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Surface Water Quality in the Peri-Urban Areas in Dar es Salaam, Tanzania: The case of Ng'ombe River

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ABSTRACT

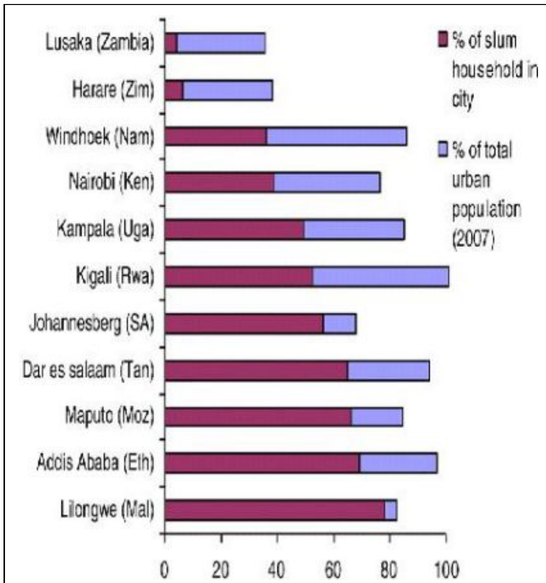
This work made an ecological assessment of the Ng'ombe River based on water chemistry. Ng'ombe River traverses the unplanned and densely populated areas in Dar es Salaam forms and discharges into the Msimbazi River. This particular study sought to identify the pollution levels and their sources. River water-sampling locations were chosen and samples of water were taken from the river and analyzed according to standard analytical procedures. The water quality parameters that were studied include temperature, pH, total suspended solids (TSS), electrical conductivity (EC), turbidity, biochemical oxygen demand (BOD_5), phosphate (PO_4^{3-}), total phosphorus (TP), nitrate-nitrogen (NO_3-N) and faecal coliform. Interviews were carried out with at least 100 residents to measure their awareness, perception on the river pollution and the importance they place on conserving the River. The study gave an indication of organic and faecal pollution on Ng'ombe River. Bacteriological quality of the River was found to be low, with BOD_5 and faecal coliform levels exceeding the permissible limits. The BOD_5 ranged from 80 to 190 mg/l and the faecal coliform concentration was between 1200 to 5200 cfu/100ml. The physical water quality was consistently low during rainfall periods, with some parameters exceeding Tanzania Bureau of Standards (TBS) or World Health Organization (WHO) permissible limits. Some of the monitored physico-chemical parameters of river includes; Electrical conductivity (EC) which ranged from 1725 to 2950 S/cm; Total suspended solids (TSS) ranged from 80 to 180 mg/l and turbidity from 33 to 200 NTU. Further, the nutrient concentrations were NO_3-N, which ranged from 0.80 to 1.71 mg/l, PO_4^{3-} from 0.26 to 0.54mg/l and total phosphorus (TP) from 0.10 to 0.24 mg/l. Generally, water from stations located in unplanned or informal settlements had higher levels of pollutants compared to those from planned or formal settlements. It was also noted that the river pollution increased from upstream to downstream end. There was a clear impact of runoff manifested by the elevation of nutrient concentrations during rainy season. The results show degradation of the water quality of the river by anthropogenic activities in the area with poor solid management and low level of sanitation being significant causes of the pollution.

