Africa International Journal of Multidisciplinary Research (AIJMR) ISSN: 2523-9430 (Online Publication) ISSN: 2523-9422 (Print Publication), Vol. 2 (5) 1-9, October, 2018 www.oircjournals.org

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Type of the Paper: Research Paper.
Type of Review: Peer Reviewed.
Indexed in: worldwide web.
Google Scholar Citation: AIJMR

How to Cite this Paper:
Ontumbi, G. M., and Sanga J. K., (2018). **Spatial Temporal Variation of Selected Water Quality Parameters along River Sosiani, Uasin Gishu County.** *Africa International Journal of Multidisciplinary Research (AIJMR), 2 (5), 1-7.*

Africa International Journal of Multidisciplinary Research (AIJMR)
A Refereed International Journal of OIRC JOURNALS.

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ARTICLE INFO

Received 28th July, 2018
Received in Revised Form 12th September, 2018
Accepted 31st September, 2018
Published online 9th October, 2018

Keywords: River Sosiani, Temporal variation, spatial assessment, Water quality

Abstract

Surface water is a vulnerable resource to pollution on the earth surface due to the deterioration of its quality attributed to diverse sources of pollution. This paper sought to assess the spatial and temporal water quality variation along River Sosiani. Understanding of the spatial-temporal distribution of pollutants and identification of the sources in the river systems is a requirement for the protection and sustainable utilization of the global water resources. The objectives of the study were: determine the spatial variability in water quality and infer the main pollution factors. The water quality data were collected during the period (2013–2015) from eleven sampling stations distributed on the river quarterly along the River Sosiani. The water quality parameters sampled included; total dissolved solids (TDS), Phosphates (Po_4), Sulphates (so_4^{-2}), Nitrates (NO3-) and pH. Descriptive statistical techniques of primary data were used to investigate the temporal and spatial variations of the water quality. The results showed that there were variations in water quality characteristics mainly related to non-point source contamination which would include; domestic, industrial wastewater and municipal and point sources of contamination of waste water originating from lagoons. Conclusively, this study showed that the water quality of River Sosiani is deteriorated and therefore potentially unsafe for human use and highlighted the need to treat industrial and municipal wastewater and encourage sound agricultural practices.

Background to the study

Approximately 70% of the earth's surface is covered by water consequently therefore water is the most precious natural resource that exists on the planet, without which life would be nonexistent as observed by Akali *et al.*, (2011). Masese *et al.* (2012) observe that rivers play a major role as sources of water for both domestic and industrial use in many parts around the world. The decrease of available water resources, the water quality degradation and the rapid increase of population combined with the growth of human activities; today impose the development of a science that concerns the Management of Water Resources with more emphasis on water quality than water scarcity.

Amongst inland water resources rivers are the most major readily available sources of water for human consumption, agricultural needs, industrial and recreational purposes (Kumar *et al.*, (2005). So, it is important to have reliable information on trends of water quality for effective water management (WHO, 2004). Eldoret town with a rapid population growth attributed to the large influx of people seeking employment and those for education especially at tertiary level, agricultural runoffs and land use/ land cover dynamics has had its impacts transferred to the nearby River Sosiani. The quality of river Sosiani's water is, therefore negatively affected by the anthropogenic, natural processes and industrial activities which are discharging wastewater as constant polluting

sources predominantly affected by climate, land use/land cover dynamics and topography of the watershed (Ontumbi & Chebet, 2017 and Masakha *et al.*, 2017).

Erosion as a natural process provides sediments and organic matter to water systems and that could lead to loss of soil fertility in crop land areas and deterioration in water quality through sedimentation (Ayivor & Gordon 2012). The nutrient discharge is contributed by inappropriate use of farming fertilizers and agrochemicals which may result to high nutrient loads in the rivers. In many regions of the world, human activities have altered natural erosion rates and greatly altered the volume, rate, and timing of sediment entering streams and lakes thereby affecting physical and chemical qualities of the river's water. Large losses of nutrients from agricultural land may be caused by intensive use of fertilizers where several investigations have shown that concentrations of nutrients in river water are strongly correlated to the percentage of agricultural land in the study basins as observed by Stalnacke *et al.* (2003). Unfortunately, with increasing population, adequate food supplies can only be maintained by the use of fertilizers which have resulted to loss of biodiversity in the rivers and lakes. Once it rains the exposed soil sediments are carried to the river resulting to increased amounts of total dissolved solids (TDS), Nitrates and phosphates.

