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Physico-Chemical Parameters and Levels of Nutrients During Wet and Dry Seasons Along River Ewaso Narok, Laikipia County, Kenya

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Abstract

River and surface water pollution is a growing problem especially in developing countries where population growth and urbanization are never adequately checked. Downstream most urban areas live huge communities of humans and animals who rely on surface water and rivers for survival. Literature indicates rising levels of pollution in rivers in Kenya. There are also reports of environmental degradation and water borne diseases in both humans and animals. This study assessed water quality by determining the levels of nitrates (NO_3^-) and phosphates (PO_4^{3-}) besides physico-chemical parameters namely: Hydrogen ion concentration (pH), Temperature (T), Electrical Conductivity (Ce), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) along river Ewaso Narok, Laikipia County, Kenya, during wet and dry seasons. Water sample analysis for nutrients was done using UV-visible spectrophotometry whereas Physico-chemical Parameters were determined *in situ* using their individual probes. Seasonal changes were found to influence the levels of pollutants. Samples taken near urban settlements were found to contain higher concentrations of the pollutants.

Keywords: Nitrates, nutrients, phosphates, physico-chemical parameters, water-pollution

Introduction

Water quality is an important consideration before water is put into any use. In developing countries surface water quality is compromised especially due to anthropogenic activities (Nguyo, 2011). Urban areas have expanded without proper planning and most lack proper waste disposal and treatment capacity which results in release of vast quantities of toxic waste into rivers and

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wetlands (Thebo et al., 2017). Downstream most of the urban settlements live large populations of people and animals that heavily rely on the water for survival (Thebo et al., 2017).

Sectors such as agriculture, manufacturing/industrial, mining, fishing among others heavily rely on chemicals to improve productivity. Out of lack of proper waste disposal mechanisms, these chemicals and their hazardous wastes drain into rivers (MEMR, 2011). Studies show that most rivers in Kenya are polluted by, among other pollutants, nitrates and phosphates. Further, studies show that most surface water bodies are susceptible to pollution more in the wet season than the dry season. Effects of water pollution are manifested in observed and reported cases of diarrhoea, typhoid, birth and developmental abnormalities and terminal diseases such as cancer and diabetes (Laikipia CIDP, 2018 & NDMA, 2018). This study assessed water quality along River Ewaso Narok by determining the levels of nitrates (NO_3^-), phosphates (PO_4^{3-}), hydrogen ion concentration *(pH),* temperature *(T),* electrical conductivity *(Ce),* total dissolved solids *(TDS)* and total suspended solids *(TSS)* in water during wet and dry seasons.

River Ewaso Narok traverses two urban settlements, Nyahururu and Rumuruti in Laikipia West, two of the most commercially vibrant thus densely populated towns in the county. Like most urban settlements in developing countries, the towns face challenges in population growth, chaotic informal settlements, poor and/or overwhelmed waste management systems, etc., posing a great health risk to the nearby surface water bodies. Downstream the river forms the main source of irrigation water for both small and large scale farms along it (Laikipia CIDP, 2018). Both these levels of farming involve heavy use of chemical fertilizers and pesticides. Besides farming, water from the river is used by residents in watering livestock, washing and drinking, small scale fishing and other domestic uses.

Methodology

Sample collection for wet season was done during the short rains of October and November 2019 while those for the dry season were collected in February 2020. Physico-chemical parameters were measured *in situ* using their individual probes at the same sampling points as water samples.

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Water Sampling

Five sampling points were selected along the river; one before Nyahururu town (WSP_1) and another just after Rumuruti town (WSP_5) and three in between. At each sampling point about 100ml of water sample was collected at a depth of 10-15cm to avoid unpredictable changes in concentration and temperature. This was done in the middle of the river and at the banks. The three samples were then mixed thoroughly in a large container and one 100ml homogenized sample obtained. In one season, this procedure was repeated three times to avoid unpredictable chemical and physical changes in the river water. In the laboratory the samples were stored in a freezer at below 5^oC awaiting analysis.

Digestion and Preparation for UV-visible Analysis

To prepare samples for nitrate analysis, 50mL of the water sample was filtered into a 50mL volumetric flask, into which 2mL of 1M hydrochloric acid was added to dissolve any metallic ion present and preserve nitrate ions. Preparation of samples for phosphate analysis was done using the molybdenum method.