Keywords: *Informal settlement, Ng'ombe river, Urban rivers, Water Quality.*

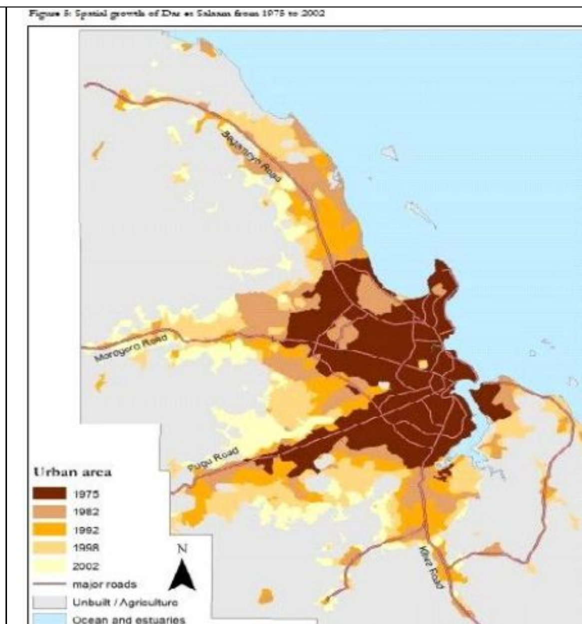
INTRODUCTION

Surface waters in informal settlements suffer from poor water quality mainly due to inadequate sanitation and drainage facilities in the informal settlements (Garcia-Armisen *et al.*, 2014; Glińska-Lewczuk *et al.*, 2016). In most poor urban communities, solid waste management has proven to be a big problem and this causes most of the surface water ways in these areas to be contaminated with solid waste (Zhang *et al.*, 2015; Chinyama *et al.*, 2016). Currently, the global concern is rapid unplanned urbanization (Figure 1A) and a mismatch in the growth of infrastructure and service delivery. In most cases this is accompanied by decreasing water security both in quantity and quality (van den Brandeler *et al.*, 2018). Many water pollution problems are related to human activity as well as increasing population pressure in the catchments. Studies have reported such contamination worsen the global problem of eutrophication of fresh water sources, that in turn lower the ecological integrity of the systems and therefore negatively affect the aquatic life (Njenye *et al.*, 2010; Zhu *et al.*, 2018).

Figure 1B shows that Dar es Salaam city has been growing rapidly over the years. In accordance with the National census the population of Dar es Salaam has been growing rapidly from 74,000 people in 1960 to 1.04 million and 1.66 million in 1985 and 1995, respectively. The population of Dar es Salaam increased to 2.48 million in 2002 and nearly double in 10 years to 4.36 million in 2012 (National Bureau of Statistics, 2012)..



A: Proportion of Urban Slum in %, in selected cities in Sub-Saharan Africa. (**Source**: UN-Habitat, 2008a).



B: Dar es Salaam City Urbanization trend, 1975-2002 (**Source**: Abebe, 2011)

Figure 1: The State of Major cities in Africa

In Tanzania, river water quality is fast declining especially for rivers passing through industrial and residential areas (Marwa, 2011; Nuhu and Mpambije, 2016). Most of these rivers drain and receive treated and untreated discharges of various types (Mero, 2011; Kayombo and Mayo, 2017). This may include wastes from industries that do not have waste treatment facilities, disposal of wastes from domestic and commercial uses and runoff from areas with agricultural activities (Mwegoha *et al*., 2012; Kihila *et al*., 2014; Kayombo, 2015). It is estimated that about 70% to 75% of the population in Dar es Salaam inhabits in poor, unplanned settlements (World Bank, 2002; U.N. Habitat, 2008b). Further, of the 4,161 tons of waste that is being generated per day in Dar es Salaam, only 1533 tones is collected, i.e. 67% (Kasala, 2014).

Tandale area in Dar es Salaam has a population of about 54,781 people (Census of 2012). This study focused on the River traversing through this densely populated unplanned settlement, the Ng'ombe River, which discharges into the Msimbazi River Valley. Despite of its poor water quality, the riparian communities rely on the river as a source of water for their domestic water needs and agricultural activities such as feeding animals and irrigating vegetables, while the river health conditions might be unsafe for human consumption (Kayombo and Mayo, 2018). Poor drainage, inadequate sanitation and inadequate infrastructure for solid waste management add to the challenges of the poor sanitation in these areas. The study area was observed to suffer from frequent urban floods mainly due to poor drainage. Moreover, indiscriminate dumping of solid waste, especially on open drains poses a threat to the quality of rivers going through these residential areas.

Similar concerns of inadequate solid waste management and subsequent flooding of informal urban slums in Dar es Salaam is reported by Sakijege *et al.* (2012), who attributed the poor quality of urban river bodies to the poor solid wastes dumping resulting into leachate eventually finding its way to open waters during the rainfall season. All these, has caused Tandale area in Dar es Salaam to be one of the areas that is most prone to waterborne diseases and outbreaks and even Cholera in some rare occasions (Silva, 2017; Nuhu and Mpambije, 2016). Other possible threats include coastal waters pollution since Ng'ombe River drains into Msimbazi River which eventually drains to the Indian Ocean. Moreover, the Sanitation needs of the study area, like in unplanned most urban poor communities, are met by onsite systems such as pit latrines, septic tanks and soak away pits, which is not the best option for these densely populated, high groundwater table areas. Notably, this poses a potential threat of contamination of groundwater.

Owing to all these concerns, there is a need to determine the quality of the Ng'ombe River, with respect to its use by the riparian community, possible sources of pollution, and the extent to which the river has been polluted. This study therefore attempts to assess the water quality of the Ng'ombe (Sinza) River and the associated magnitudes of the pollutants responsible for degradation of the river's water quality, as an indication of the ecological state of the river. Knowing the pollution levels of the river gives strong support to management efforts in monitoring, enforcement of standards and regulations towards better pollution management and control so as to ensure the suitability of the water for various uses. Hence this study attempts to analyze the source of river water quality deterioration. This study is limited to the spatial extent covering some parts of the river between longitude 39.228625 to 39.243041 and latitudes -6.790046 to -6.790758 (Figure 2).

