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Spatial and temporal variations of physicochemical parameters in surface water of Wami River, Tanzania

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Abstract

The study analysed physicochemical parameters of the Wami river, in Tanzania to establish a diagnostic of surface water quality status of the river. Samplings were carried out on 15 points that regarded as upstream, mid-section and downstream during the dry season and rainy season. Results obtained show that almost all parameters analysed relatively good quality compared to international standards for fresh water. Temperature shows a slight drop changes in ranges seasonally from 27^{o} C to 30^{o}C during dry season to 24^{o} C to 28^{o} C during rainy season which is within the recommended range for aquatic life safety. A pH obtained are within the recommended range of 6.6 to 7.4 in both seasons. Furthermore, the progression of pH does not vary considerably between upstream and downstream in seasons. A rise in EC particularly in the dry season, 518 µScm^{-1} was observed compared to that of 208 µScm-1 in rainy season. The oxygen amount in water measured as DO and BOD exhibit a large spread of mean values seasonally and spatially with DO values of 0.02 ppm (downstream) to 9.80 ppm (upstream) both obtained on rainy season. BOD recorded values from 0.40ppm to 56.00ppm.

Keywords: Water Quality; Physicochemical Parameters; Seasonal Variation; Wami River; Tanzania

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1. Introduction

Water quality describes the physical, chemical, and biological characteristics and conditions of water and aquatic ecosystems, which influence the ability of water to support the uses designated for it (Yongabi et al., 2012). Pollution of lakes and rivers may occur from a variety of sources. Various processes influenced by anthropogenic activities may contribute to increase concentration of pollutants (Gray, 2008). They include run-off from agricultural and urban areas, discharges from mining, factories and municipal sewer systems, leaching from dumps, and former industrial sites and atmospheric depositions (Weiss et al., 2016).

Pollution from natural and anthropogenic processes threatens available fresh water resources, as the case for Wami River in Wami/Ruvu basin in Tanzania (GLOWS-FIU, 2014). A relationship between the intensity of land-use, water abstraction, and resource extraction on the functioning condition of wetland-riparian areas was identified in Wami river water quality assessment and link to aquatic organism life and biodiversity was not considered (GWSP and FIU, 2016). The anthropogenic sources include human activities near the water bodies or far at upstream and later carried out through water movement. These activities include and not limited to; agricultural activities, domestic discharges, leachates from waste dumps mining and industrial effluents (Shrivastava and Mishra, 2011). The pollution at Wami River is aggravated by agricultural and industrial wastewater from upstream sources that poses risks to health and livelihoods, with most affected communities located downstream of the catchment (Ngana et al., 2010). Therefore this paper intends to depicts the water quality by analyzing physicochemical parameters of the Wami river in order to establish a diagnostic of surface water quality status.

2. Material and methods

2.1. Description of study area

Wami River is a sub-basin catchment of Wami-Ruvu basin in Tanzania that consists of two main river systems, the Wami being major one with 40,000 km2 and the Ruvu consist of 17,700 km2 of area (Gritzner and Sumerlin, 2007). Coastal rivers North of Dar es Salaam are part of this basin. The basin as a whole covers an area of 72,930 km2 (Yanda and Munishi, 2007). Wami sub-basin is located between 5°–7°S and 36°–39°E, extends from the semi-arid of Dodoma region to the humid inland swamps in Morogoro region to Saadani Village in the coastal Bagamoyo district. It encompasses an area of approximately 43,000 km2 and spans an altitudinal gradient of approximately 2260 meters (WRBWO, 2007).

The sampling was done in three (3) sites along the Wami River: considered as upstream, mid-section and downstream of the river that fall down to Mandera, Mkoko, and Matipwili villages, respectively (Figure 1).

