Physicochemical Parameters and Major Nutrient Levels in Water

The mean and standard deviation of triplicate samples results (n=3) for each parameter in each site have been recorded in dry and wet seasons in Table 2.

The pH of water samples collected from the ten sites were in the range of 6.67 to 66.81 and 6.08 to 6.64 during dry and wet seasons respectively Table 2. The pH values in both seasons were within World Health Organization [1] stipulated range of 6.5 to 8.5 for domestic purpose. The mean pH values in dry and wet seasons were at 6.72 and 6.38 and were almost similar to the values reported by Kimani et al. [14] from Chania River, Kenya, of 6.45 and 6.12 respectively, but were lower than 7.23 and 7.20 levels reported by Eliku and Leta [15] from Awash River, Ethiopia. The dissolved oxygen (DO) values during dry season ranged from 6.8 to 8.7 and in the wet season, the values ranged from 8.7 to 10.4. The DO values for both seasons were above the WHO [1] recommended values of >6.5 for the survival of aquatic organisms Therefore, the DO level of the Sulal River does not adversely affect the lives of aquatic organisms. Electrical conductivity (EC) values ranged from 167 to 181µS/cm in dry season and from 180 to 256 µS/cm in wet season. The EC values in both seasons were below the 1000 µS/cm values recommended by the WHO (2017) for drinking and domestic use. Total dissolve solids (TDS) levels ranged from 84 to 97 in dry season and 105 to 160 in wet seasons. The mean values of TDS in both seasons lie within the <500 mg/l standard limits for domestic water as recommended by WHO [1]. Nitrate-nitrogen ($NO_3$-N) levels ranged from 0.42 to 0.84 mg/l in dry and 0.90 to1.49 mg/ l during the wet seasons Table 2. The mean values of $NO_3$-N in both seasons were below the WASREB (2008) standard limit of 2.5 mg/L for likelihood of eutrophication and the recommended standard limit by KEBS (2012) and WHO [1] of <10 mg/l for drinking and domestic use. Thus, nitrogen do not pose health issue problems to the domestic use of water from Sulal River. The mean $NO_3$-N value in wet season (1.19±0.22 mg/l) was lower than the mean $NO_3$-N value (2.91±0.74 mg/l) reported in different rivers passing through tea estate in Nandi Hills, Kenya (Sharon et al. 2018). Phosphate-phosphorous ($PO_3$-P) levels in dry season were below detection limits of 0.012 mg/l. During the wet season, $PO_3$-P values ranged from 0.01 to 0.27 mg/l. The values of $PO_3$-P obtained in Sulal River were above the permissible limit for domestic water use of 0.025 mg/l stipulated by KEBS (2012) and WHO [1]. The values were also above the 0.005 mg/l for the likelihood of eutrophication (WASREB, 2012). The high phosphorous level confirms the pollution status of Sulal River with phosphorous. Phosphorous increase the growth of aquatic vegetation in water decreasing the amount of dissolved oxygen and hence the death of aquatic organisms [16]. The potential source of phosphate contamination in water during wet season is farms where fertilizers had been applied. Rain can flush out soil containing phosphates from the farm and carry them into nearby waterways (Boer et al. 2019). Potassium (K) levels during dry season ranged from 0.15 to 0.4 mg/l while in wet period, the potassium levels ranged from 0.64 to 1.10 mg/ l. The levels of K in both seasons remained below the 12ppm [1] (KEBS, 2012) maximum limit for drinking and domestic water.