MATERIALS AND METHODS

Study Area Description

The Sinza (Ng'ombe) River is one of the three tributaries of the Msimbazi River, the other two being the Ubungo and Luhanga rivers. It has its source at Changanyikeni and flows through Sinza, Tandale and all the way downstream where it merges with the Msimbazi River and pours its waters into the Indian Ocean through the Selander Bridge (Figure 2). As the river passes through Tandale it is named the Ng'ombe River (cow dung carrying river) because at some point it was used for dumping cow dung from low income individuals who kept animals under zero grazing.

The climatic condition of the area through which the river flows is mainly tropical, with average temperatures of about 29°C to 35°C during the hottest season which is between October and March. The area receives rainfall between 800 mm and 1400 mm per annum the average rainfall of about 1000mm. The topography of the area is relatively flat and the soil type is mostly sandy with a high water table. The area is a densely populated areas and mainly peri-urban in nature with sparse small scale vegetable agricultural activities mainly grown on the valleys.

The population of Tandale ward is 54,781 with a population density of 47,254 inhabitants per square kilometer and that of Sinza ward is 40,546 with a density of 12142 inhabitants per square kilometer (National Census, 2012). Residents of Sinza ward are of a middle income level. On the other hand the residents of Tandale are a low income class, who live in squatters and lack basic services such as water supply, improved sanitation and drainage systems.

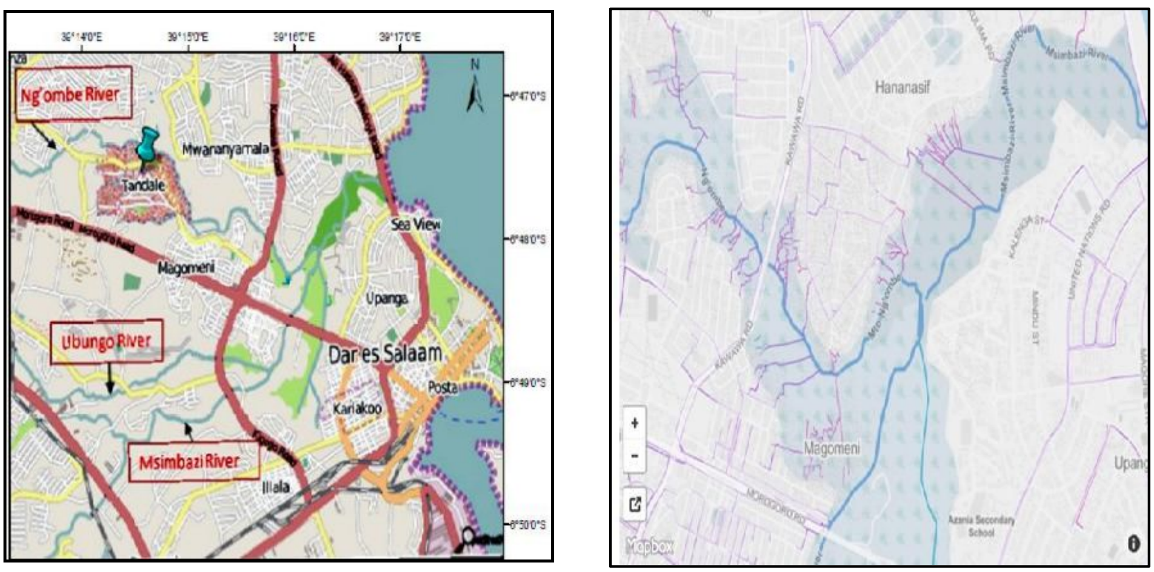


Figure 2: Map of the study area location, figure on the RHS detailing the location of the Ng'ombe River

SAMPLING DESIGN

Prior to the sampling design; an extensive field survey of the study area was carried out in an effort to find the best place to locate our sampling points and also to visually observe the sanitary conditions of the area. The tested water quality variables were; temperature, pH, electrical conductivity (EC), Turbidity, total suspended solids (TSS), phosphate (PO_4^{3-}), total phosphorus (TP) and nitrate-nitrogen (NO_3-N); Fecal Coliform (FC) and 5-day BOD. The pH was measured using a pH meter (Sartorius) while EC meter (inoLab, Conel7110) was used for measuring electrical conductivity (EC) of water. Turbidity measured in Nephelometric Turbidity Units (NTU) was measured using a microprocessor turbidity meter (HANNA, HI 93703). On the other hand, the total suspended solids (TSS), phosphate (PO_4^{3-}), total phosphorus (TP) and nitrate-nitrogen (NO_3-N) were measured using a photometer (Palintest, photometer 7500). The 5-day BOD test was carried out according to APHA standard methods. (APHA *et al.*, 2012). All these were collected on all sampling points.

Selection and location of Sampling Points

Assessment of the water quality of the river entailed a sampling scheme that was mainly composed of four sampling points S1, S2, S3 and S4, located along the river. Their location was recorded by a GPS unit and plotted on a map using ArcGIS 10.1 tool (Figure 3). Sampling points were selected on the basis of the likelihood of identifying point and non-point sources of pollution as well as effects of streams or small tributaries on the river water quality.