Results and Discussion

Physico-chemical Parameters

Table 1 shows the values obtained for the Physico-chemical parameters along River Ewaso Narok during the wet and dry seasons.

Water pH

The average pH value of water during the wet season was 7.46 ± 1.02 whereas that in the dry season was 8.56 ± 0.51. The figures 1(a) and (b) show the general trend in pH downstream R. Ewaso Narok in the wet and dry seasons respectively.

Table 1: Physico-chemical parameters assessed

Parameter	Season	WSP1	WSP2	WSP3	WSP4	WSP5
		$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$
pH	W	7.7 ± 0.3	8.6 ± 0.2	6.3 ± 0.3	6.5 ± 0.2	8.2 ± 0.2
	D	8.2 ± 0.8	9.0 ± 0.2	8.6 ± 0.6	9.1 ± 0.2	7.9 ± 0.5
Temperature T, (oC)	W	11.34±1.4	12.30±0.5	14.82±1.5	15.50±1.4	15.61±0.6
	D	12.33±2.1	14.67±1.2	16.17±2.4	17.00±1.8	17.67±1.6
Conductivity Ce, (μS/cm)	W	35 ± 5	105 ± 10	70 ± 2	505 ± 17	50 ± 3
	D	40 ± 8	110 ± 5	80 ± 5	530 ± 20	60 ± 5
TDS (mg/L)	W	28 ± 3	81 ± 1	59 ± 3	350 ± 10	50 ± 4
	D	33 ± 2	85 ± 5	65 ± 4	379 ± 10	52 ± 6
TSS (mg/L)	W	9 ± 2	22 ± 1	30 ± 3	56 ± 4	35 ± 5
	D	4 ± 3	19 ± 3	20 ± 2	45 ± 3	24 ± 3

Generally, the pH was lower in wet season as compared to the dry season. pH is not a factor of volume, rather, a measure of the concentration of hydrogen ions (Covington *et-al.*, 1985) as defined by equation **(A).**

$$pH = -log[H^+] \quad \text{OR} \quad pH = log\frac{1}{[H^+]} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(A)}$$

Change in water volume therefore does not change the concentration of H^+ ions and so will not affect the pH (Holmes-Farley, 2004; Otieno, 2008). This implies that the seasonal variation of pH in water from the river was not a result of change in water volume, rather the availability of 'H^+-ion-influencing conditions' including dissolved heavy metal ions, carbonates, hydroxides etc. The pH during the wet season was low because dissolved heavy metal ions were high (Jaishankar *et-al.*, 2014; Krol et-al., 2020*)* as a result of run-offs from farmlands where they're used in form of fertilizers and pesticides (Mobegi, 2015; Omwancha, 2017). Near urban settings pH was high because of the presence of carbonates, hydroxides, etc., from cleaning agents, sewage and other municipal wastes (Akoto et al., 2008; Otieno, 2008).

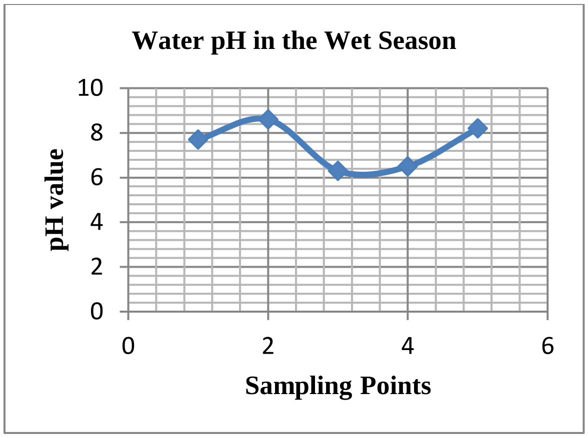

Fig. 1 (a): Water pH downstream during the wet season

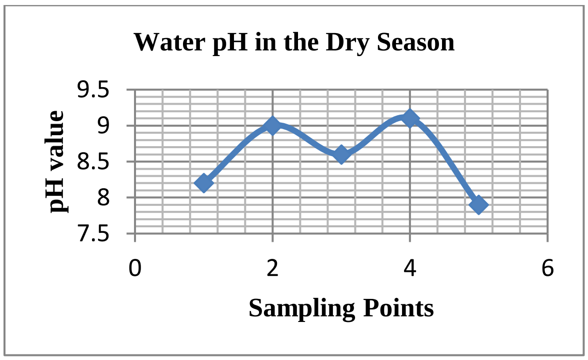

Fig. 1 (b): Water pH downstream during the dry season

Temperature (T)

