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Spatial and Temporal Variability of Phosphates, Nitrates and Selected Physico-Chemical Parameters of River Nzoia

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Abstract

Several agricultural activities are practiced within the River Nzoia catchment area, most of which involve application of chemicals in form of fertilisers and pesticides. Most of these chemicals end up in the river in form of phosphates and nitrates, thus affecting the aquatic life of the river. Spatial and temporal variability of major pollutant loads of the River Nzoia has been determined with a view of assessing the safety of river. This study reports the current contaminant loads determined in River Nzoia catchment area, which were; nitrates (NO_3-N) and phosphates (PO_4-P), the physico-chemical parameters; pH, temperature, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS). All these were tested in the three matrices; the soil, sediments and water. The stratified samples were collected from eight (8) different sites from Kitale down to Mumias in the River Nzoia in both the dry and wet seasons. The samples were then digested by the wet method and analyzed for nitrates and phosphates using the colorimetric technique. Titrimetric method was used for COD analysis while the DO meter was used to measure the BOD based on incubation. TDS was analyzed using the evaporation vs weight change method. pH, temperature, conductivity and DO were determined in situ using respective meters. Collected data were analysed descriptively using MS Excel spreadsheets and statistical package for social science (SPSS) version 20. Comparison for variations between the sampling sites was done using one way ANOVA. Levels of nitrates in water were found to be higher than the maximum permissible levels in water samples from Cherangani [12.30 ± 0.05 mg/L], Moi's Bridge [14.4±1.15 mg/L], Pan-Paper [17.2 ± 0.15 mg/L] and Mumias [15.3 ± 0.35 mg/L]. However, phosphates, temperature, DO, BOD, conductivity and TDS were within permissible limits in all the sites while COD [51.0 ± 13.7 mg/L] at Mumias site was found to be relatively above the recommended limit. There seems to be an accumulation of some pollutants in River Nzoia as it progresses towards Lake Victoria. Therefore, control measures should be taken within the catchment area to avoid the river manifesting serious environmental pollution.

Keywords: Spatial, Temporal, Variability, Parameters, Pollution

INTRODUCTION

It is apparent that there is a persistent and continuous population growth worldwide (Gu et al., 2021; Walker, 2016). Much of this increasing population is in Sub-Saharan Africa where livelihoods of people still are dependent on resources obtained from the environment (Timko et al., 2010; Serdeczny et al., 2017; Mitchell, 2013). Subsequently there is concern stemming from persistent human pressure on the environment (Patrick et al., 2021; Carvalho, 2017). Thus, as increased demands for water, fuel energy and other environmental resources to sustain the burgeoning populations continues, signs of human induced environmental stress are beginning to occur in many parts of the global environments with concomitant disruption of the normal environmental equilibrium (Brennan & Owende, 2010; Hernandez et al., 2014). The gravity of these environmental concerns in Kenya has not been fully exposed (Adamo et al., 2005).

Though perturbations and the problems of environmental changes are not new in most ecosystems of the world, they have been persistently aggravated in recent years as a result of increased anthropogenic activities associated with urbanization and agricultural development as evidenced in the Trans-Nzoia catchment region (Wu et al., 2010).

River Nzoia rural region is a densely populated area with the inhabitants relying heavily on locally grown crops as constituents of diets consisting of a limited number of food items (Kipkulei et al., 2022; Onywere et al., 2011). Due to the high cost of living, the residents here grow their own crops on large- and small-scale farms available (Wafuke, 2012; Sakataka & Namisiko, 2014). To increase production, the farmers use commercial fertilizers and organic manure (Nyilitya et al., 2020; Patt, 2006). The region has access to fertile soils, reliable rainfall and water for irrigation purposes (Onyango et al., 2007; Nyilitya et al., 2020). It has been reported that there has been a rapid increase in the use of nitrogen and phosphate-based fertilizers in the recent past, which has contributed significantly towards the spectacular increase in food production (Basweti et al., 2018). However, no studies have been done to monitor how much of these nutrients are washed down the river. Consequently, this has caused nitrate and phosphate pollution in river Nzoia leading eventually to eutrophication.