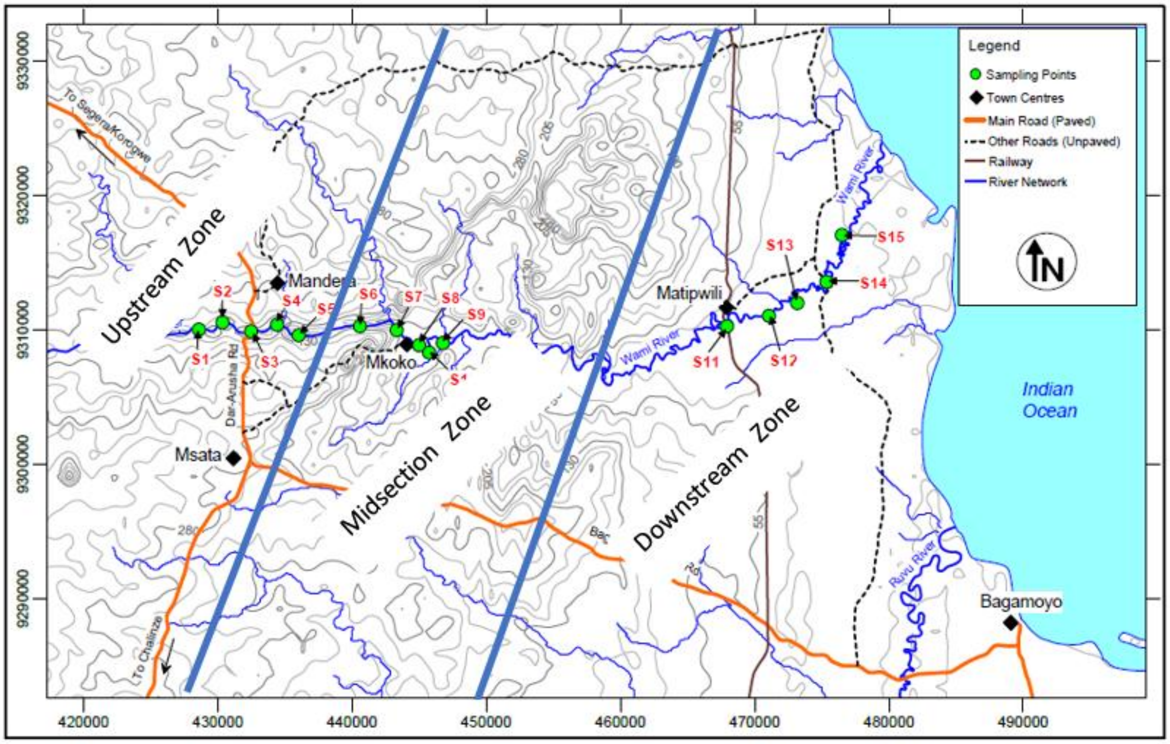

Figure 1. A map of study area showing zoning and water sampling points along Wami River

The selection was based on the fact that wetlands are not in protected areas and the use of natural resources is not restricted, consequently affecting other organisms. In addition, the selected areas were easily accessible by road for collection of water samples. A total of 15 sampling points were identified such that every section (upper, middle and lower section) had 5 points.

2.2. Water Sampling and *Insitu* physicochemical water parameters analysis

Water sampling was done in two dry (August-September 2015) and wet (April-May 2016) seasons. At selected points and at different distances away from the river Duplicate water samples were collected by grab sampling method from 5 random points at each section (upstream, mid and downstream) making total of 15 water samples in duplicates Two parameters; Temperature and pH were analysed in situ immediately after sampling by using Thermo Orion Star (A 329 multi-parameters) and the analysed values are shown in figure 3 (Temp) and figure 4 (pH).and kept in 300ml sterilized glass bottles at 4oC for preservation and transported for analysis to Ardhi University Laboratory. For spatial variations samples were collected at different distances away from the river, from well-mixed section of the river (main stream), 30 cm below the water surface using a weighted bottle. Two identical visits were made one during dry season and another one after heavy rain for comparison.