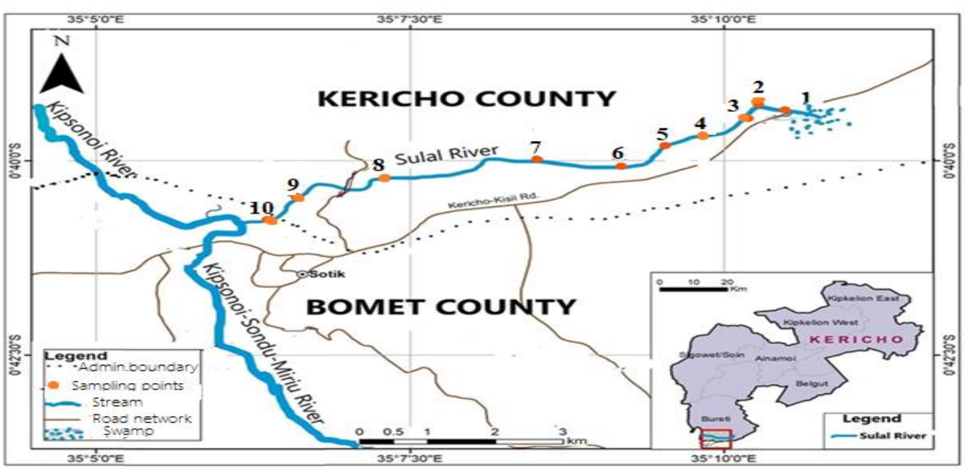



**Fig. 1. Map of Sulal river showing sampling sites**

**Table 1. The summary of the sampling sites in Sulal river**

| Sites | Latitude | Longitude | Description |
|---|---|---|---|
| 1 | 0°39'14"S | 35°10'41"E | These sites are in upstream. The river has a very wide channel, which is also swamp. Water current was very slow especially in dry season. There is a lot of sediment. |
| 2 | 0°39'23"S | 35°10'39"E | |
| 3 | 0°39'22"S | 35°10'26"E | |
| 4 | 0°39'26"S | 35°09'59"E | |
| 5 | 0°39'31"S | 35°09'28"E | Situated midstream. The river follows a zig-zag shape. There is more water than in the upper course and moves faster than upper course. Deep. |
| 6 | 0°39'40"S | 35°09'11"E | |
| 7 | 0°39'53"S | 35°07'13"E | |
| 8 | 0°39'54"S | 35°07'13"E | Situated downstream. Site 8 is situated next to a bridge where there is a carwash while Site 10 is where the river joins Kipsonoi River. Channel is narrow and water moves faster because the land is steep. |
| 9 | 0°40'19"S | 35°06'57"E | |
| 10 | 0°40'44"S | 35°06'15"E | |

## 3.2 Seasonal Variations of Water Parameters

Seasonal variations in the levels of physicochemical parameters and major nutrients in water samples are presented in Fig. 2. The mean levels of water parameters samples from 10 sites were compared in each season using t-test and recorded in Table 3.

The pH levels in all sampling sites were higher in dry season than wet season and reduced downstream Fig. 2). The mean pH value during dry season was significantly higher than during wet season Table 3. This could be due to inflow of acidic salts from agricultural run-off from the adjacent small-scale tea farms. All sampling sites had lower DO levels in the dry than wet seasons. The mean DO value during dry season was significantly lower than during wet season at (t=-9.545, p= 0.000). The lower DO values observed during dry than wet seasons could be due to the result of nitrification activity where oxygen is largely used during the process (Rounds et al. 2013). These results agree with a study by Achieng et al. (2018) in Sosiani River, Kenya. According to Achieng et al. (2018), the reduced DO levels during the dry season is attributed to higher temperatures in that season. Oxygen dissolves easily in warm than cold water [17]; high water temperatures, therefore, favor increased DO and, hence the survival of aquatic organisms. EC levels of water samples in all the sampling sites were higher in wet season than dry season and increased from upstream to downstream during wet season. The mean value was significantly different (t=-4.547, p=0.001). The higher EC level in wet season is possibly because nutrients and other salts that conduct electricity are carried into water bodies by water run-off. All water samples had higher TDS levels in wet season than dry season and showed an increasing trend from upstream to downstream during wet season. The mean TDS levels was significantly higher in wet than dry season (t=-4.173, p=0.002). This can be attributed to inflow of dissolved solids from agricultural farms run-off [18]. The seasonal variation in the study differed with that of Tukura et al. [19] in Mada River, Nigeria. According to Tukura et al. [19], TDS decreased during wet season due to dilution of river with fresh water. The levels of nitrogen in all water samples were higher in wet season than dry season and increase from Site 1 to Site 10 during wet season. The results also showed that $NO_3$-N levels was significantly higher in wet than dry season (t=-0.7284, p>0.001) possibly due to accumulation of considerable amount of nitrate in water as a result of water run-off from the agricultural tea farms. Nitrate form of nitrogen is loosely bound to soil, hence can easily be washed by rain into surface water (Barker and Bryson, 2016). The seasonal variation of nitrate-levels obtained in this study agrees with that reported from Nyamasogota River, Kisii by Nyaboke [20]. $PO_3$-P in all the samples were recorded in wet only and increase from Site 1 to Site 10 during wet season. The mean value of $PO_3$-P was significantly (t=- 3.776, p< 0.004) higher during wet season than dry. According to Kroiss, et al. [21] and Dunn et al. [22], there isn't a lot of ortho-phosphate in water during dry season because it is incorporated into sediments and aquatic plants during wet season. Continuous accumulation of soil sediment in the bottom of the river will then make phosphorus to settle too deep to be reintroduced to the water surface. Potassium levels in all the sites were higher in wet season than dry season. The mean value of potassium was significantly (t=-8.611, p< 0.001) higher during wet season than dry. The higher concentration of potassium in wet season is possibly because potassium in soil is not bound to organic materials [23] and so significant amounts can be washed into water by surface runoff during wet season. Similar seasonal variation was recorded by Kimani et al. [14] in Chania River catchment.