In East Africa, land use changes caused by rapid urbanization and clearance of forests to create room for agriculture have emerged as major stressors of streams and rivers (Kasangaki *et al*., 2008). Raburu *et al*. (2009) eludes that near stream human activities like sand mining and row crop agriculture have been reported to cause the greatest influence on stream habitat and biotic characteristics due to change in water quality characteristics. For water scarce countries, including Kenya as observed by WRI, (2007) the water catchment areas should be managed properly so as to retain their capacity to supply good quality water all year round.Research on spatial-temporal variations of river water quality has been conducted in many basins. Studies investigating the spatial and seasonal variability of water quality have reported that water quality issues, such as eutrophication, are highly dependent on land use patterns and influence from watershed runoff discharge (Mouri, *at al*. (2011); Fu *et al*., 2009). Therefore, regularly monitoring and evaluating the quality of river water is required for integrated management of these water resources as observed by Shrestha & Kazama, 2007). For monitoring the quality of river water, sampling networks seem to be an outstanding source of information for local and temporal visualization of the state of river water (Zabiegała *et al*., 2010).

Statement of the problem

Worldwide the deterioration of surface water quality is attributed to both natural processes and anthropogenic activities which include; hydrological processes, climate change, precipitation, agricultural land use and sewage discharge. Information on water quality and pollution sources is important for the implementation of sustainable water-use utilization and management strategies. Therefore assessing spatial-temporal variations of river water quality at a watershed level is an important aspect for the physical and chemical characterization of aquatic environments.

Research on spatial-temporal variations of river water quality has been conducted in many basins in Kenya. Subsequently Studies investigating the spatial and seasonal variability of water quality have reported that water quality issues, are highly dependent on land use pattern, agricultural activities and runoff discharge from the water catchments. Subsequently it is important to assess the spatial temporal variation of selected water quality parameters along river Sosiani, Uasin Gishu County so as to determine how the anthropogenic activities have influenced and degraded the surface water and damaged their use for drinking, industrial and agricultural purposes.

Study objectives

The study was guided by the following objectives:

i. Determine the spatial variations in selected water quality parameters a long River Sosiani.
ii. To infer main pollution factors a long River Sosiani.

Scope

In this study the spatial variations of water quality parameters in River Sosiani were studied. The study aimed to investigate the state of water quality parameters and how the water quality changes between upstream and downstream. Secondary data from Eldoret water and Sanitation Company supported by desktop literature was used for this research. The results showed the type of water pollution in the catchment. This was necessary

since point and non-point based pollution require different mitigation measures for effective action on water quality degradation

Literature Review

The quality and quantity of river water is influenced by both natural processes and anthropogenic interferences. However, anthropogenic activities constitute one of the major causes of environmental problems that alter the hydrochemistry in our river systems. Rivers are highly heterogeneous at spatial as well as temporal scales. Variation in the quality and quantity of River water is widely studied across the globe. Tropical rivers display profound temporal and spatial heterogeneity in terms of environmental conditions as observed by Kilonzo *et al.* (2014). This aspect needs to be considered when designing a monitoring program for water quality in rivers by constantly assessing the physico-chemical composition and the nutrient loading of the rivers and their main tributaries.