2.3. Statistical analysis

Descriptive and multivariate statistical analysis were applied to all the physicochemical data obtained from the two seasons which include the mean, standard deviation (SD), the range, and standard error. Moreover, the spatial and temporal or seasonal variations of the observed water quality parameters were evaluated using the coefficient of variation (CV), one-way analysis of variance (ANOVA) at 5 % level of significance and the paired-samples t-test, using IBM SPSS Statistics (v. 20) software package.

3. Results and discussion

3.1. Social economic activities

Freshwater is the most important commodity within the communities living along and surrounding areas. Water abstraction in the Wami River is largely for irrigation, domestic and industrial use. Questionnaire survey (n = 20) results show that 100% of community use water for bathing, washing and cleaning (Figure 2). Water for drinking is obtained from tap for the few who have access to the service, while 75% and 90% are still using river water for drinking and cooking purposes, respectively.

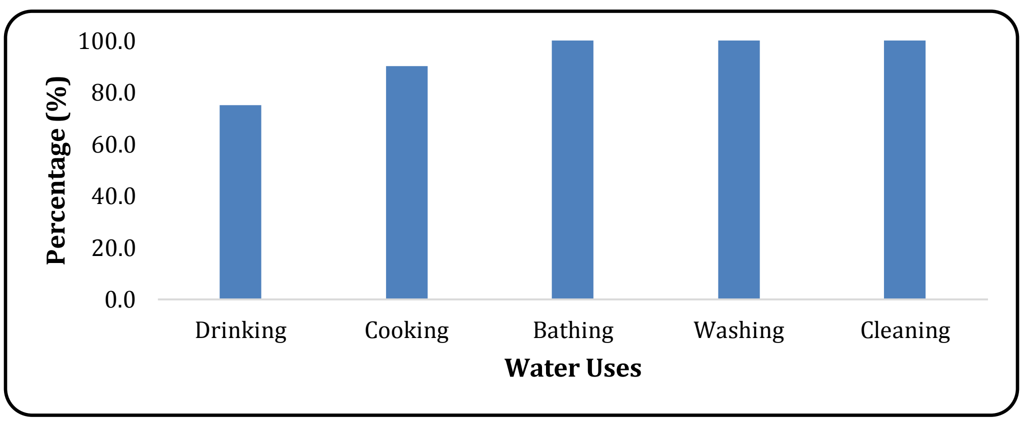

Figure 2. Surface water use at Mkoko and Matipwili communities along Wami River

Apart from direct water use, water from Wami River is also widely used for livestock keeping as well as large and small scale irrigation, where vegetables and fruits like tomatoes, watermelon, spinach, green peppers and bananas are grown. However, majority of these farms extend to the edge of the river bank within 60m distance which is against the regulations. Irrigation activities are common to most farmers where water pumps (5.5 HP) are used to extract much water more than the needed amount. Of recent, there has been an increase in the number of users abstracting from the Wami River both upstream and downstream leading to management challenges especially for the unlicensed water abstraction. There is also a widespread use of pesticides that could impact quality of water and living organisms that depend on the river.

3.2. *Insitu* Temperature and pH

Temperature and pH results were presented in Figure 3.