### 3.3 Correlation results of water parameters

The degrees of correlation between any two of the analyzed parameters in water are shown in Tables 4

During dry season, a significant ($p<0.05$) positive correlation exists between EC and $NO_3$-N ($r=0.673$). Significant ($p<0.05$) negative correlations were also seen between pH and EC ($r=704$) and between DO and TDS ($r=659$). There was strong significant ($p<0.001$) negative correlation between pH and $NO_3$-N ($r=0.882$). In wet season, there are significant ($p<0.05$) positive correlations between EC and $PO_3$-P ($r=0.673$), TDS and $NO_3$-N ($r=0.705$), TDS and $PO_3$-P ($r=0.739$), and $NO_3$-N and $PO_3$-P ($r=7.44$). Strong significant ($p<0.01$) positive correlations also exist between pH and $PO_3$-P ($r=0.820$) and between EC and TDS ($r=834$). A significant ($p<0.05$) negative correlation exists between pH and EC ($r = -0.695$).

### 3.4 Physicochemical Parameters of Sediments Parameters

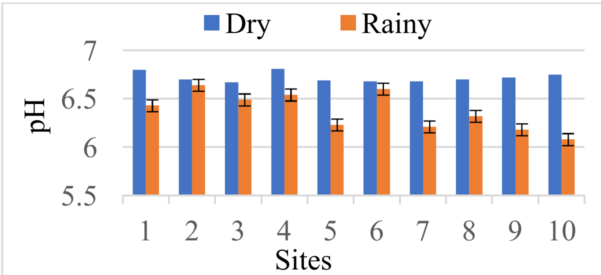
The mean and standard deviation of triplicate sediment samples results ($n=3$) for each parameter in each site have been recorded in dry and wet seasons in Table 5.

The pH ranged from 6.10 to 6.80 and 6.45 to 6.95 in dry and wet seasons respectively (Table 5). The diverse levels are possibly due to irregular deposition of different substances in the bottom of the river [24]. The pH levels were all in conformity to the World Health Organization stipulated limits (6.6-8.5) for domestic purposes [1]. Sediment water content (WC) ranged from 11.54 to 23.24 and 121.85 to 137.95%. The variations of sediment water contents in different sites are attributed to different amounts of organic matter which may include nutrients from agricultural sources (Avimelech et al. 2011). Electrical conductivity (EC) ranged from 56 to 78.00 µS/cm in dry season and 41.00 to 60 µS/cm in wet season. The levels are below the maximum recommended limit of 1500 µS/cm for unpolluted river [1]. The levels of nitrate-nitrogen ($NO_3$-N) during dry season ranged from 0.17 to 1.17 mg/kg. During wet season the levels ranged from 0.07 to 0.79 mg/kg. $NO_3$-N levels during both seasons were within the WHO (<10mg/kg) and KEBS(<10mg/kg) standards for drinking and domestic water and Kenya WASREB(<5mg/kg) limit for likelihood of eutrophication. Therefore, the nitrogen level of the Sulal River does not adversely affect its waters. Phosphate-phosphorous ($PO_3$-P) levels during dry season ranged from 0.18 to 0.99 mg/kg and 0.70 to1.89 mg/kg during the wet season. The values of phosphorous obtained in both seasons were all above 0.005 ppm minimum limit set by WASREB for the likelihood of eutrophication and 0.025 ppm minimum limits of drinking and domestic water set by WHO [1]. This reveals the polluted status of Sulal River with phosphorous. High phosphorus in sediments can lead to eutrophication [16]. Potassium (K) levels during dry season ranged from 0.99 to 2.19 and 2.47 to 3.39 mg/kg in wet season. The mean levels in both seasons remained below the WHO and KEBS (12ppm) maximum limit for drinking and domestic water.