Kenya's growing and rapidly urbanizing population has put pressure on its river systems. In 1992, the country had 647 m^3 of renewable freshwater resource per capita per annum which has declined by more than 200 m^3 per capita per annum to date (Onyango *et al.*, 2015. Rivers are important as they cater for the irrigational needs in the agricultural areas and at the same time water domestic and industrial use. Kenya's economy is dependent on agriculture and as population increase so does food productivity which results in putting a strain on land use to cater for food production and available water resources for irrigation (Kithii, 2011). Downstream land has been converted to cater for urbanization and as a result more farming mushroom upstream in the river catchments. Land use changes coupled with poor farming practices increase water pollution in rivers originating from this catchment areas and impacts high cost for water treatment and poor health to downstream water users (Mwangi *et al.*, (2010) & Marshalls, 2011)

Rivers can get polluted through natural pollution as a result of leaf falls, decaying animals, fresh erosion of banks, run-off of silt or through anthropogenic sources such as industrial waste water, domestic sewage and agriculture. Anthropogenic sources can further be divided into point and non-point sources of pollution (Elias *et al.*, 1989). Any identifiable source from which pollutants are discharged like a pipe, factory, industrial outlets or waste water treatment plants are regarded to as point sources of pollution while nonpoint sources (NPS) are sources that can be harder to identify such as runoffs from agricultural land and mining sites. Urban NPS may include runoffs from roofs, streets and construction sites (Hill, 2010). Strict guidelines are usually enforced by environmental control bodies such as the national environmental management agency (NEMA) in Kenya to protect rivers from point based pollution. However this type of command and control measure are bound to fail in addressing non-point based pollution.

Materials and methods

Study area

River Sosiani is one of the nine major tributaries of River Nzoia that drains into Lake Victoria. The tributary originates from Kaptagat forest in the highlands of the Keiyo escarpment. Sosiani River passes through Eldoret town, flowing south east to North West to join River Nzoia. Pollution in Sosiani River possibly is leachate from the dumpsite and the sewage reaching the river (Amadi, 2013). Efforts in the recent past to restore the river back to its natural state have been initiated, but it has not achieved significant results. A number of illegal activities such as car washing near the river have been dealt with and the enterprises have been shifted to far off areas.

However, much still has to be done on the restoration of the riparian zones and waste management since it is still common to find dumpsites along the river and activities that impact negatively on river water quality still being carried out along the river which is a major source of water to many residents and provides food supplies such as fish to the population living downstream (Ontumbi *et al*., 2015). The river collects waste generated in town and haphazardly dumped along the roads and the river. Most of the garbage collected in Eldoret is disposed of at the County landfill at Huruma, along River Sosiani creating new types of waste in forms of toxic liquid leachate.

Methodology

pH

It is a measure of the intensity of acidity/alkalinity and the concentration of hydrogen ion. Its range is give between 0 – 14. The pH 7 being neutral, less than 7 being acidic and above 7 being basic or alkaline. In this study the pH of sample water was

determined by pH meter model 320 serial No Mu150. First tested the pH meter with distilled water and calibrated to zero. Followed by standarditization with pH 4 and pH 7. Then rinse the electrode of pH meter with distilled water. The sample water in 50 ml beaker and pH meter electrode dips in at and the readings taken when it stabilizes.

Nitrates

Nitrate salts originate naturally on earth as large deposits, particularly of nitrates. Nitrites are produced by a number of species of nitrifying bacteria, and the nitrate compounds nitrates are mainly produced for use as fertilizers in agriculture because of their high solubility and biodegradability. The UV-VIS Spectrophotometer series DR4000 was used for estimating nitrate-N content in water samples.

Sulfate

Sulfates are a mixture of sulfur and oxygen and are a part of naturally occurring minerals in some soil and rock formations that contain groundwater. The mineral dissolves over time and is released into groundwater. High concentrations of sulfate in drinking water cause a laxative effect when combined with calcium and magnesium. UV-VIS Spectrophotometer series DR4000 was used for estimating sulfate content in water samples.

Total Dissolved Solids (TDS)

It refers to that fraction of solids that pass through a 0.45 µm filter paper. Small particles of certain wastewater materials can dissolve like salt in water. Electrical conductivity was expressed in units of mS m-1. Conductivity can be regarded as a basic indicator of water quality, since it is related to the sum of all ionised solutes or total dissolved solid (TDS) content, and the value expressed using this formula.

TDS (mg/l) = EC µ S/cm x 0.7

Phosphate:

Water samples were collected in plastic bottles that have been cleaned with 1:1 Hydrochloric Acid Solution and rinsed with deionised water. Samples were placed in cool box at 4 °C and prompt analysis done. Filtration through a 0.45-µm-pore-diameter-membrane filter separates dissolved from suspended forms of phosphorus. The UV-VIS Spectrophotometer series DR4000 was used for estimating phosphates content in water samples by selecting the appropriate range.