In the wet season, the water temperature was generally lower than in the dry season with an average temperature of 13.91 ± 1.96°C. The temperature range was between 11.34°C (upstream) and 15.61°C (downstream). The temperatures thus gradually increased with decrease in altitude. The cold temperature upstream is consistent with the cold temperatures experienced in higher altitude regions like Nyahururu. The temperature range was however lower than the reported range of annual temperatures within Laikipia County (16°C to 26°C).

Water in the area around Rumuruti was generally warmer than that around Nyahururu due to its lower altitude. Water in the river was generally warmer in the dry season than in the cold season. The average temperature of the water was 15.57 ± 2.13°C, ranging between 12.33°C at the uppermost sampling point and 17.67°C at the lowest sampling point. The higher temperature in the dry season can be attributed to, among other reasons; solar radiation, atmospheric heat transfer, turbidity, confluences and human activities. Values recorded at midday were higher due to the intensity of heat from the atmosphere (Pasquero, 2008). The line graphs in figure 2 illustrate the general trends in temperature downstream in the two seasons.

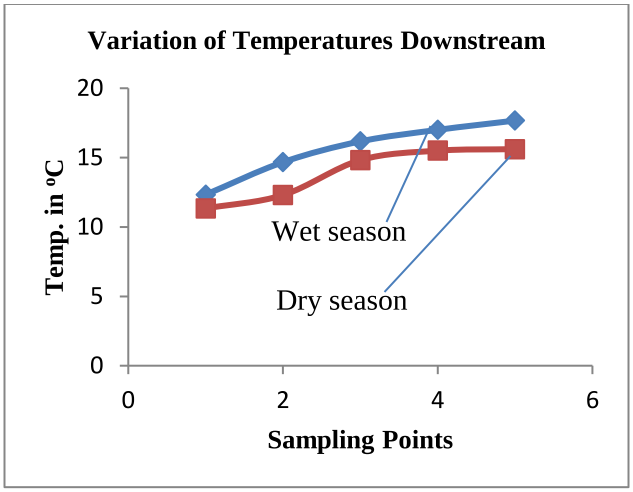

Fig. 2: Water temperature downstream

Electrical Conductivity (Ce)

Literature reports that electrical conductivity is a factor of temperature and TDS/salinity, such that the higher the temperature the more the dissolved ions/salts thus the higher the conductivity (FELC, 2014). The general water conductivity during the dry season is higher than during the wet season and this is consistent with the fact that electrical conductivity depends on temperature. Conductivity is however highest at sampling point 4 for both seasons although it still falls within the recommended limit.

The average electrical conductivity value of the water from the river in the wet season was 153 ± 198.5µS/cm, while that in the dry season was 164 ± 206.23µS/cm. For both seasons, the lowest conductivity was reported for water at sampling point 1(just before Nyahururu town) as the highest was reported at sampling point 4 (near Rumuruti town). The line graphs in figure 3 show the trends in electrical conductivity downstream for both seasons.

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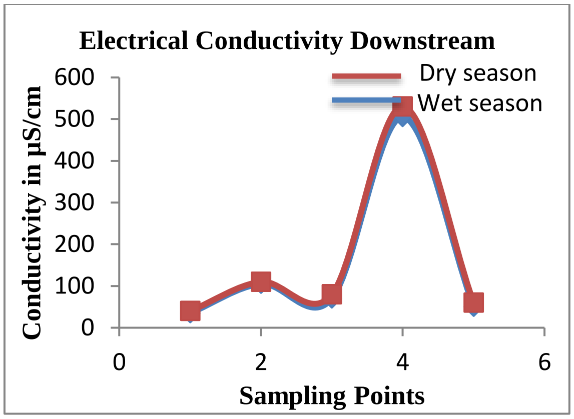