The location of the sampling points is such that S1 is chosen to be at the upstream of Tandale (in Sinza) so as to obtain the base condition of the water quality at Sinza (a planned settlement). Sampling point S2 is located at the beginning of Tandale which is a densely unplanned settlement characterized by poor sanitation and solid waste disposal; while S3 is at Tandale Kwa Ali Maua. Sampling point S3 is close to two large drainage canals, one of which drains water along Shekilango and Tandale roads. S4 is located at Tandale Kwa Mtogole a few meters from where a stream (named Kiboko stream) that drains a part of Tandale and Manzese joins the Sinza River. There was no sampling point on the downstream of Tandale settlement because the settlements after Tandale are similarly unplanned (these include settlements near Hananasif).

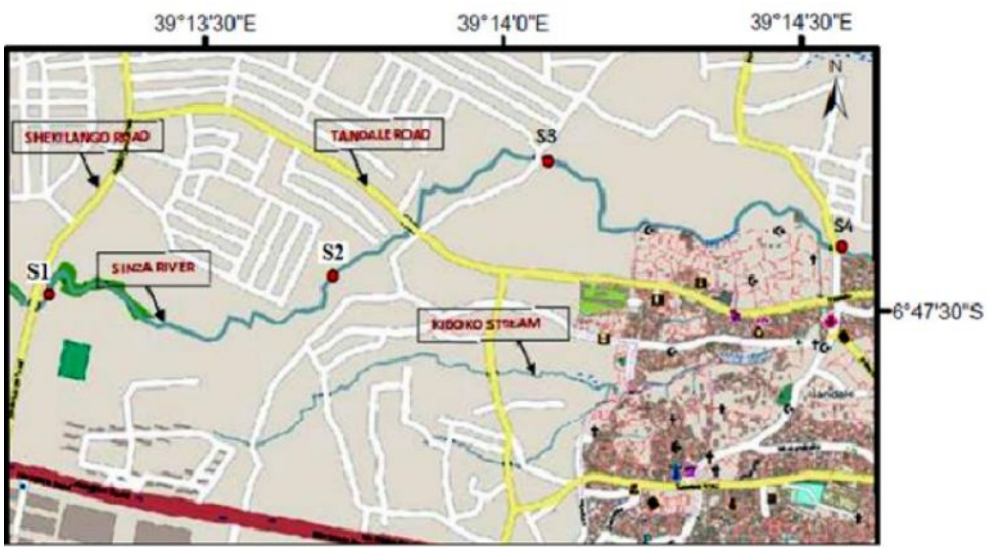


Figure 3: Map showing the Sinza (Ng'ombe) River and Sampling Points (Source: OpenStreetMap)

Sampling Frequency and Analysis

Sampling was done in two phases; i.e.at the beginning of April 2015, when the rains had just begun and in the middle of May 2015, several days after heavy rains. Water samples were collected from the sampling points and analyzed in the laboratory according to standard methods (APHA *et al.*, 2012). The parameters that were analyzed included temperature, pH, electrical conductivity (EC), total suspended solids (TSS), turbidity, 5-day biochemical oxygen demand (BOD_5), phosphate (PO_4^{3-}), nitrate-nitrogen (NO_3-

N), total phosphorus (TP) and faecal coliform.

RESULTS AND DISCUSSION

Ng'ombe River Water Quality

The water quality was determined through the analysis of nine parameters as mentioned in the methodology. These are pH, electrical conductivity (EC), total suspended solids (TSS), turbidity, 5-day biochemical oxygen demand (BOD_5), phosphate (PO_4^{3-}), nitrate-nitrogen (NO_3-N), total phosphorus (TP) and Faecal Coliform (FC). These were checked against the TZS Permissible Limits for Municipal and Industrial Wastewaters (TZS 860:2006) and TZS Quality of Drinking Water Supplies where available since we do not have the stipulated allowable standards for inland surface waters recommendable for human consumption. The results of the monitoring, conducted prior to, and after the rainfall seasons are presented in figure 4 to 8 and table 1, for all the fours selected sampling points along the Ng'ombe River.

High Electrical conductivity (EC) values were noted ranging from 1725 - 2640 µS/cm before the rains and 2,092-2950µS/cm after the rains events (Figure 4). Tanzania standards are silent on this parameter. Ng'ombe river waters can be considered to be slightly saline, according to Rhoades (1992), as they fall within the range of 700 and 2000 µS/cm. Moreover, it is known that freshwater and river streams EC ranges from 0 to 1500 µS/cm, which is also the recommendable healthy limit of drinking water (WHO, 2011). The present study EC values are therefore on the high side and notably, they were gradually increasing along the river course, implying the contribution from man-made pollution on the catchment. It is worth mentioning that, EC values obtained from the field gives us an indication of amount of inorganic dissolved solids in the stream. EC can be affected by the nature of the bedrock through which the stream flows through or from external discharge into the stream. Since there is an increasing trend along the river course, most likely, there is seepage from sub-surface waters of nearby high table densely populated sites and salt inputs from settlements along the river. Moreover, there is a contribution from runoff, suggesting also contribution from diffuse contaminants originating from the surrounding informal urban settlements.