Data collection

The study depended on the data collected by ELDOWAS (Eldoret Water and Sanitation Company) from January 2013 to October 2015. The water samples from river were collected quarterly and thereafter taken immediately to the laboratory for the assessment of various Physical-chemical parameters. Samples were collected from 11 sampling stations distributed along the river namely Nb(Nairobi bridge),Kb(Kisumu bridge),Kip/b(Kipkaren Bridge),Qu/s(Quarry Upstream),Qf/e(Quarry final effluent),Qd/s(Quarry downs stream),Bu/s(Boundary upstream),Sf(Sosiani Falls),Ss(Sosiani scheme),Kapti(Kaptinga),Bf/e,(boundary final effluent) during different in (2013 to 2015). The stations were located upstream, mid and downstream.

The physical parameters such as pH were obtained using Digital pH Meter (Systronics). The chemical parameters of water such as, sulphates, phosphates and Total dissolved solids were determined in the laboratory as per the standard procedures for testing of the physical chemical. The methods adopted descriptive statistics for analysis where the averages where calculated for each parameter per sampling point entered in excel and bar graph drawn to show the levels of water parameters per site of sampling in the study period.

Results

Six parameters are analysed for water samples from eleven (11) sampling stations, Descriptive statistics done to physico- chemical parameters of surface water samples from river were done.

pH

The highest value for pH was observed at Qfe and Qfe and the lower value at Qus .the average pH value for river sosiani was 7.06for the study period and temporally 2013 recorded lower pH value compared to 2014 and 2015. In this study the pH value varied between 6.83 – 7.94

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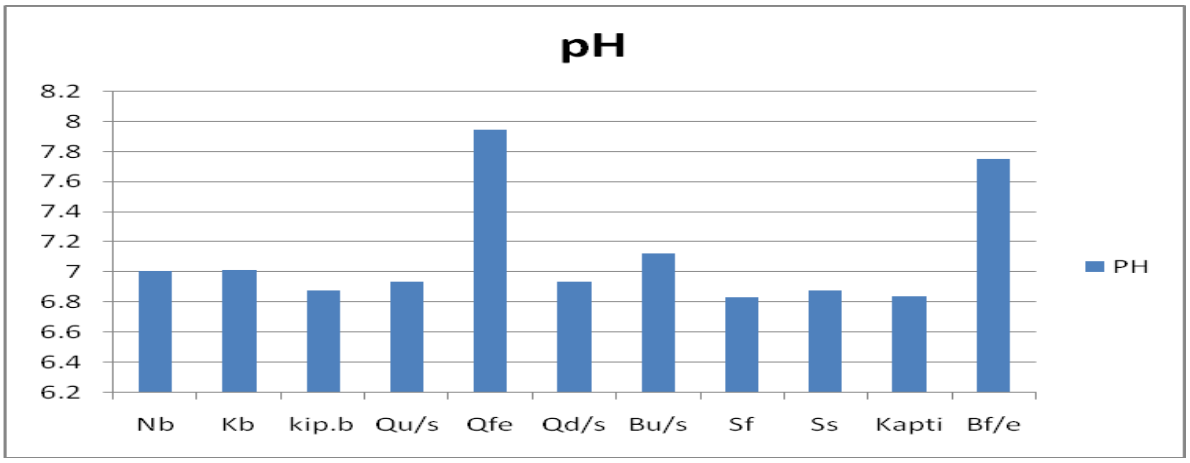
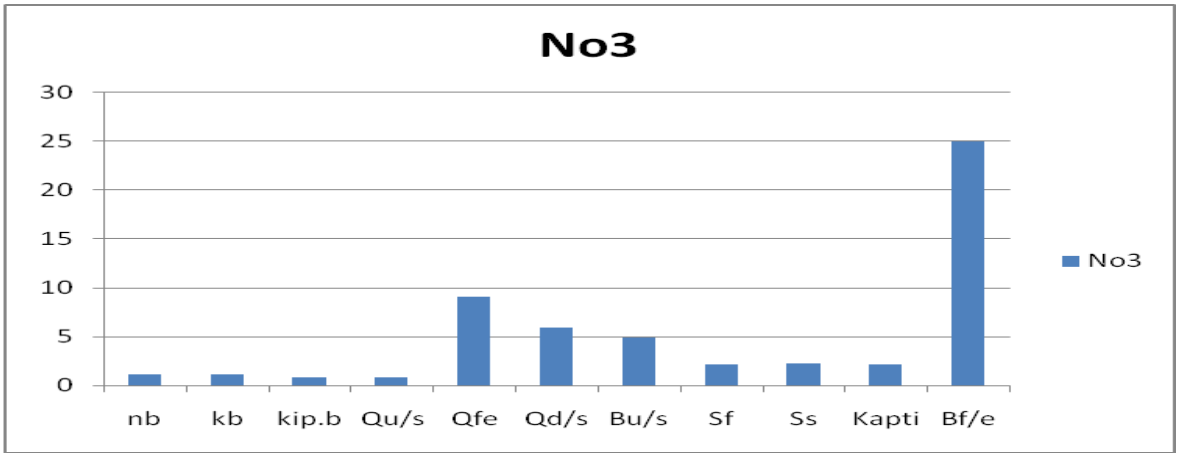