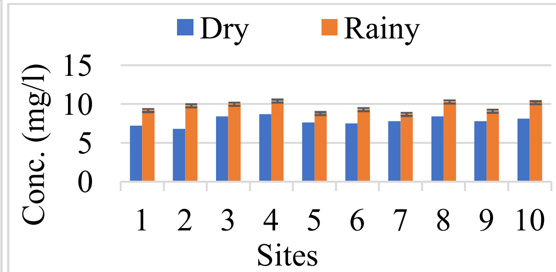
### 3.5 Seasonal Variations of Sediment Parameters

Seasonal variations in the levels of physicochemical parameters and major nutrients in sediment samples are presented in Fig. 3. The mean levels of sediment parameters were compared in each season using t-test and recorded in Table 6.

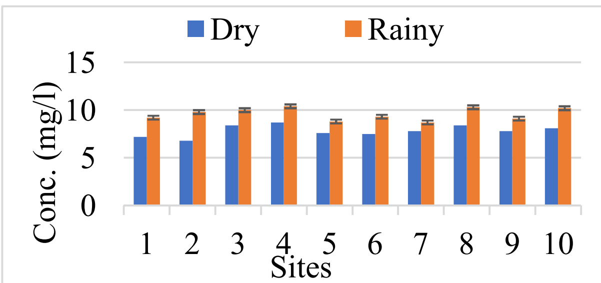
The results in Fig. 3 showed that the pH of samples in all the sites except site 7 were more acidic in dry than wet season and this may have resulted from dilution effects of rain [25]. There was significant seasonal variation ($t=-2.414$, $p=0.039$). The slightly lower pH in midstream and downstream than upstream during both seasons is possibly due to increasing sedimentation of soil particles containing heavy metals, pesticides and fertilizers along the river course [24]. Water content was significantly higher in rainy season than dry season. The trend in EC tends to increase from site 1 to 10 in both seasons and this is attributed to increasing sedimentation of soil particles containing substances that can transmit electricity downstream [24]. The seasonal variation of soil EC was significantly lower in wet season than dry season ($t=5.203$, $p=0.001$) and this is possibly because salts tend to settle in sediments after the rains and are flushed out during wet season [26].



