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The Impacts of Anthropogenic Activities on the Physicochemical Water Quality of Pinyinyi River, Arusha-Tanzania

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Abstract

Anthropogenic activities are responsible for degrading rivers and decreasing their capacity to offer ecosystem services. This paper reports the findings of a study carried out to assess the impacts of anthropogenic activities in Pinyinyi River water quality using physicochemical parameters. BOD, COD, phosphate, pH, EC, TDS, turbidity, DO and nitrate were analysed. Anthropogenic activities around Lake Natron Ramsar Site also documented. pH, EC, TDS, turbidity and DO measure in-situ using potentiometric method (HANNA HI 9829). Phosphate and nitrate analysed using photometric method (HACH DR/2700). BOD and COD analysed using bottle incubation method for five days (BOD incubator) and dichromate method (COD digester) respectively. Structured questionnaires used to collect data about anthropogenic activities taking place around Lake Natron Ramsar Site. DO, BOD, COD and turbidity were above the permissible limit. Phosphate, pH, EC, TDS and nitrate were within permissible limit. Irrigation, livestock keeping, fishing, bathing, washing, deforestation, water diversion, sand mining, making bricks along the river, tourist guidance, soda ash harvesting and selling soda ash are the anthropogenic activities taking place around Lake Natron Ramsar Site. River water was found to be unsafe for drinking purposes and was found to be safe for irrigation purposes. The study recommends sustainable anthropogenic activities along Pinyinyi River and mitigation measure to restore the lost ecosystem services.

Keywords: Anthropogenic activities, Biodiversity, Physicochemical parameters, Water Pollution, Water quality

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1. Introduction

Rivers support millions of people who live along their banks and depend on them directly for irrigation, fishing, transport people and goods, provision of water for hydroelectric power production, industrial purpose, domestic purpose, medicinal herbs, construction materials, firewood, grazing and shelter (Mezgebu et al., 2019). Su et al. (2014) & Lalika et al. (2015) reported that, rivers are important for, tourism, habitat and biodiversity, soil and sediment regulation, nutrient regulation and cultural values aesthetics. Anthropogenic activities such as unsustainable agriculture, overgrazing, and deforestation, are the major driver of rivers water pollution and put remarkable pressure on the ecological conditions and sustainability of aquatic ecosystems (Lalika et al., 2015; Pearl et al., 2014). Glibert (2012) documented that, releasing of nutrients such as nitrate and phosphorus, organic matters and suspended particles from agricultural activities, affects the water quality of rivers. Lalika et al. (2015); Liu et al. (2014) reported that, application of fertilizers and pesticides in agriculture activities alter the chemistry of rivers water that affects the aquatic ecosystem. These activities are also alarming to affect the water chemistry of Pinyinyi River (PR) found in northern Tanzania (Mgimwa et al., 2021). As a result, PR shows ecosystem degradation and reduction of its services.

Since PR pours its water in Lake Natron Ramsar Site (LNRS), these impacts have also been reported to degrade the ecosystem services offered by this lake. Lake Natron Ramsar Site (LNRS), which is located in East Africa, is currently facing an uncertain future due to those unsustainable anthropogenic activities taking place around its catchments including Pinyinyi, Moinik, Ewaso Ngiro and Ngare Sero catchments (Yona et al., 2022). These activities contribute to poor water quality, reduced water quantity, less oxygen for aquatic species and reduced pH, high level of BOD, chemical fertilizers, pesticides, herbicides, turbidity and high soil erosion. All of these contribute to the watershed degradation and the breeding cycle of Lesser Flamingoes (Mgimwa et al., 2021). While most studies came up with scientific findings of significance to the conservation and management of the site, there is still a knowledge gap on the impacts of these

anthropogenic activities conducted around the catchments of LNRS and the river water quality by using physicochemical indicators. The study by Mgimwa et al., (2021) established the relationship between physicochemical indicators and food production for the Lesser Flamingo and Lesser Flamingo abundance at the site. The study used dissolved oxygen, water turbidity, phosphate, nitrate and ammonium as indicators. However, the study was conducted on the lake waters and didn't consider data from Pinyinyi River as one of the catchments. The current study intended to bridge the missing link. The study used physicochemical indicators namely; total dissolved solid (TDS), Biological oxygen demand (BOD), Chemical oxygen demand (COD), Nitrate (NO_3^-), Phosphate (PO_4^{3-}), pH, electrical conductivity (EC), turbidity and dissolved oxygen (DO) to establish impacts of anthropogenic activities at three sampling points (upstream, midstream and downstream) at Pinyinyi River. Moreover, the study also documented the anthropogenic activities taking place around the catchments of Lake Natron Ramsar Site.