Fig. 3 Trends in electrical conductivity downstream

Sampling point 4 and 5, which had recorded high temperatures, also recorded higher conductivities with sampling point 4 (near Rumuruti town) recording an exceptionally high conductivity in both seasons. The water at that point was suspected to contain higher concentration of dissolved salts and inorganic materials like alkalis, chlorides, sulphides, carbonate compounds, etc., (Miller et-al., 1988; EPA, 2012) from agricultural run-offs and sewage leak. Sampling point 5 (just after Rumuruti town) recorded a lower conductivity, against expectation, something that could be attributed to two reasons; one, sedimentation caused by the somehow gentle terrain of the area that resulted in reduced speed of water, encouraging sedimentation, and two, the increased water volume which dilutes the salinity concentration (Ruhakana, 2012).

Sampling point 1 (before Nyahururu town) registered the lowest conductivity in both seasons. This is consistent with the fact that; first, temperatures were low in this section of the river and therefore lower concentration of dissolved ions. Secondly, the water volume is generally high during the wet season, thus reducing salinity concentration and thirdly, being a point before an urban centre, the section of the river is less polluted. Sampling point 2, just after Nyahururu town, recorded an increased conductivity compared to other points in both seasons. This is an indication of pollution the sources of which are most likely sewage leaks and surface intoxicants from the urban centre (Mobegi, 2015).

Total Dissolved Solids (TDS)

The concentration of TDS was higher in the dry season as compared to the wet season. The average concentration of TDS in the water during the wet season was 113.6 ± 133.5mg/L. In the dry season, the average concentration of TDS was 122.8 ± 144.5mg/L. The graph in figure 4 below shows the levels TDS in both seasons.

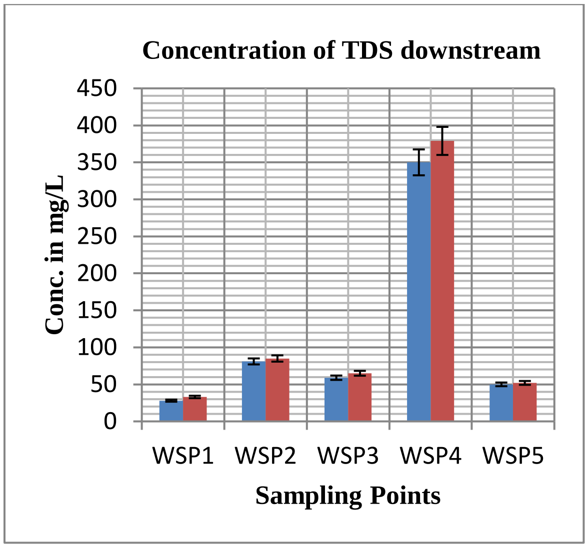

Fig. 4: Concentration of dissolved solids downstream

Very closely associated with conductivity is TDS and as such sampling point 4 which had the highest conductivity in both seasons also recorded the highest TDS in both seasons. The high TDS can be attributed to effluents due to sewage leaks from the nearby town and agricultural run-offs from farms which contributed ions such as chloride, sodium, magnesium, sulphate, calcium, potassium, bicarbonate, bromide, etc., (Sommer and Spitzer, 2004). In the dry season, temperatures were higher thus more salts/ions dissolved whereas in the wet season fewer ions dissolved due to the low temperatures. It is also possible that during the wet season the salts were dissolved and diluted by the large volume of water.

The sampling point before Nyahururu recorded low TDS in both seasons indicating less pollution levels as compared to the point just after the town which recorded an increased level of TDS. Sampling point 5 recorded low TDS, consistent with the conductivity recorded, and this can be attributed to sedimentation due to the general terrain and increased water volume. EPA recommends an upper TDS limit of 500mg/L in water (Oram, 2014), hence, TDS level in the river fell within this limit.

Total Suspended Solids (TSS)

The average concentration of TSS in water from the river in the wet season was 30.4 ± 17.36mg/L whereas in the dry season an average of 22.4 ± 14.74mg/L was recorded. The graph in figure 5 below illustrates the trends in TSS downstream R. Ewaso Narok.