Lake Victoria whose main inlet is River Nzoia is currently crippling with hyacinth weed which is rapidly growing and blocking the lake (Wanyonyi, 2019; Twongo, 2019). Fishing in the lake is now almost at a standstill hence costing the country heavily on GDP since fishing is the major GDP contributor in the Nyanza region (Yara, 2019). It is believed that the major cause of this eutrophication phenomenon is amount of nitrates and phosphates washed off from the Nzoia agriculturally influenced catchment area (Ontumbi et al., 2015; Nadir et al., 2019). According to Nadir et al. (2019), River Nzoia near Webuye town is polluted with nitrates, iron, copper, chromium, and BOD and COD above environmental restrictions. Upper River Nzoia basin has heavy copper, magnesium, and iron sediments (footslopes of Mt. Elgon). Lower catchment sediments had high nitrate and phosphate levels. Therefore, this study determined the spatial and temporal variability of phosphates, nitrates and selected physico-chemical parameters of River Nzoia which solidified Nadir et al. (2019) findings ten years before their studies.

MATERIALS AND METHODS

Sampling

Samples of water, soil and sediments were collected from Kitale, Cherangani, Uasin Gishu, Moi's Bridge, Lugari, Webuye, Pan-Paper and Mumias along the river profile twice (Nov-March, 2007) and (April-June, 2007) to capture temporal variability between seasons. For soil samples three field points were selected randomly near river banks at which soil cores were dug to depth of 30 cm using a 2 cm internal diameter soil corer. The samples were then mixed thoroughly and divided into three replicates of about 500 g and then transported to the laboratory for analysis in ice for nitrate and phosphate analysis. Water samples were collected (sub- surface and ¾ below surface) and mixed thoroughly then divided into three replicates and stored in clean 100 mL plastic containers and transported back to the laboratory (Sundaram et al., 2009). Dissolved oxygen was measured at sampling points using a dissolved oxygen meter for the analysis of biochemical oxygen demand (Haider et al., 2010). Temperature was also measured at site using a thermometer (Sharma et al., 2015).

Determination of Nitrates

Standard solutions of potassium nitrate were made from the 1000 mg/L stock solution. A volume of 1 mL of salicylic acid solution was added to each test tube containing portions of each standard and sample, mixed well and left for 30 minutes followed by 10 mL of sodium hydroxide. The contents were then mixed and left for one hour for full colour development. The absorbance was then determined at 410 nm in a colorimeter. A calibration graph was plotted with the correlation coefficient being $R^2 = 0.9978$ from which the concentrations were determined.

Determination of Phosphates

Phosphate analysis involves the formation of molybdophosphoric acid, which is reduced to the intensely coloured complex, molybdenum blue. This analytical method is extremely sensitive and is reliable up to concentrations below 0.1 ppm phosphorus per litre. The Spintronic 20 spectrophotometer was employed in the measurement of colour intensity of the blue solution at wavelength of 650 nm.

Glassware was washed thoroughly with hot water followed by rinsing with distilled water without using phosphate-containing detergents. Standards from stock phosphate solutions were prepared to get a calibration graph.

Colour Development in Sample

A 25 mL portion of the water sample was placed in an Erlenmeyer flask. One mL of ammonium molybdate solution was added into the flask and swirled to mix. Two drops of stannous chloride solution were again added into the flask and mixed by swirling. A blue colour developed (for samples with phosphate) to a maximum intensity in 5 minutes. While waiting for the blue colour to develop, the wavelength was set to 650 nm on the spectrophotometer. The blank solution was used to set it to read zero absorbance. Using 650 nm wavelengths, the absorbance (after 5-15 minutes' development) of the blue sample was measured.

Preparation of Standards Plot

A calibration graph with the correlation coefficient $R^2 = 0.9953$ was used to determine concentrations (mg/L).

Determination of Chemical Oxygen Demand

Five ml of sample was transferred to a 250 Erlenmeyer flask and to it were added 0.2 g mercury II sulphate crystals. A 10 mL solution of potassium dichromate was pipetted and carefully added into the flask. A few pieces of glass were put and the flask fixed under the condenser. A 28 mL portion of sulphuric acid reagent was added slowly through the open end of the condenser. These were then heated for two hours. The flask was removed carefully and immediately with the use of a cloth between gloves and held above the heater. These were rinsed through the condenser with distilled water while holding the flask still until the solution stopped bubbling. The flask was put on the cork ring a little without letting it cool on the metal ring. After 10 minutes the flask was corked and cooled further with cold water under the tap. To this solution, 2-3 drops of ferroin indicator solution was added then titrated against ferrous ammonium sulphate (FAS) until end point. Colour change was from light yellow to blue green and then finally to brownish red. The end point was sharp, while for blank, distilled water was used (Behera, 2009).