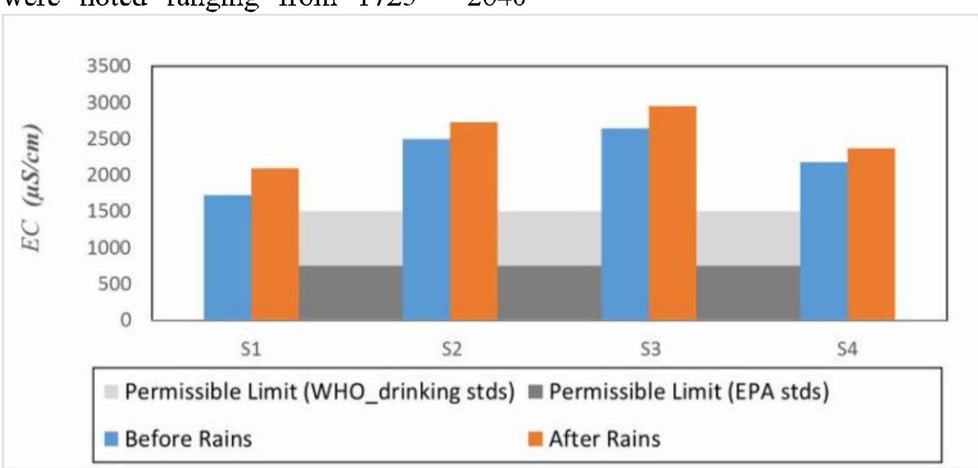


Figure 4: Electrical Conductivity along the Ng'ombe River from upstream (S1) to the downstream (S4)

On the other hand, the total suspended solids (TSS) levels were observed to be fairly good with results ranging from 80-180 mg/l (Figure 5). TSS has no drinking water standard and the results were therefore compared with Permissible Limits for Municipal and Industrial Wastewaters (TZS 860:2006). According to municipal effluent standards, allowable limits for TSS were noted to have been exceeded at the most downstream point of the river, at sampling point S4, located just before Ng'ombe River drains into the Msimbazi Valley. In both TSS and EC values, higher values were noted after the rains. Similar pattern is noted for the rest of the monitored parameters.

Moreover, Ng'ombe River water was found to be fairly turbid, with Turbidity values ranging between 33 and 100 NTU prior to the rains and 62-200 NTU post-rainfall periods (Figure 6). These turbidity values are way higher than the the recommended WHO drinking water quality standards of 5 NTU and 5 - 25 NTU TBS recommended values for portable water in Tanzania. Unusually high Turbidity was observed at S3 sampling point, most probably due to the presence of two large ditches draining water into the river just on the upstream of this location.

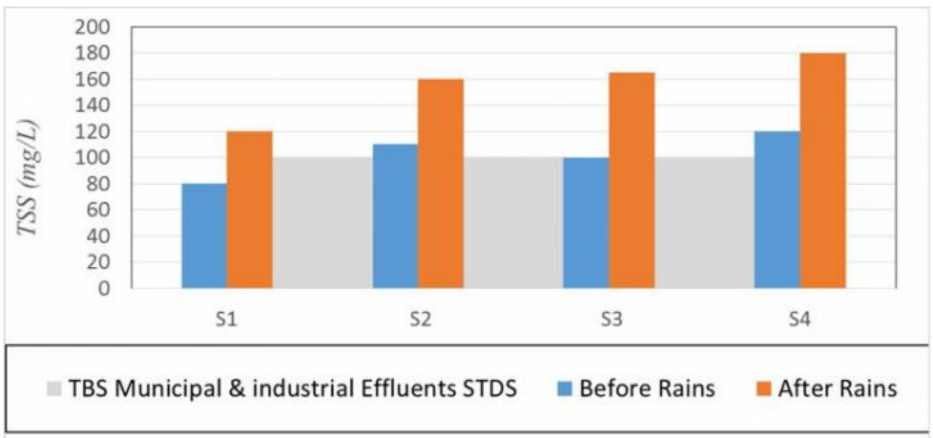


Figure 5: Variation of Total suspended Solids (TSS) along the Ng'ombe River from upstream (S1) to the downstream (S4)