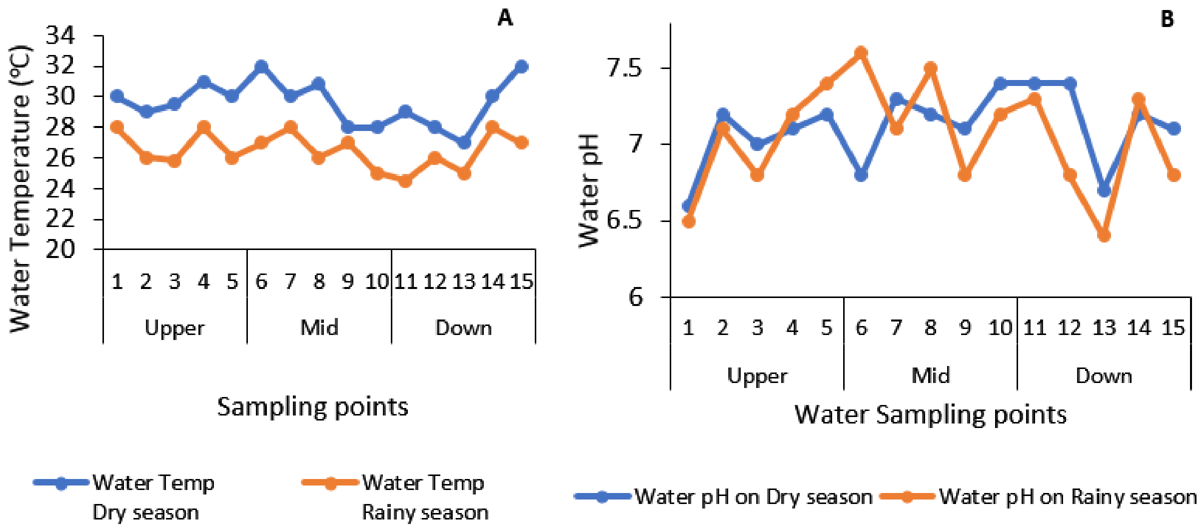

Figure 3. Water temperature (A) and pH (B) in both seasons

Temperature variations follow the climate of the region. Water temperature was almost constant through the seasons and found to range 27o °C to 30 °C during dry season while, 24o C to 28oC observed during rainy season. However, the maximum temperature of 32 °C was observed during dry season at points 14 and 15 of the river while the minimum temperature of 24 o C also observed at downstream section, this time during the rainy season. Relative variability with coefficient of variation (% CV) = 4.48% – 5.00% among seasons was observed while for the variance range spatially, parameters showed slight variation (Var) of 1.40 – 2.19 about the mean value within sampling points. Since temperature influences the quantity and diversity of aquatic life, an increase in water temperature during the dry season has been reported by other researchers that it can be the reason of rapid growth of plants and microscopic aquatic animals (Mahananda et al., 2010; Radulescu et al., 2014; Togue, et al., 2017). Many fish and other aquatic animals breed at this time of year because there is warmer waters and abundant foods.

The pH values fluctuated between 6.6 and 7.4 at the upstream to the downstream during dry season and between 6.4 and 7.6 during the rainy season (Figure 3). A constant trend was observed on three points near the downstream points before it suddenly dropped to the lowest point. As for recommended ranges, the pH values obtained for this study is considered to be within the international limits of 6.5 - 8.5 for WHO guidelines for drinking and other domestic purposes (WHO, 2011) and 6 - 9 for EU guidelines for protecting fish culture and the general aquatic life (European Commission, 2012). Paired-samples t-test indicated a significant variation in pH (t (14) = 0.706, $p < 0.05$ (2-tailed)) between seasons. The range of measure of relative variability (% CV) were statistically evaluated and found to be 3.47 % – 5.05 % for the two seasons. This parameter, however recorded the lowest range of variance (Var = 0.061-0.127), which indicates the closely spread of data around the mean.

3.3. Results of physicochemical parameters

3.3.1. Electrical conductivity (EC)

The EC and turbidity values are presented in Figure 4, whereas DO and BOD are presented in Figures 5. The EC value was detected higher (518 µScm-1) at the upstream in rainy season while the lowest value (208 µScm-1) was detected during dry season at the mid-section of the river. However the EC for natural fresh water is recommended to range from 50-1500 µScm-1 (WHO, 2011) hence, the values obtained are within the recommended range. Following the variation of EC in two seasons, the coefficient of variation (%CV) was determined and found to range from 24% to 25.9%. Furthermore a paired samples test was performed using t-test among two seasons and shows the EC values was statistically significant, t (14) = -1.354 with $p < 0.05$ (2-tailed). The high value of EC recorded at the upstream section might be due to the decomposition of organic matter and soil fertilizers that are taken by runoff especially during rainy season.