Determination of Dissolved Oxygen (DO)

The dissolved oxygen meter (DO meter) and probe (electrode), which was calibrated immediately prior to use had the cable connection between the probe and the meter checked to ensure it was in proper working condition. The probe was then filled with electrolyte solution, and the membrane checked to confirm that there were no wrinkles, and bubbles trapped on its face (Hargreaves & Tucker, 2002).

Once the meter was turned on, 15 minutes were allowed for equilibration before calibrating after which, the meter was not turned off until the sample was analyzed. The probe was placed in the stream below the surface, to measure DO and temperature. The temperature reading was allowed to stabilize and recorded on the field data sheet. The meter was then switched on to read DO and the DO level recorded.

Determination of Total Dissolved Solids

To measure TDS, the water sample was filtered, and then the filtrate was evaporated to dryness in a pre-weighed dish in an oven at 180^0C, until there was no more change in weight of the dish. The increase in weight of the dish represented the total dissolved solids, and was reported in mg/L (Dash et al., 2008).

Determination of Biochemical Oxygen Demand

At every site two BOD bottles were submerged into the river to collect samples and capped while still under water. The contents of the first bottle at every site were poured into a beaker and the electrode of the DO meter inserted after confirming that the meter was functioning. The contents of the beaker were slowly mixed while simultaneously switching on the meter. The reading was recorded after the indicator needle had stabilized. The second bottle from each site was transported back to the laboratory and incubated at 20°C for five days. The DO level was determined in each bottle at the end of the incubation period (Boman et al., 2002).

Determination of pH

Water Samples

Potentiometric determination of pH was determined *in situ* using calibrated pH meter (Jenway 370 model). Before and after each reading, the probes were washed with deionized water and dropped 1.25 inches into the sample for stabilised readings (Makubalo, 2020).

Soil and Sediments Samples

The sample soil was dried in the oven at 30^O C. A 20 g portion of ground and sieved sample was then transferred into a 50 mL beaker and 20 mL of distilled water added with a pipette, stirred and left to stand for an hour. The pH meter was calibrated using buffer 7.00 then buffer 4.00 before use. The electrode was then immersed into the sample and pH read when it stabilized and results recorded. After each measurement, the electrode was rinsed with distilled water (Maguire & Heckendorn, 2005).

Determination of Conductivity of Water

in situ determination of EC was done using conductivity meter. Before analysis, the conductivity meter was calibrated by turning the gauge knob of the potentiometer to point at 300 micro-Ohms/cm and dipping the electrode in a solution of supersaturated calcium sulphate. The knob 'temp' was then adjusted to read 2200 microhms (the EC value of $CaSO_4$). The conductivity of the sample was then measured and recorded. The electrode was rinsed with distilled water after each reading (Corwin & Yemoto, 2020).

Determination of Water Temperature

A thermometer was dipped into the river approximately 15 cm under the surface and the temperature readings taken at three different points in all the sites. The average temperature was then calculated and used as the temperature of that site (Meride & Ayenew, 2016).

Quality Control and Method Evaluation

When determining COD, no outside organic material should be accidentally added to the sample. A blank sample was, therefore, created by adding all reagents (such as acid and oxidizing agent) to a volume of distilled water. COD was measured for both the water and blank samples, and the two are compared. The oxygen demand in the blank sample was subtracted from the COD for the original sample to ensure a true measurement of organic matter. Distilled water was used as blank for BOD and TDS analysis.

Data Analysis

Collected data were analysed descriptively using MS Excel spreadsheets and statistical package for social science (SPSS) version 20. Results were presented using means, standard deviations, and graphical representation. Comparison for variations between the sampling sites was done using one way ANOVA.

RESULTS AND DISCUSSION

Spatial and Temporal Variations in Concentrations of the Selected Nutrients in Water, Soil and Sediments

Nutrient mean values along river Nzoia within the entire sampling period are shown in Figure 1, which illustrates the variation of nitrate levels in soil, sediments and water in the 8 sampling stations. Kitale showed the lowest levels of NO_3^-. Increases of NO_3^- $_3$values were observed at Cherangani, Moi's Bridge, Pan-Paper and Mumias.