Graph showing average pH values per sampling point.

NO3-

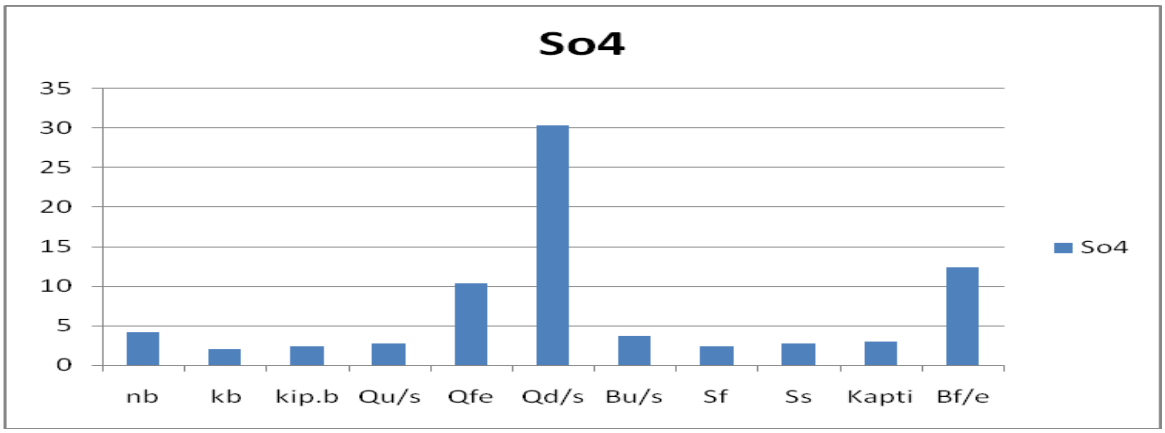
Nitrates concentration during the study period showed lower values at Nb,Kb,Kip/B,and Qu/s and higher values at Qfe and B/fe.the year 2013 had and average of 1.79mg/llower value compared to 5.59mg/l for 2015,In this study nitrates nitrate level varies between 0.79 -24.97 mg/L.



Graph showing average Nitrates values per sampling point.