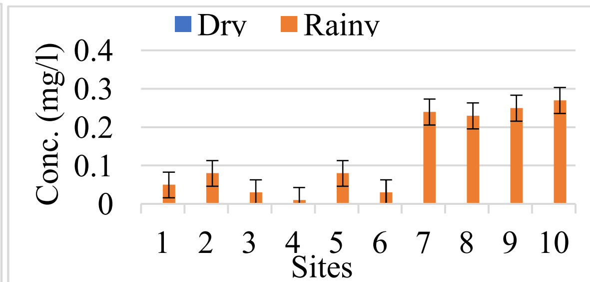

1. pH



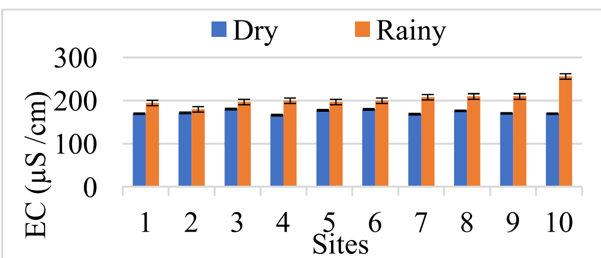

5. $NO_3$-N



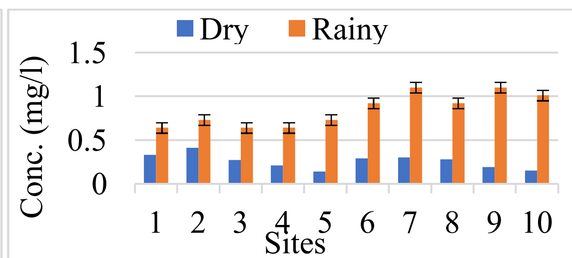

2. DO



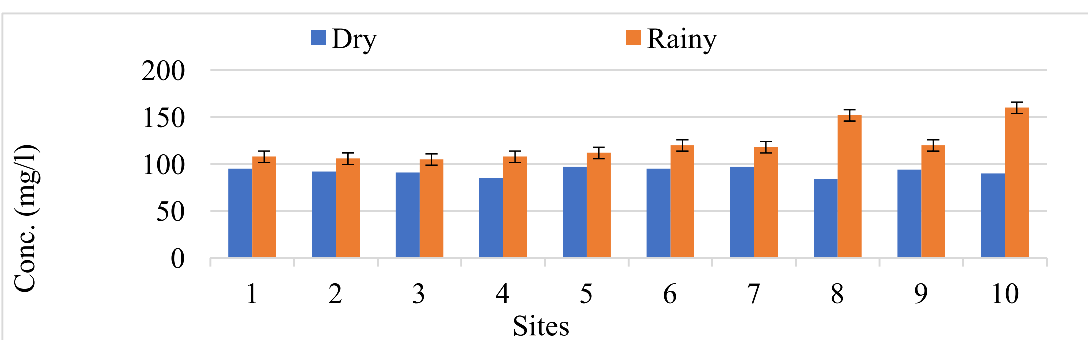

6. $PO_3$-P




3. EC




7. K




4. TDS

**Fig. 2. Seasonal variations in physicochemical properties of water**

**Table 2. The levels of analyzed water parameters during dry and wet seasons**

| | **Dry Season** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter/ Site** | **pH** | **DO** (mg/l) | **EC** (µS /cm) | **TDS** (mg/l) | **$NO_3$-N** (mg/l) | **$PO_4$-P** (mg/l) | **K** (mg/l) |
| 1 | 6.80±0.14 | 7.2±0.06 | 170±5.20 | 95±7.61 | 0.48±0.36 | BDL | 0.33±0.14 |
| 2 | 6.70±0.12 | 6.8±0.06 | 172±2.20 | 92±10.01 | 0.63±0.21 | BDL | 0.41±0.09 |
| 3 | 6.67±0.08 | 8.4±0.13 | 181±10.20 | 91±3.45 | 0.84±0.72 | BDL | 0.27±0.08 |
| 4 | 6.81±0.03 | 8.7±0.11 | 167±3.64 | 85±5.50 | 0.42±0.09 | BDL | 0.21±0.01 |
| 5 | 6.69±0.07 | 7.6±0.04 | 178±5.20 | 97±10.21 | 0.64±0.85 | BDL | 0.14±0.02 |
| 6 | 6.68±0.09 | 7.5±0.07 | 180±9.08 | 95±5.92 | 0.71±0.08 | BDL | 0.29±0.02 |
| 7 | 6.68±0.02 | 7.8±0.09 | 169±3.08 | 97±2.80 | 0.79±0.03 | BDL | 0.30±0.24 |
| 8 | 6.70±0.14 | 8.4±0.12 | 177±0.00 | 84±6.27 | 0.60±0.10 | BDL | 0.28±0.09 |
| 9 | 6.72±0.13 | 7.8±0.13 | 171±7.09 | 94±6.90 | 0.53±0.36 | BDL | 0.19±0.05 |
| 10 | 6.75±0.08 | 8.1±0.14 | 170±7.90 | 90±10.20 | 0.50±0.15 | BDL | 0.15±0.03 |
| Range | 6.67-6.81 | 6.80-8.70 | 167-181 | 84-97 | 0.42-0.84 | 0.00-0.00 | 0.14-0.41 |
| LOD | | | | | 0.08 | 0.012 | 0.03 |
| **M± SD, n=10** | **6.72±0.05** | **6.78±0.59** | **174±5.02** | **92±4.59** | **0.58±0.21** | **0** | **0.26±0.08** |
| | **Wet season** | | | | | | |
| 1 | 6.43±0.09 | 9.2±0.09 | 195±10.34 | 108±4.80 | 0.98±0.45 | 0.05±0.02 | 0.64±0.32 |
| 2 | 6.64±0.08 | 9.8±0.11 | 180±6.25 | 106±6.78 | 0.90±0.09 | 0.08±0.06 | 0.73±0.14 |
| 3 | 6.49±0.11 | 10.0±0.07 | 197±3.45 | 105±2.50 | 1.04±0.45 | 0.03±0.01 | 1.01±0.42 |
| 4 | 6.54±0.05 | 10.4±0.03 | 200±10.50 | 106±5.54 | 0.95±0.22 | 0.01±0.02 | 0.64±0.15 |
| 5 | 6.23±0.12 | 8.8±0.14 | 192±3.24 | 112±2.90 | 1.10±0.56 | 0.08±0.03 | 0.92±0.23 |
| 6 | 6.60±0.15 | 9.3±0.07 | 202±3.95 | 120±3.48 | 1.37±0.91 | 0.03±0.02 | 0.73±0.11 |
| 7 | 6.21±0.11 | 8.7±0.09 | 208±6.71 | 118±9.45 | 1.28±0.65 | 0.24±0.11 | 1.10±0.48 |
| 8 | 6.32±0.15 | 10.3±0.12 | 210±1.00 | 152±4.89 | 1.40±0.67 | 0.23±0.09 | 0.92±0.32 |
| 9 | 6.18±0.06 | 9.1±1.03 | 210±2.31 | 120±5.53 | 1.49±0.30 | 0.25±0.14 | 1.10±0.20 |
| 10 | 6.08±0.01 | 10.2±0.10 | 256±9.21 | 160±2.09 | 1.38±0.18 | 0.27±0.01 | 0.64±0.21 |
| Range | 6.08-6.64 | 8.70-10.40 | 180-256 | 105-160 | 0.90-1.49 | 0.01-0.27 | 0.64-1.10 |
| M± SD, n=10 | 6.38±0.21 | 9.58±0.64 | 205±20.14 | 121±19.6 | 1.19±0.22 | 0.13±0.84 | 0.84±0.19 |
| WHO, 2017 | 6.5 to 8.5 | >6.5 | >1000 | <500 | <10 | <0.030 | <12 |
| KEBS, 2012 | - | - | - | - | <10 | <0.025 | <12 |
| WASREB, 2008 | - | - | - | - | <5 | <0.005 | - |