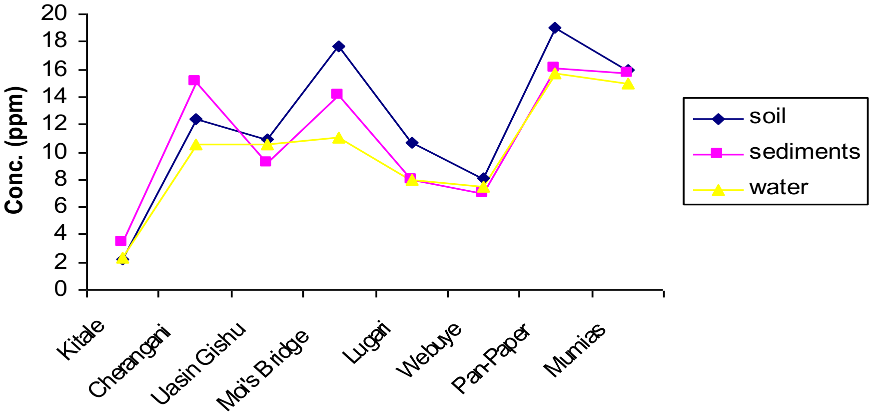

Figure 1: Variation of nitrate levels in the 8 sampling stations in water, soil and sediments along river Nzoia.

This could be attributed to the runoff from the diffuse sources, which include urban effluents, factory effluents and agricultural runoffs. All the three stations are also home to major factories along the river coupled with agricultural farms along the river, which utilize a lot of nitrate fertilizers. Uasin Gishu (10.5 ± 0.45 mg/L), Lugari (9.1 ± 0.05 mg/L) and Webuye (8.4 ± 1.25 mg/L) had significantly lower values ($p<0.05$) of NO_3^-. This could be attributed to the dilution effect from Moiben River in Uasin Gishu and Nzoia tributary at Webuye, coupled with the fact that there are lesser agricultural activities in these sites. Nitrate levels in waters of Cherangani, Moi's Bridge, Pan-Paper and Mumias were found to be above the recommended standards for water, 10 ppm (WHO, 2007). Similar research was conducted by Limo (2013), who reported in Spatial and Temporal Variations in Physico-Chemical Parameters, Nutrients Within Kapsabet River, Kenya that NO_3^- concentrations in water ranged from 0.6 to 4.5 mg/L, whereas NO_3^- concentrations in soil and sediments ranged from 5 to 5.2 mg/L and 8 to 8 mg/L, respectively. Also, Misigo & Suzuki (2018) revealed that substantial nitrogen concentration from Awach-Tende and Awach-Kibuon (dominated by Phaeozems and Acrisols leached in rainy seasons) can be attributed to intensive use of nitrogen fertilisers in Kisii highlands for cereal and Tea production. Recent studies in Lake Baringo reflected the presence of algae at river Molo inlet due to rich inflow of nutrients into the lake from the catchment areas (Ndiba et al., 2018).

Figure 2 illustrates the variation of phosphate levels in soil, sediments and water within the entire sampling period in the eight sampling stations within River Nzoia. The highest concentrations of phosphates were found in Moi's Bridge and Pan-Paper with values of (15.0 ± 1.05 mg/L) and (15.6 ± 1.33 mg/L), respectively. These levels could be due to agricultural runoffs from flower farms in Moi's Bridge and sugarcane farms in Pan-Paper area combined with effluents from the paper factory. It could also be attributed to leachates from waste dumps and municipal runoffs, which contain detergents in these areas.

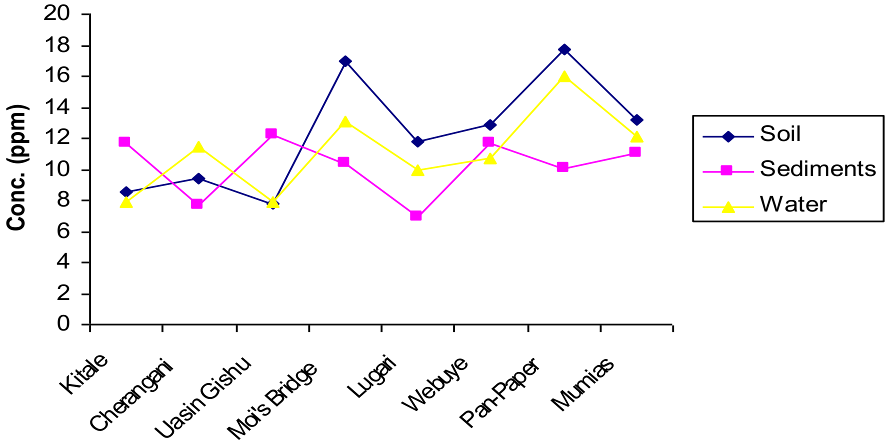

Figure 2: Variation of phoshate levels in the 8 sampled stations in water, soil and sediments along river Nzoia.