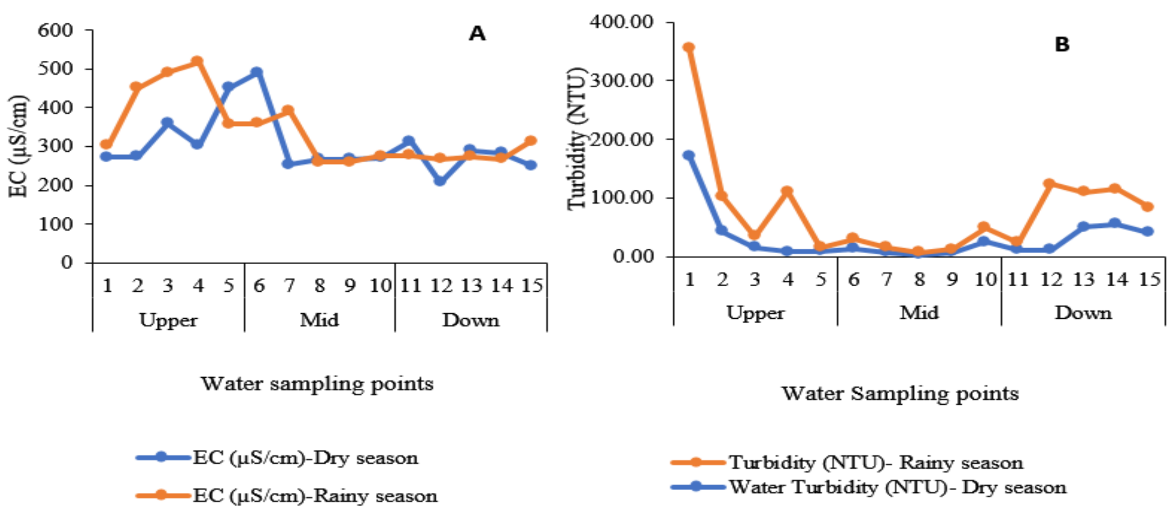

Figure 4. Water Electric conductivity (A) and Turbidity (B) values during dry and rainy seasons

Turbidity

Turbidity values were found to be on average of 47.67 NTU with the minimum value of 3.6 NTU from one point at mid-section during dry season while the highest value of 182 NTU at the very first point on upstream during the rainy season. These values are within the range obtained from Ruvu river in the same water basin that found to range 0-170 NTU (GLOWS-FIU, 2014).The high turbidity found in this area is due to different reasons which include (not limited to) different human activities found such as fishing, agriculture and presence of huge number of hippopotamus that usually stirring water when swimming. Moreover paired-samples t-test, the difference among seasons of the Turbidity values was statistically significant with t (14) = -1.857, p < 0.05 (2-tailed).

3.3.2. Dissolved oxygen (DO)

In comparison to seasons, minimum and maximum values of DO were found as 0.02ppm (downstream) and 9.80 ppm (upstream) respectively during rainy season. These results were similar (1.23 ppm to 9.80 ppm) to that analysed by GLOWS-FIU, (2014) from Ruvu river which is flows in the same basin as Wami river. The study Variation of DO in two season as analysed by coefficient of variation (%CV) ranges from 40.8% to 55.3% and range of variance (Var = 5.12-10.14) was recorded for both seasons, which indicates a spread data around the mean value. The t-test for paired samples test among two seasons shows statistical significance with the value of t (14) = 0.049, p<0.05 (2-tailed). Seasonally, the DO values of during dry season is less than during rainy season. This is true when compared to other researchers that the warming of the water and the low flow of river water cause a decrease in the dissolved oxygen which aggravated by an increase in the consumption of oxygen by living organisms in water and a fall of wind speed (Radulescu et al.; 2014; Ramchander et al., 2015)