*BDL-Below Detection Limit*

**Table 3. Paired sample T test for differences in mean levels between dry and wet seasons**

| Parameter | pH | DO | EC | TDS | $NO_3$-N | $PO_4$-P | K |
|---|---|---|---|---|---|---|---|
| t | 5.513 | -9.545 | -4.547 | -4.173 | -7.284 | -3.776 | -8.611 |
| p | 0.001 | 0.000 | 0.001 | 0.002 | 0.000 | 0.004 | 0.000 |

**Table 4. Bivariate parson correlation between any two parameters of water in dry and wet seasons**

| **Dry season** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | pH | DO | EC | TDS | $NO_3$-N | $PO_3$-P | K |
| pH | 1 | | | | | | |
| DO | .143 | 1 | | | | | |
| EC | -.704* | .017 | 1 | | | | |
| TDS | -.341 | -.659* | .101 | 1 | | | |
| $NO_3$-N | -.882** | -.071 | .634* | .389 | 1 | | |
| $PO_3$-P | c | c | c | c | c | 1 | |
| K | -.139 | -.529 | .009 | .046 | .288 | c | 1 |
| **Wet season** | | | | | | | |
| | pH | DO | EC | TDS | $NO_3$-N | $PO_3$-P | K |
| pH | 1 | | | | | | |
| DO | .258 | 1 | | | | | |
| EC | -.695* | .278 | 1 | | | | |
| TDS | -.597 | .353 | .834** | 1 | | | |
| $NO_3$-N | -.610 | -.143 | .630 | .705* | 1 | | |
| $PO_3$-P | .820** | -.082 | .673* | .739* | .744* | 1 | |
| K | -.390 | -.456 | -.118 | -.073 | -.404 | .417 | 1 |

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*
*c Cannot be computed because at least one of the variables is constant*

These results agree with a recent study performed under similar environment by Ondoo et al. [27]. According to their findings, the different levels of EC was attributed to different levels of nutrients in sediments. Except sediments from Sites 2, 3 and 6, all other sampling sites had higher $NO_3$-N levels during dry season than wet season. However, the seasonal variation was not significantly different (t=2.144, p=-0.061). Upstream concentration levels were slightly lower than downstream in dry season. There was no trend in wet season. The higher levels of $NO_3$-N in most sites during dry season is attributed to sedimentation of fertilizer nutrients after the rains and from decomposition of organic matter that had settled on the top surface [26]. The low nitrate levels observed in the wet season may be attributed to heavy flooding that remove the top layer of sediments and continuous flow of water in the river systems [28,29]. The observation differed from those of Ruto et al. [30] in sediments along Saiwa Swamp Ecosystem, and Tukura et al. [19] in Mada River, Nigeria where the levels of nitrates was lower during dry season than wet season, but similar that of Ondoo et al. [27] in River Sio, Kenya, who concluded that heavy rains wash out nitrate from sediments and nitrate levels decrease drastically with continuous rains.