Lowest values were detected in Kitale (8.9 ± 0.05 mg/L) and Uasin Gishu (7.5 ± 1.25 mg/L) and were significantly lower ($p>0.05$). This could be attributed to dilution factor from rivers Ainomaget and Moiben, respectively and also from natural self cleansing or purification capacity of the river itself. Generally, the PO_4^{3-} concentrations in the Nzoia area were found to be within the (WHO, 2011) standards of 10 ppm. Njuguna et al. (2020) conducted similar research in Kenya's Tana River and concluded that the river is at danger for eutrophication since the total phosphorus content observed surpassed the acceptable threshold. Misigo & Suzuki (2018) revealed that Nyando River has significant phosphorous contents, mostly from forest and catchment biomass (sugar, rice and other cereals refuse).

Temporal Variations in Concentrations of the Selected Nutrients in Water, Soil and Sediments

Seasonal variation of nitrate levels in the 8 sampling stations along River Nzoia is shown in Figure 3. There was a general significant ($p<0.05$) increase in nitrate during the rainy season compared to the dry season. This could be attributed to heightened runoff and the fact that most farmers wait for the rainy season, which usually coincides with the planting season for annual crops and top-dressing season for tea and sugar cane to start applying the nitrate and phosphate fertilizers.

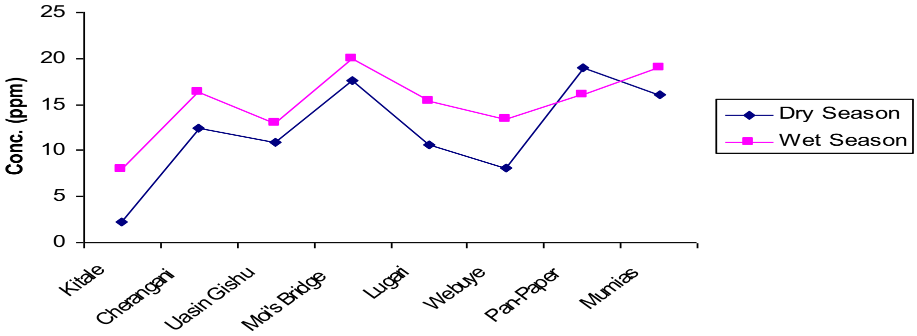

Figure 3: Variability of nitrates in all the sampled stations between dry and rainy seasons.

Figure 4 illustrates the seasonal variation of phosphate levels in the 8 sampling stations along River Nzoia. Phosphate concentration showed a significantly different ($p<0.05$) increase during the rainy season in Kitale, Uasin Gishu, Pan-Paper, Webuye and Mumias, while the rest of the stations recorded higher values during the dry season. This could mainly be attributed to application of phosphatic fertilizers used for planting, which is usually done during the rainy season. The results of this study agreed with the findings of Limo (2013), who reported that there were significant spatial and temporal variations (ANOVA; p 0.05) in the concentration of phosphates in water, soils, and sediments in Kapsabet River, with the wet season having the highest levels of phosphates in all of the media.

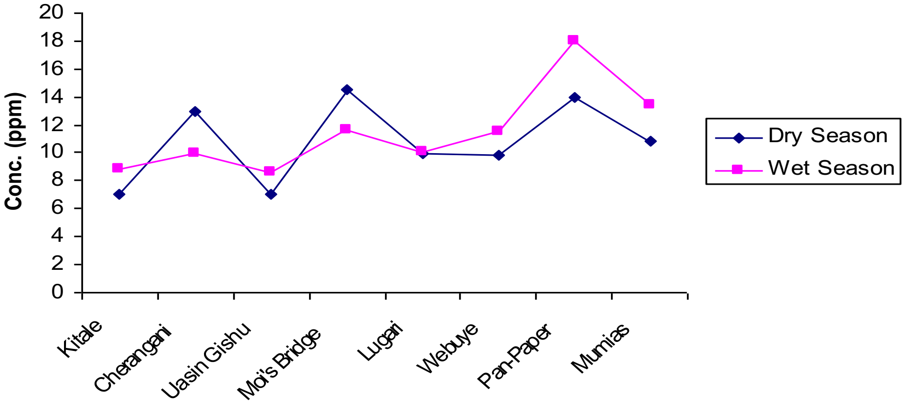

Figure 4: Variability of phosphates in all the sampled stations between dry and rainy seasons.