Sulfate

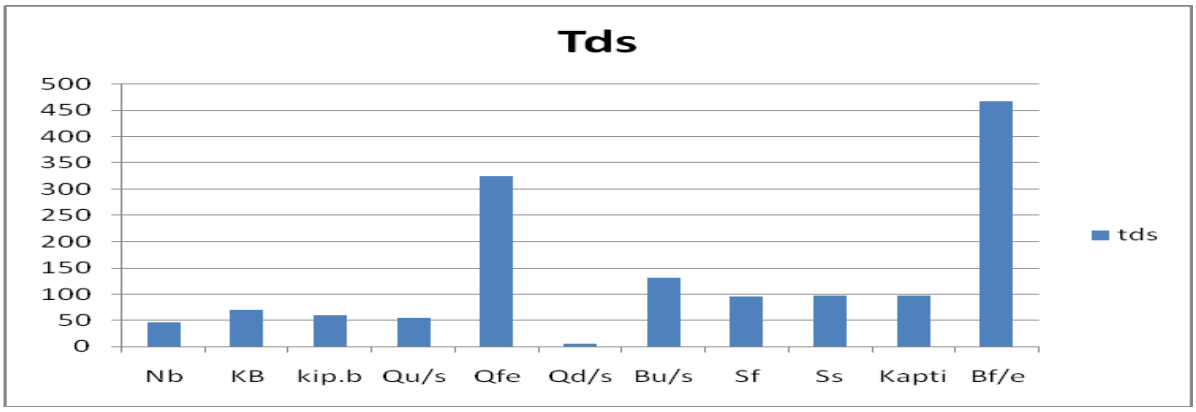
The Sulfate content in the water samples according to this study ranges from 2.05mg/l at Kb and highest at Qfe 12.39 mg/L.2014 recorded lower average value compared to 2013 and 2015



Graph showing average Sulfates values per sampling point.

Total Dissolved Solids (TDS)

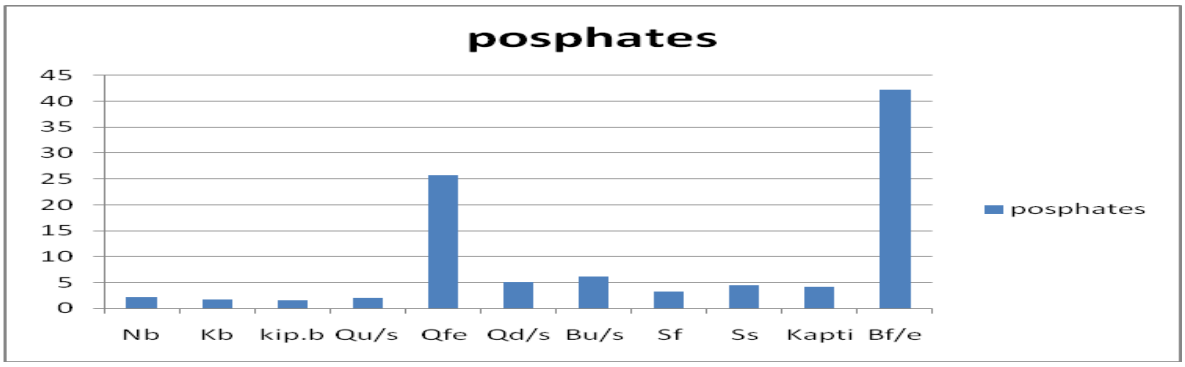
In this study the maximum mean (468mg/L) value of total dissolved solids was recorded at Bf/e whereas minimum mean (46 mg/L) value was noted at Qd/s.2013recorded lower average value of 85.93mg/l compared to highest value in 2015 of 169.84mg/l.



Graph showing average Nitrates Total Dissolved Solids values per sampling point.

Phosphate:

In the present study the range of phosphate content was 2.01mg/l to 48.32mg/L. the total phosphate was highest in quary final effluent 33.14mg/l and boundary final effluent with 48.32mg/l. Temporally 2013 recorded lower value of 5.16mg/l compared highest value of 12.67mg/l in 2015, in all the study period October recorded high values of phosphates compared to Jan.Apr.and Dec.



Graph showing average phosphates values per sampling point.

Conclusion

In current investigation, pH was within the WHO standardsNO3, $So4^{-3}$., were within the permissible limit. So, the Sosiani River water is considered as polluted water. The physico-chemical characteristics of Sosiani River water suggested that the river is not a good source for drinking water. Pollution levels showed increasing trend from 2013 to 2015 for the chemical parameters, in all the parameters two sampling points showed constant rise in levels of all the parameters studied that is Qf/e and Bf/e, this could be due to the fact that this points are where lagoons discharges waste water to the river,

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