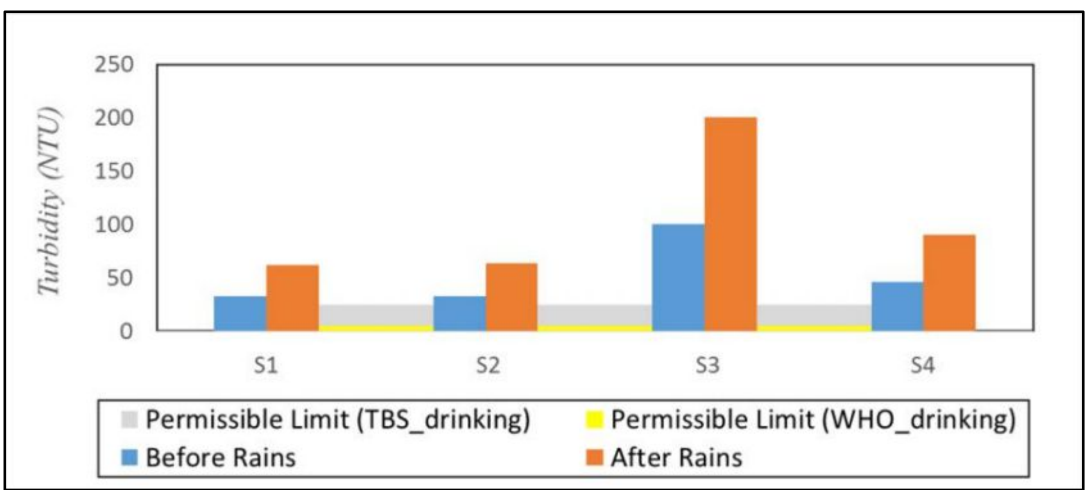


Figure 6: Turbidity Variations along the Ng'ombe River from upstream (S1) to the downstream (S4)

The river was also checked for Bacteriological quality. The results showed the quality to be poor with similar trends of increasing pollution towards the downstream. Biological Oxygen Demand (BOD_5) levels ranged from 80- 150 mg/l and 100-190mg/l before and after the rains respectively (Figure 7). The BOD values obtained exceed the maximum allowable limit of 30 mg/l (TZS 860:2005). Higher BOD_5 in the wet season is likely the result of stormwater runoff received from the informal settlements washing the organic pollutants into the river. High BOD5 levels indicate presence of organic pollution. Again, this may be originating from untreated sewage discharge or waste disposal of other organic matter. Likewise, FC ranged from 1200-4800 counts/100ml during the first sampling and increased up to 5200 counts/100ml in the second sampling (after the rains). These values are way higher than the permissible *TZS 789:2008* Microbiological Limits for Quality of Drinking Water Supplies of 10 counts/100ml and the WHO limits of 200counts/100ml for recreational water as well as 1000counts/100ml for irrigation water (Figure 8). FC counts indicate the presence of faecal matter in the river. A gradual increase in values of both FC and BOD_5 is noted in the course of the river, indicating water pollution associated with anthropogenic activities rather than environmental factors in the catchment.

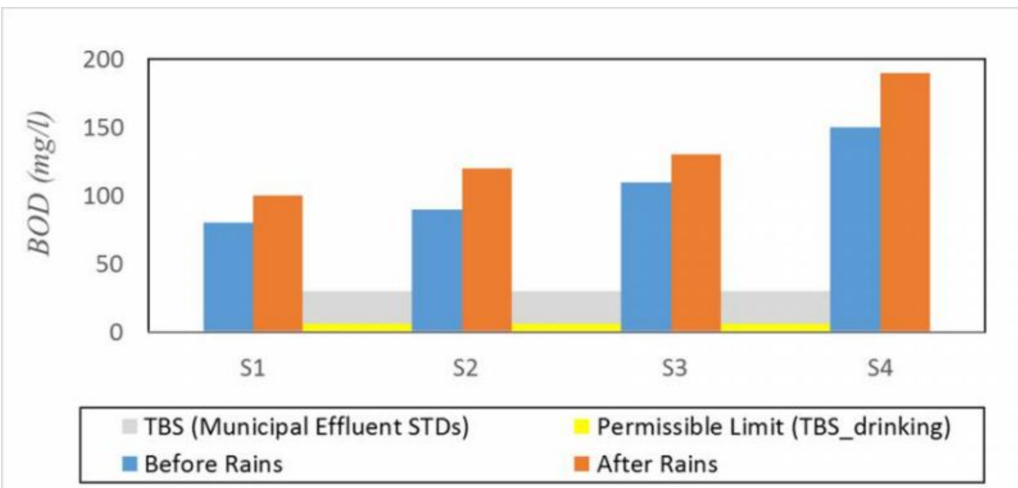


Figure 7: Variations of BOD_5 Concentration along the Ng'ombe River from upstream (S1) to the downstream (S4)

Additionally, Phosphorous and Nitrogen Nutrients levels were monitored so as to see the potential risk of eutrophication of the surface water body and the possibility of nutrient export by the river to the coastal waters. The presence of these nutrients would also indicate possible contamination from probably overflows or seepage from incorrectly installed or managed septic tank systems, trash and garbage wash or from agricultural systems into the river.