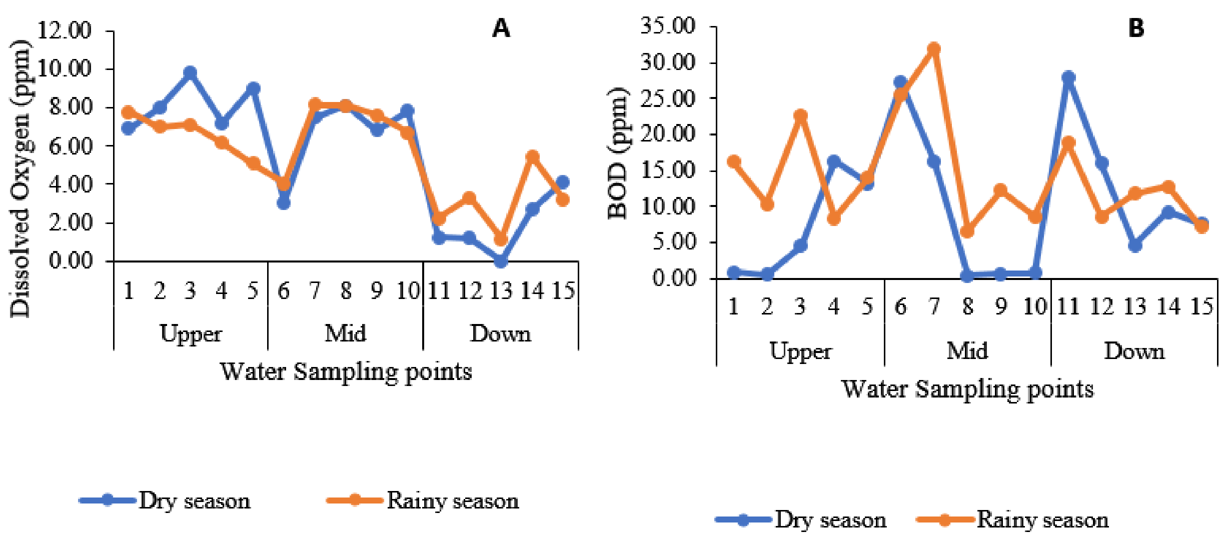

Figure 5. Water DO (A) and BOD (B) values in both seasons

3.3.3. Biological oxygen demand (BOD)

The minimum value of 0.40 ppm was recorded during dry season at the mid-section of the river while the maximum value of 56.00ppm was also found during dry season, at the downstream point. A range of variance (Var =53.76-247.21) was recorded for both seasons, which indicates a spread data around the mean value. A t-test for paired samples test among two seasons shows no significance difference, t (14)= 0.259, p<0.05.

BOD is closely linked to oxidation of biodegradable organic materials (Togue et al., 2017). The high levels of BOD that increases from upstream to downstream during dry season may be explained by the introduction of the degradation conditions of the organic matter due to microorganisms whose activity intensifies with the decrease in flow velocity and with the warming of the waters (Umedum et al., 2013). This activity, consuming oxygen, is at the origin of the self-purification of the waters.

4. Conclusion

The downstream part of the Wami river is subjected to discharges of waste water from different activities that occurred at upstream points which are (but not limited to); agriculture, industries and fishing activities, as well as frequent car accidents occur on the highway at Wami bridge (Mandera upstream section) that goes along the river bank which cause oil spills to water sources and subject to the main causes of variations in water quality in the Wami River. However, most of the physicochemical parameters studied remain compatible with water standards according to WHO water quality standards and no pesticide parameters detected. At-test for paired samples test, with 95% confidence level for individual parameters were performed among two seasons and most of them show statistical significance.

There is existing correlation between the different parameters and a seasonality difference from the water quality in the study area. This gives the importance of water parameters to be monitored in water systems. Wami river is one among major rivers that have important ecosystems that serve for communities for directly providing water for domestic use, agricultural, and industrial (WRWBO, 2007) and being ending to the ocean, it gives a unique ecosystem biodiversity to be taken care of (GLOWS-FIU, 2014). It is important that, the required minimum concentrations of key physicochemical parameters need to be monitored for the sustainable use of this ecosystem. The effect of seasonal variation, frequency of observation on changes in water quality would be also essential to be assessed.

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