Except in Site 4, phosphorous levels were all higher in wet season than dry season. The seasonal variation was significantly higher in wet season (t=-4.758, p=0.001). The higher level of phosphorous in wet season observed in this study may be due discharge and subsequent sedimentation of suspended particulates from phosphate fertilizers, and domestic wastes discharged into the river as a result of rainfall. Unlike nitrogen, phosphates cling tightly to sediments [31]. The variation agrees with a research done by Basweti, et al. [32] in sediments in River Nzoia, Kenya and Ondoo et al. [27] in sediments in River Sio, Kenya. Upstream concentration levels were slightly higher than downstream in wet season. Potassium level was significantly higher during wet season than dry season (t=-8.61, $p<0.001$). The higher concentration of potassium in wet season might be due to inflow of agricultural influents from the surrounding villages and is readily retained by the soil constituents of sediments [33,34]. Similar seasonal variation was recorded by Ruto et al. [30] in sediment samples collected along Saiwa Swamp Ecosystem, Trans Nzoia County, Kenya.

### 3.6 Correlation Results of Sediment Parameters

There were significant negative correlations with between pH and $NO_3$-N ($p<0.01$) and positive correlations between EC and $NO_3$-N ($p<0.05$) and between EC and $PO_3$-P ($p<0.01$) during dry season. The correlations were not significantly different in wet season.

**Table 5. Levels of analyzed sediment parameters during dry and wet seasons**

| | **Dry season** | | | | | |
|---|---|---|---|---|---|---|
| **Parameter/ Site** | **pH** | **WC (%)** | **EC** (µS /cm) | **$NO_3$-N (mg/kg)** | **$PO_3$-P (mg/kg)** | **K (mg/kg)** |
| 1 | 6.65±0.48 | 11.54±0.91 | 60±5.00 | 0.30±0.18 | 0.27±0.02 | 2.05±0.43 |
| 2 | 6.70±0.50 | 14.00±2.30 | 62±10.50 | 0.60±0.23 | 0.46±0.13 | 1.31±0.72 |
| 3 | 6.68±0.43 | 15.81±2.02 | 64±5.61 | 0.17±0.03 | 0.18±0.08 | 2.12±0.91 |
| 4 | 6.75±1.08 | 12.28±3.01 | 69±10.06 | 0.63±0.08 | 0.99±0.32 | 1.21±0.32 |
| 5 | 6.80±0.56 | 17.89±0.89 | 56±8.03 | 0.90±0.41 | 0.26±0.09 | 1.23±0.62 |
| 6 | 6.72±0.82 | 20.03±1.03 | 72±2.58 | 0.36±0.08 | 0.54±0.17 | 1.44±0.27 |
| 7 | 6.68±0.09 | 15.03±2.50 | 73±5.38 | 1.14±0.09 | 0.52±0.20 | 2.19±0.71 |
| 8 | 6.57±0.15 | 17.74±1.39 | 70±11.09 | 0.83±0.25 | 0.69±0.26 | 1.45±0.60 |
| 9 | 6.10±0.92 | 21.99±3.00 | 78±4.98 | 1.17±0.87 | 0.30±0.12 | 0.99±0.32 |
| 10 | 6.52±0.52 | 23.24±3.41 | 67±9.30 | 0.90±0.22 | 0.68±0.42 | 1.04±0.45 |
| Range | 6.10-6.80 | 11.54-23.24 | 56-78 | 0.17-1.17 | 0.18-0.99 | 0.90-2.10 |
| **M±SD, n=10** | **6.62±0.20** | **16.96±3.95** | **67±6.66** | **0.7±0.35** | **0.49±0.25** | **1.53±0.45** |
| | **Wet Season** | | | | | |
| 1 | 6.95±0.24 | 136.80±1.20 | 43±3.90 | 0.13±0.15 | 0.91±0.19 | 2.65±0.87 |
| 2 | 6.87±0.90 | 130.53±0.81 | 51±12.21 | 0.62±0.29 | 0.88±0.20 | 2.47±0.80 |
| 3 | 6.91±0.91 | 121.85±3.45 | 42±9.1 | 0.20±0.08 | 0.78±0.50 | 2.65±0.80 |
| 4 | 6.78±0.29 | 137.95±1.08 | 41±8.03 | 0.21±0.03 | 0.89±0.35 | 2.56±0.43 |
| 5 | 6.75±0.50 | 128.34±1.28 | 50±10.00 | 0.34±0.11 | 0.70±0.35 | 2.93±0.50 |
| 6 | 6.88±1.10 | 127.56±2.91 | 53±6.72 | 0.79±0.09 | 1.08±0.98 | 3.20±0.63 |
| 7 | 6.45±0.57 | 130.56±3.41 | 45±5.08 | 0.07±0.02 | 1.15±0.67 | 3.20±0.09 |
| 8 | 6.77±0.67 | 125.10±5.02 | 67±7.57 | 0.67±0.21 | 1.65±0.61 | 3.39±0.89 |
| 9 | 6.48±0.80 | 132.76±4.76 | 69±8.90 | 0.53±0.40 | 1.89±0.70 | 2.75±0.44 |
| 10 | 6.68±0.32 | 126.98±4.08 | 60±7.50 | 0.61±0.09 | 1.43±0.80 | 2.84±0.79 |
| Range | 6.45-6.95 | 121.9-137.95 | 41-69 | 0.07-0.79 | 0.70-1.89 | 2.40-3.30 |
| M±SD, n=10 | 6.75±0.17 | 129.84±5.00 | 52±10.19 | 0.42±0.23 | 1.14±0.40 | 2.86±0.31 |
| WH0, 2017 | 6.5 to 8.5 | - | 100-1500 | <10 | <0.030 | <12 |
| KEBS, 2012 | - | - | - | <10 | <0.025 | <12 |
| WASREB, 2008 | - | - | - | <5 | <0.005 | - |