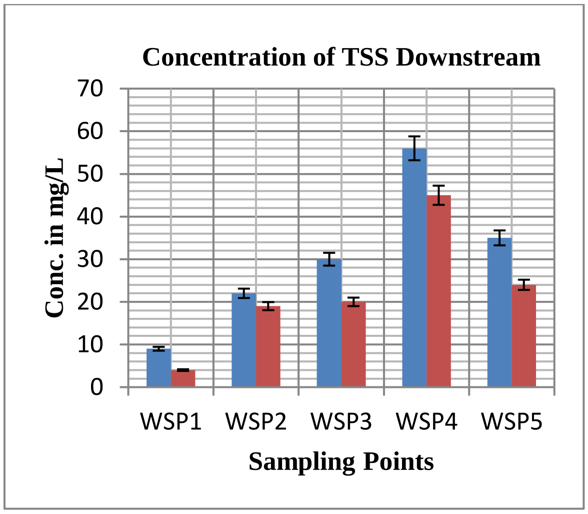

Fig. 5: Changes in concentration of suspended solids downstream

The highest concentration of TSS was recorded at sampling point 4 in both seasons and the lowest at sampling point 1. More particles were present in the river during the wet season largely due to run-offs from farms and the urban centres, and due to erosion of the river bank and nearby farmland (Ruhakana, 2012; Mobegi, 2015). Sampling point 4 was closest to an urban centre, Rumuruti town, with increased human activities and so it recorded more TSS. Sampling points 3 and 5 also recorded fairly high amounts of TSS, especially during the wet season and this can be attributed to run-offs from nearby agricultural fields – the sections of the river characterized by heavy agricultural activities – and erosion of the river bank (Ruhakana, 2012).

The wet season saw lower values of all parameters (except TSS) recorded in all sampling points. This is because pH, T, Ce and TDS are directly related. That is, whenever temperature is high, more ions dissolve in water and the more the ions present in a water system the higher the electrical conductivity.

Nutrients in Water

Nitrates (NO_3^-)

Table 2 below shows the concentrations of nitrates and phosphates recoded in water from the five water sampling points in mg/L. Farming activities increase as one proceeds downstream from sampling point 1. The mean concentration of nitrates recorded during the wet season was *110.3122 ± 62.1294mg/L* from a sample size of 15, ranging between *52.4765 ± 0.026mg/L* at sampling point 4 and *213.2863 ± 9.603mg/L* at sampling point 3. This mean was found to be significantly higher than WHO permissible limit of 11.0mg/L at α = 0.05. In all the points of sampling, the concentration of nitrates was found to be higher than the recommended maximum permissible limit. During the wet season surface run-offs from farms carry soil contaminated with farm chemicals, especially fertilizers containing potassium and ammonium nitrates, into the river. Besides, human sewage and livestock manure may be transported by rain-water into the river (Omwancha, 2017). Figure 3.6 is a graph showing the concentration of nitrates downstream during the two seasons.

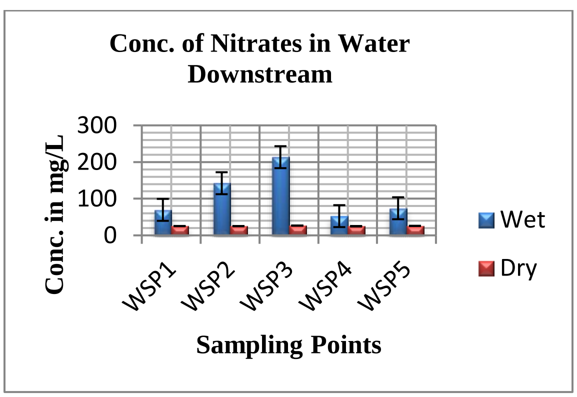

Fig. 6: Concentration of nitrates in water

Table 2: Nutrients in water

N	S	WSP1	WSP2	WSP3	WSP4	WSP5
		$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$	$\bar{X} \pm sd$
NO_3^-	W	69.569±0.022	142.275±0.127	213.286±9.603	52.477±0.026	73.955±0.121
	D	25.365 ±1.143	25.183 ± 0.297	26.643 ± 2.182	24.864 ± 1.323	25.836 ± 1.980
PO_4^{3-}	W	0.089	0.092± 0.001	0.086±0.012	0.230±0.006	0.037±0.004
	D	0.127 ± 0.121	0.193 ± 0.109	0.046 ± 0.069	0.118 ± 0.092	0.296 ± 0.132
N= Nutrient, S= Season						