Spatial Variations in Concentration of the Selected Physico-Chemical Parameters in Water, Soil and Sediments

Figure 5 illustrates the variations of the levels of selected physico-chemical parameters in the eight sampling sites. Temperature showed a general increasing trend from Kitale down river to Mumias. It varied from 13°C to 28°C with mean values of (13 ± 3 mg/L) at Kitale, (17 ± 3 mg/L) at Cherangani, (18 ± 4 mg/L) at Uasin Gishu, (19.5 ± 4.5 mg/L) at Moi's Bridge, (21 ± 4 mg/L) at

Lugari, (24 ± 4mg/L) at Webuye, (27.5 ± 2.5 mg/L) at Pan-Paper and (28 ± 3 mg/L) at Mumias. The increasing trend could be attributed to the fact that sampling was started in the morning downriver and completed in the evening. This was affected by the fact that temperatures fluctuate normally in any given day because of exposure of the surface water to sunlight and are highest at around 4 pm in the river. Another reason could be due to variation in the depth of the waters. Apart from Pan-Paper temperature values at all the sampled stations were found to be within normal temperature range for aquatic life, 27° C.

The levels of dissolved oxygen showed a decreasing trend downriver ranging from a minimum of 6.8 mg/L and a maximum of 11.3 mg/L with mean values of (11.3 ± 1 mg/L) at Kitale, (9.57 ± 0.5 mg/L) at Cherangani, (9.4 ± 0.7 mg/L) at Uasin Gishu, (9.055 ± 0.655 mg/L) at Moi's Bridge, (8.44 ± 0.2 mg/L) at Lugari, (7.825 ± 0.205 mg/L) at Webuye, (7.46 ± 0.39 mg/L) at Pan-Paper and (6.8 ± 0.45 mg/L) at Mumias. This variability could be explained by the fact that DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Nyakeya et al. (2018) conducted an identical investigation in Lake Baringo, where they found that DO exhibited noteworthy changes over the entire study period, with station S2 recording 5.3 mg/l in 2017 and 5.5 mg/l during the sampling periods of June 2014 and May 2015.

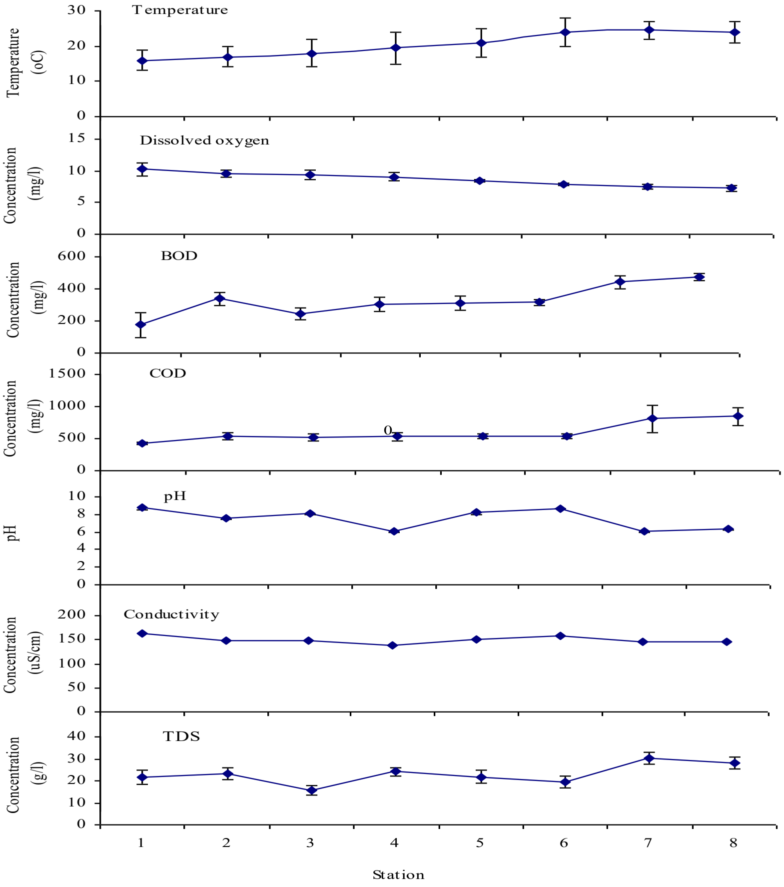

Figure 5: Variations in physico-chemical parameters among the sampled stations.