Specifically, nitrogen-nitrate (NO_3-N), total phosphorus (as P) and phosphate (PO_4^{3-}) were measured. A gradual increase in nutrient loading was found from the upstream towards the downstream, clearly indicating some level of nutrient enrichment contribution from the Tandale urban population. Again, there is evidently, a seasonal trend in these nutrient concentrations, whereby, as noted previously, higher values are recorded after the rainfall season. Table 1 presents these parameters where Total phosphorus (TP), Phosphate and Nitrogen-Nitrate values are below the permissible limits.

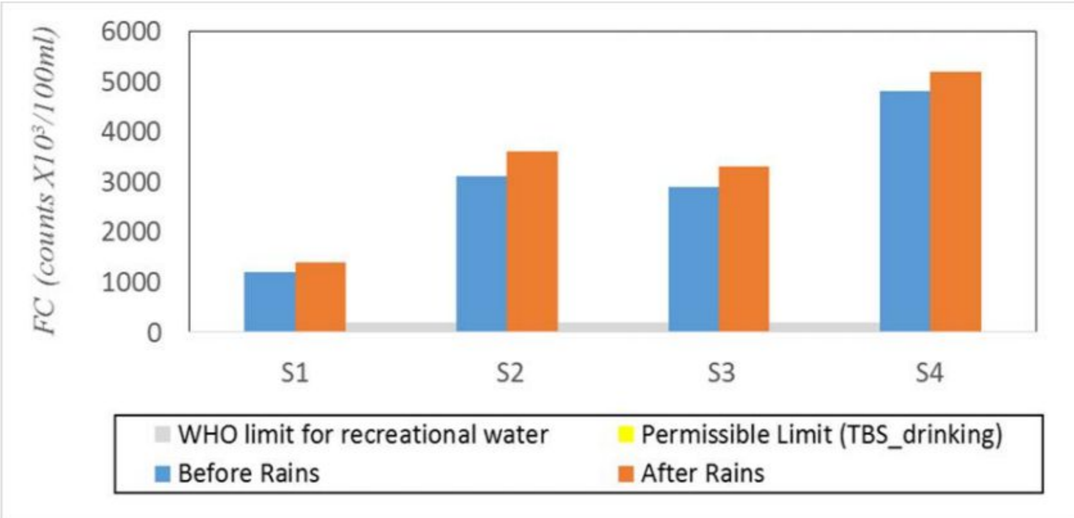


Figure 8: Variations of FC along the Ng'ombe River from upstream (S1) to the downstream (S4

The potential sources of the observed pollution

Generally the water quality of all the four sampling points revealed the quality of water to be poor, with an exception of the parameters in Table 1 where the results were within the allowable standards. Of the nine parameters monitored, five exceeded the recommended standards.

This study has demonstrated that Ng'ombe River water quality is deteriorating, as one move from the upstream to the downstream. This indicates that the river goes through a number of either or both points and/or diffuse sources of pollution. Moreover, for almost all parameters monitored, the pollution increases with the rains. This is attributed to possibility of leachate drainage from solid wastes and other poor sanitation facilities being washed into the river by runoff. Diffuse sources of pollution normally depend on runoff as a transport mechanism into the surface waters while point sources variation is unrelated to meteorological factors (St Laurent and Mazumder, 2014). The results of the study indicate a diffuse type of pollution of the surface waters for all variables measured, with an exception of turbidity values at S3 point, suggesting point source pollution.

Of the observations made, it was noted that, nutrient values (Table 1) were within the allowable limits for effluent discharge from municipal and industries. However, it is important to note that, the riparian communities use the river water as a source of domestic water supply without any other treatment process. The indicated water quality levels, even though are within the allowable limits of inland waters, would not be recommendable for drinking standards unless pre-treatment is done to bring them to safe standards for human consumption.

Field observations of the sanitation conditions in the catchment

In an effort to make sense of the water quality results observed, site observations were made. Figure 9 and 10 show the site conditions within the river catchment areas. It was noted that there is a major problem is with haphazard improper solid waste disposal from the residential areas. It was further noted that there are many households that discharge their sewage and other effluents directly onto the land and open channels around them. Field work visits ascertained that the residents use on-site sanitation systems like pit latrines, while the water table in this area is noted to be high, causing water logging during the rainfall season.