During the dry season, concentration of nitrates in the river ranged from *24.8643 ± 1.3233mg/l* at point 4 to *26.6428 ± 2.1822mg/l* at point 3 with an overall mean concentration of *25.5787 ± 1.4487mg/l*. This mean too was significantly higher than WHO limit. Evaporation of water in the river concentrated the amount nitrates, however the levels were low and this can be associated with sedimentation occasioned by the reduced water speed and turbulence. Incidentally, sampling point 3 – a section of the river characterized by heavy agricultural activities – recorded the highest amount of nitrates in both seasons. This is evidence that there is heavy use of agrochemicals containing nitrates in nearby farms.

Sampling point 4 recorded the lowest concentration of nitrates in both seasons. The reason could be little farming activities around and given that the section is near Rumuruti town urban setting, then the amount recorded has its source most likely in sewage effluents from the town and livestock manure (Water Quality Association, 2013; Omwancha, 2017). Sampling point 2 near Nyahururu town recorded a relatively higher concentration in both seasons. The main source of nitrates here is surface effluents and sewage leaks from the town.

The United States Environmental Protection Agency (EPA) has set the maximum permissible limit of nitrates, measured as $NO_3^- - N$, in drinking water at 10.0mg/L whereas WHO has set the limit at 11.3mg/L. The maximum limit for nitrites $(NO_2^- - N)$ by the said organizations is 1.0mg/L (Water Quality Association, 2013). Given these limits, the level of total nitrates in water along the river was high in both seasons, much higher in the wet season.

Phosphates (PO_4^{3-})

Observed concentration of phosphates in the river ranged between *0.037* ± *0.004mg/L* at point 5 and *0.230* ± *0.006mg/L* at point 4 in the wet season. The mean concentration was *0.1068* ± *0.07249mg/L*. The mean, in comparison with WHO permissible limit of 0.025mg/L, was found to be significantly higher at α = 0.05. The concentration of phosphates was found to be highest in water at point 4, near Rumuruti town, and lowest at point 5, past Rumuruti town.

The concentration of phosphates in the river in the dry season ranged between minimum *0.04645* ± *0.06930mg/L* at point 3 and maximum *0.29591* ± *0.13235mg/L* at point 5. The mean concentration in the same season was *0.13761* ± *0.09574mg/L* from a sample size of 14, this mean being significantly higher than the limit by WHO at α = 0.05. Figure 3.7 shows the concentrations of phosphates at various sampling points downstream in the two seasons.

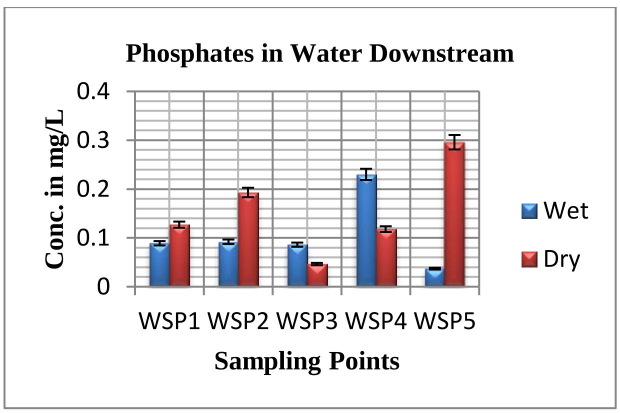

Fig. 7: Concentration of phosphates downstream

Literature recommends a maximum permissible concentration of 0.10mg/L of total phosphates in a natural water system above which there is possible accelerated eutrophication and other associated problems. Sampling point 4 recorded an exceptionally high concentration of 0.230 ± 0.006mg/L. This can be attributed to the heavy agricultural activities, effluents of which wash into the river during downpour (Omwanza, 2017). Another suspected source is sewage leaks and municipal/domestic waste (Mobegi, 2017) from Rumuruti urban setting. The latter is the case at sampling point 4 which recorded the highest concentration during the wet season. Sampling point