This suggests that at higher temperature the amounts of DO in water should be much lower because of reduced solubility at higher temperature. This could also have occurred through biochemical utilization of DO along the river channels due to intense human activities down the river channel. A comparable study was conducted by Kerich & Ndege (2020), who reported that the measured dissolved oxygen levels were 3.75±0.21 mg/l at Nyaguru (Downstream) and 6.84±0.02 mg/l at Daraja (downstream).

Chemical oxygen demand levels mean values ranged from 22.5 mg/L to 51.0 mg/L at the sampling stations Kitale, Cherangani, Uasin Gishu, Moi's Bridge, Lugari, Webuye, Pan-Paper and finally Mumias. There was, however, a drastic increase of the levels at Pan-Paper and Mumias sites while the rest of the stations maintained almost a constant level. Again, this could have been contributed by effluents from Pan-Paper factory in Webuye and Mumias sugar factory in Mumias. Apart from Mumias, all the sites recorded values that were within the recommended standards for drinking water, (50 mg/L) (WHO, 2011). Sivamanikandan and John (2015) conducted similar studies on the water of the Mullaiperiyar River in the Theni district of Tamil Nadu, India, and observed that the COD ranged from 7.2 to 240 mg/l at nine sampling points. The COD values of the water samples were found to be high due to an increase in the water's organic and inorganic composition caused by sewage discharge and public human activities.

Annual pH ranges for River Nzoia were from 6.0 to 9.0 with lowest values recorded at Moi's Bridge (6.0±0.1), Pan-Paper (6.2±0.1) and Mumias (6.3±0.2) and highest in Webuye (9.0±0.1). There was a significant difference ($p<0.05$) in all the sites and these could be due to the fact that though pH is usually regulated by the amounts of H^+ ions, significant shifts in the pH often occur subject to variations in the water volumes, which changed at Moi's Bridge due to incoming tributary. This, therefore, means that any shift in pH could be attributed to the changes in water composition within the catchment area. This is an important component because water that gets into the river has to pass through large settlement areas where its quality can be impaired considerably. Similar research by Ochuka et al. (2019) found elevated pH levels in Lake Baringo and its tributaries. High pH readings in River Endau, River Perkerra, and River Molo inlets may be due to surrounding horticulture and sisal fields and irrigation schemes.

Transport of water across the urban sites like Webuye is likely to introduce many substances in water of River Nzoia that could elevate levels of pH in water. Apart from Moi's Bridge, Pan-Paper and Mumias (lower) and Webuye (higher), all the other sites were within the recommended values (6.5-8.5) for water and aquatic life (WHO, 2011).

In this present study, conductivity values of River Nzoia ranged from 137 µS/cm to 167.5, varying significantly ($p<0.05$) along River Nzoia. The highest conductivity values were recorded in Kitale (164 ± 3.5 µS/cm) followed by Webuye (158.2 ± 1.9 µS/cm) while the lowest was recorded in Moi's Bridge (138.65 ± 1.65 µS/cm). The high conductivity values could be due to runoff from the nearby Kitale town since the area is topographically steep and the river is therefore exposed without flora cover, hence, receiving all runoff without the filtering effect. All the sites, however, recorded values within the recommended standards (1000 µS/cm) for both domestic water and fresh water for supporting aquatic life (WHO, 2011). This tends to agree with (Sampson et al., 2020), who investigated physicochemical analysis of selected groundwater sources in Ikot Abasi Urban, Akwa Ibom State, and found EC values between 19.6 - 416µS with an average value of 131.85 µS. The study attributed the differences in the EC levels to the underlying geology of the study area where different chemical species interact with various anions and cations in aquifers to affect the water quality of the area.