Table 1: Other monitored Water Quality parameters along the River; from upstream (S1) towards the downstream (S4)

Parameter	Sampling period	Sampling Point				Permissible limits	Standard
		S1	S2	S3	S4		
Total Phosphorus (mg/l)	Before rains	0.10	0.13	0.16	0.20	6	TBS Effluent Standard
	After rains	0.14	0.16	0.19	0.24		
Phosphates (mg/l)	Before rains	0.26	0.35	0.40	0.47	0.1	US EPA standard
	After rains	0.34	0.41	0.49	0.54		
Nitrate-Nitrogen (mg/l)	Before rains	0.8	1.2	1.0	1.5	20	TBS Effluent Standard
	After rains	0.92	1.3	1.24	1.71		
Temperature (^oC)	Before rains	29.0	28.5	29.0	29.0	20-35	TBS Standard
	After rains	27.0	26.0	27.5	27.0		

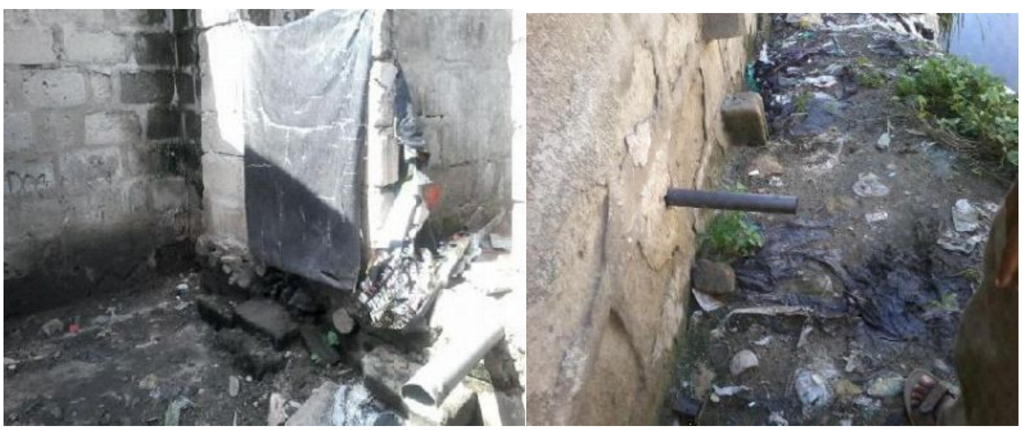


Figure 9: Sanitary condition at Tandale where waste water (sewage) is released directly to the open land

Figure 10: Site observations of poor solid waste management and solid waste disposal on open drains carrying the leachate to the river

Relating to this, studies have shown that high proportion of the solid waste generated in Dar es Salaam, about 33% comes from unplanned settlements (Dar es Salaam City Council, 2010). The river catchment area, including Tandale, is no exception in the generation of solid waste. The area evolved from agricultural to residential and is now rapidly growing into a commercial area. All these activities in the area lead to generation of a great amount of waste.

Most of the waste is dumped either into the river or the drains. Moreover, a common practice for informal unplanned settlements like Tandale, passageways are often too narrow to enable waste collection trucks to enter thus proper waste disposal is a major problem. This too was noted to be the case during field surveys.

From the above observations, it is thought that the source of river pollution in this area is poor sanitation and lack of waste disposal facilities, acting as sources of bacteriological pollution, especially when they flooding. A gradual increase in Organic loading along the river length is most likely originating from sewage and solid waste which is caused by the poor sanitation level in Tandale areas. Moreover, water quality monitoring showed an increase in BOD_5 and FC levels after the rains. The wet season surge in concentration may be related to the influx from the runoff from anthropogenic activities. Since the area is unplanned and majority use on-site sanitation systems, the heavy rains flooded the area and the sewage systems such as pit latrines and septic tanks overflew. It is also a common practice during the rains in the area for people to let sewage from their houses flow away to pathways or to trenches by being carried by runoff even if it is not flooded. The sewage is then carried away to the river hence higher pollution during the rains despite the dilution that the rain does to the river water.

CONCLUSIONS

The present study shows that the levels of nutrients and other pollutants in the river increase as one goes downstream partly due to human activities. The study has demonstrated the contribution of the Tandale, as one of the informal urban settlement areas in Dar es Salaam, to degradation of freshwater streams draining the area. The poor solid waste management and onsite sanitation systems witnessed in these densely populated unplanned settlements are likely the major cause behind the poor water quality observed on the study area. The bacteriological quality of these waters suggests that these waters are unfit for domestic use. Seasonal variation in physical, bacteriological and chemical parameters was evident. It was noted that the surface water quality further deteriorates during rainy season, most likely because of direct runoff from the surrounding urban lands and untreated sewage from poor sanitary facilities. This may imply that during urban floods, which frequently occur during peak rainfall season in these areas, the surface waters are mixed with contaminants from the urban environment. It may be important to further the study and assess the flood phase water quality in these areas and the associated healthy risks. Lastly, the present study may be considered as a pilot study of the freshwater quality in these urban slums. More conclusive results would require continuous, systematic evaluation of the river stream over longer periods of time and at a higher frequency and with higher density of sampling points (monitoring stations).

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