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2, just after Nyahururu town, also recorded an above average concentration of 0.092±0.001mg/L during the wet season, something that can be purely attributed to waste effluents from the town. The concentration of phosphates reported in the dry season was slightly higher than in the wet season, and this is as a result of evaporation of water which concentrates the nutrients making them more detectable. This was especially the case at sampling point 5, which had recorded the lowest concentration in the wet season but recorded highest concentration in the dry season. Besides, in the dry season farming along the river heavily relies on irrigation, the water of which washes back to the river.

Summary Results

Table 3 presents a summary of the results obtained in this study for all the seven (7) parameters measured.

Table 3: Measured parameters versus permissible limits by various organizations

Parameter	Season	Experimental Result	Permissible Limit	Comment
pH	Wet	7.46 ± 1.02	6.5 to 8.5 (WHO)	Not significantly different
	Dry	8.56 ± 0.51		Significantly higher
T (oC)	Wet	13.91 ± 1.96	20 to 35 (Kenya)	Not significantly different
	Dry	15.57 ± 2.13		Not significantly different
Ce (µS/cm)	Wet	153 ± 198.5	400 (EU)	Not significantly different
	Dry	164 ± 206.23		Not significantly different
TDS (mg/L)	Wet	113.6 ± 133.5	1000 (WHO)	Not significantly different
	Dry	122.8 ± 144.5		Not significantly different
TSS (mg/L)	Wet	30.4 ± 17.36	30 (Kenya)	Not significantly different
	Dry	22.4 ± 14.74		Not significantly different
NO3- (mg/L)	Wet	110.312 ± 62.129	11.0 (WHO)	Significantly higher
	Dry	25.4420 ± 1.4487		Significantly higher
PO43- (mg/L)	Wet	0.1068 ± 0.0676	0.025 (WHO)	Significantly higher
	Dry	0.1376 ± 0.0957		Significantly higher

Both one-tailed and two-tailed tests done at $\alpha = 0.05$ (5%)/ ($p < 0.05$)

The experimental results were compared with accepted limits using one-tail and two-tail tests to tell if the values were significantly higher or lower than the set limits. From the table, the water pH along the river fell within permissible limits in the wet season. In the dry season the pH was significantly higher than WHO set limit ($p < 0.05$) due to possible high concentration hydroxides. Temperature was below the recommended average and this is because of the generally higher altitude of the area and the fact that the river flows (most of the time) within a forested area. Temperature affects other physical/chemical parameters like TDS and conductivity, and so it can be argued that, the amount of TDS (and conductivity) recorded is lower due to the lower temperature of the water. The values recorded for T, Ce and TDS were higher in the dry season than in the wet season. In the wet season TSS was higher than the dry season. However, statistically the concentration was not significantly different from the set limits ($p < 0.05$). The wet season is associated with floods, erosion, increased water volume, high water speed and turbulence, thus an expected high TSS.

The concentration of nitrates was significantly higher than recommended limits by WHO in both seasons. The wet season recorded a higher concentration as compared to the dry season. The major sources of nitrates are fertilizers, pesticides, sewage and animal manure (NHES, 2006). Evidently therefore, nitrates from these sources reach the river more so during the wet season when surface run-offs easily carry/transport these wastes.

Phosphates were equally heavily present in water as evidenced by the fact that their concentrations in both seasons significantly exceeded the maximum permissible limit by WHO. The mean concentration reported in the wet season was however slightly lower than in the dry season. This could be associated with the dilution of the pollutant due to increased water volume during the wet season leading to less detectability. All the three forms of phosphates – orthophosphate, metaphosphate and organic phosphates – are suspected to be present in the water given that their possible sources are all present along river Ewaso Narok. However, the major possible source is likely to be fertilizers and organic pesticides used in farming activities. Human and animal wastes, laundry, cleaning and industrial effluents also form a category of other sources that should not be neglected.

Conclusion

The two urban centres, farming activities along the river, among other anthropogenic activities, and seasonal variations contribute majorly to pollution of River Ewaso Narok.

Acknowledgement

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