Total dissolved solids levels in River Nzoia water showed a significant variation throughout the study ($p<0.05$). The results show that the TDS values upstream at Kitale (21.7 ± 3.3 mg/L) and Uasin Gishu (15.7 ± 2.3 mg/L) were significantly lower than the rest of the stations. A significant increase was observed at Cherangani (23.3 ± 2.7 mg/L), Moi's Bridge (24.15 ± 1.85 mg/L), Lugari (21.85 ± 3.15 mg/L) and Webuye (19.5 ± 2.5 mg/L). This could be attributed to municipal and industrial runoffs within the areas from the factory at Cherangani, respectively. Pan-Paper (30.3 ± 2.7 mg/L) and Mumias (28.15 ± 2.85 mg/L) recorded the highest levels of TDS. This could also be attributed to factory effluents from the Pan-Paper and Mumias Sugar factories, which are usually released into the river. The results throughout the study period showed that all the stations were lower than maximum allowable limits for river water (100 mg/L) (WHO, 2011). Kosgei (2016) conducted a similar study on the impact of effluents discharge from Murang'a town and its environs on the water quality of river Mathioya, Murang'a County, Kenya, and reported that low levels of total suspended solids were recorded for Kosi River at Uttrakhand, Iran, and the average value of TSS varies between 3 and 174 mg/L.

In general, the physico-chemical status of River Nzoia displays a considerable heterogeneity in vertical spatial scale in as much as it displays variability in horizontal scale. According to the present results obtained from the river, temperature, DO, pH, conductivity and TDS, BOD and COD exhibited marked temporal and spatial variations among the sampled locations. Much of these variabilities are tied to the prevailing weather conditions.

Results from the correlations performed, indicated that temperature distribution seemed to have a significant effect on the solubility and distribution of DO, conductivity, and TDS. This suggests that at higher temperature the amount of DO in water tends to be much lower because of reduced solubility.

Temporal Variations in Concentrations of the Selected Physicochemical Parameters in Water, Soil and Sediments

Overall mean values of selected physico-chemical parameters in River Nzoia during the dry and rainy period are shown in table 1. Temperature showed a significant ($p<0.05$) increase in the rainy season compared to the dry season probably because it is usually generally colder in the tropics during rainy seasons due to cloud cover and more moisture.

Dissolved oxygen also showed a significant increase in the rainy period probably due to its dependence on temperature, and the fact that there is more biochemical utilization of oxygen in water bodies in the dry season.

Table 1: Overall mean variations of levels of selected physico-chemical parameters in the dry and rainy seasons

	Dry	Rainy
Temperature (°C)	24.0 ± 1.2	17.0 ± 1.3
DO (mg/l)	8.3 ± 0.2	8.9 ± 0.6
BOD (mg/l)	35.9 ± 2.7	29.1 ± 4.2
COD (mg/l)	33.5 ± 7.4	25.6 ± 3.4
pH	7.6 ± 0.4	7.4 ± 0.4
Conductivity (μS/cm)	148.2 ± 3.6	152.2 ± 3.1
TDS (mg/l)	20.4 ± 1.6	25.7 ± 1.7

BOD and COD were higher in the dry season than the rainy season probably because storm water runoff brought about dilution factor on oxygen demanding organisms and reactions. This could also be attributed to temperature increase in the dry season, which has a direct proportional relationship with BOD, hence, when temperature increases BOD also increases.

COD, on the other hand was higher in the dry season, this could be attributed to the presence of higher levels of chemical species present in waste effluents, which demand high levels of oxygen for oxidation of organic matter by a strong chemical. However, lower levels were recorded in the rainy season probably due to dilution factor.

Higher values of pH were recorded in the rainy season probably due to more river discharge in the rainy season, hence, higher levels of dissolved substances brought in by runoffs from agricultural farms, industrial effluents and dislodging of substances from the river bank by high-speed discharges due to rainfall.

Conductivity was higher in the rainy season than in the dry season because of increased runoff volumes bringing with them more dissolved substances washed away from municipal sites, roads, garages and farms. TDS was higher in the rainy season probably due to higher runoff volumes transporting dissolved substances into the water bodies along the river. Results on the temporal variation of DO, BOD, COD, pH, conductivity, and TDS over the dry and wet seasons were comparable to those published by Limo (2013), who also documented differences in temperature, pH, TDS, COD, and BOD between the four sample locations along the Kapsabet River.

CONCLUSION AND RECOMMEDATIONS

Most of the pollutants increased down the River Nzoia. Nitrates and phosphates increased in the wet season downstream. The BOD and COD varied downstream especially in the wet season. Therefore, control measures should be taken within the catchment area to avoid the river manifesting serious environmental pollution.

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