**Table 6. Paired sample t-test for differences in means of sediment parameters between two seasons**

| **Parameter** | **pH** | **WC** | **EC** | **NO3-N** | **PO4-P** | **K** |
|---|---|---|---|---|---|---|
| t | -2.414 | -46.223 | 5.203 | 2.144 | -4.758 | -8.253 |
| p | 0.039 | 0.000 | 0.001 | -0.061 | 0.001 | 0.000 |

**Table 7. Bivariate pearson correlation between any two parameters of sediments in dry and we t seasons**

| **Dry season** | | | | | | |
|---|---|---|---|---|---|---|
| | pH | WC | EC | $NO_3$-N | $PO_3$-P | K |
| pH | 1 | | | | | |
| WC | - .565 | 1 | | | | |
| EC | - .630 | .414 | 1 | | | |
| $NO_3$-N | - .952** | .439 | .724* | 1 | | |
| $PO_3$-P | -.381 | -.048 | .884** | .186 | 1 | |
| K | .416 | -.589 | -.200 | -.454 | -.356 | 1 |
| **Wet season** | | | | | | |
| | pH | WC | EC | $NO_3$-N | $PO_3$-P | K |
| pH | 1 | | | | | |
| WC | - .098 | 1 | | | | |
| EC | - .410 | -.264 | 1 | | | |
| $NO_3$-N | - .100 | -.364 | .435 | 1 | | |
| $PO_3$-P | - .596 | -.066 | .339 | .459 | 1 | |
| K | .325 | -.413 | .365 | .272 | .363 | 1 |

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*

## 4. CONCLUSION

The results of the analyzed physicochemical parameters and nutrient levels in water and sediments showed that Sulal River is polluted with phosphorous. This may have deleterious effect on the aquatic ecosystem and rural users of water from Sulal River. All other levels of the investigated parameters in both seasons were within the permissible levels stipulated by WHO, KEBS and WASREB, Kenya. Sediment parameters showed diverse levels confirming that there is irregular sediment deposition in the river. The parameters were significantly higher in wet season than dry season except pH of water which was significantly lower. There were significant differences on correlation between some pairs of parameters.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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