This study is important for establishing the impacts of anthropogenic activities conducted at Pinyinyi River on the River water quality. The findings are crucial to providing recommendations to the Tanzania Wildlife Management Authority and other stakeholders on the best approaches for sustainable management of PR and LNRS. The results of this study fill the knowledge gaps identified in the international and National Single Species Action Plan for the conservation of Lesser Flamingo. Findings contribute towards sustainable management and conservation of LNRS and its watershed and recommendation support the protection of the only breeding site for the Lesser Flamingo in Southern Africa. Findings contribute policy and decision-making process on sustainable approaches of watershed and wetland management in Tanzania.

2. Materials and Methods

2.1 Description of The Study Area

The study carried out along Pinyinyi River in Pinyinyi ward at Ngorongoro district, Arusha, Tanzania in three sampling sites namely upstream (U_1 and U_2), midstream (A_1 and A_2) and downstream (M_1 and M_2)

(Figure 1). Upstream points (U1 and U2) defined as a point where there was very minimal level of disturbance and it was used as the reference points. Livestockkeeping and deforestation are the dominant activities at the upstream points. Agricultural points (A1 and A2) defined as the points where intensively agricultural activities, livestock keeping, bathing, washing, sand mining and water diversion taking place and it is also defined as a point with maximum disturbance. Herbicide, pesticides, industrial fertilizers and animal wastes washed away to the river which also contributes to change in water quality. River mouth points (M1 and M2) defined as a point where livestock keeping is taking place, no agricultural activities taking place, because the land is covered by soda ash and also defined as a point with minimum disturbance. Animal feces washed away to the river during irrigation and rainfall, which causes an increase in organic pollutants which lowered the level of dissolved oxygen in the river.

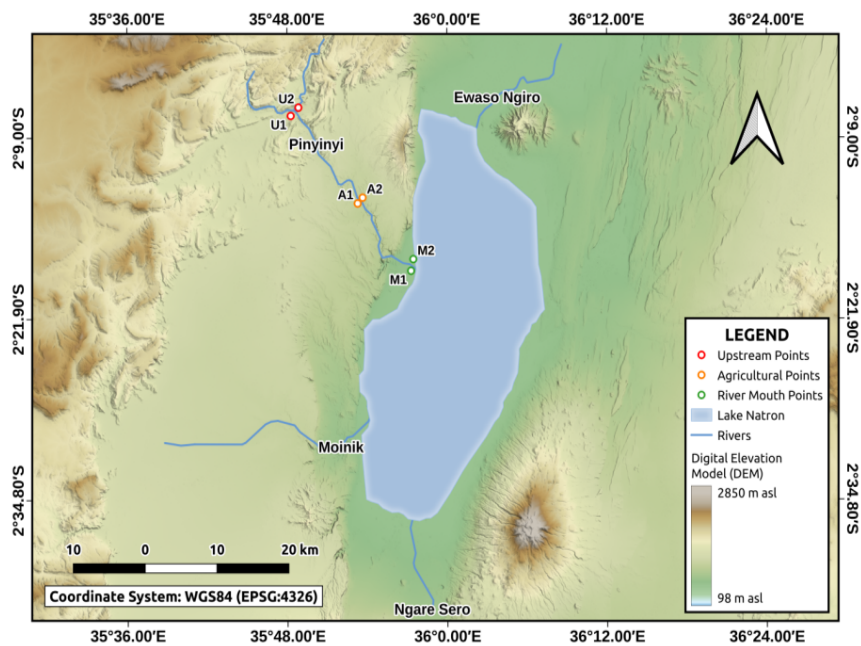


Figure 1. Map showing Pinyinyi River

The whole catchment of LNRS covers approximately 7600km² (Gichuki, 2003). This watershed is made up of four major rivers: the Ewaso Ngiro River, Pinyinyi River, Ngaresero River and Moinik River (Mgimwa *et al.*, 2021). No human activities take place around Ewaso Ngiro River because it is a conserved area. Land type around Monic and Ngaresero Rivers are covered by hard rocks and soda ash which do not influence any human activities. Intensive agricultural activities and livestock keeping are carried out around Pinyinyi River. These activities reduce the ecosystem services offered by the river and change the water quality of the river. Pinyinyi River receives water from Ngorongoro and Serengeti national parks and drains its water to the Lake Natron Ramsar Site which is the feeding and breeding site of Lesser Flamingos. Along the PR there are an estimated 6574 peoples who rely on irrigated agriculture and livestock keeping for their livelihoods (Kalacska *et al.*, 2017). The climate of the area is tropical and characterized by the interaction of the southwest monsoon winds as well as the southeast and northeast trade wind. The surrounding area of the Lake receives irregular seasonal rainfall, mainly between December and May totaling 800 mm per year. Temperature around the catchments is about 28°C and that of the Lake is frequently above 40°C (104°F) (Kalacska *et al.*, 2017). The natural land cover classes around LNRS include sand, bare land, rocks, vegetation and water.

2.2. Data Collection

2.2.1. Anthropogenic Activities Around Lake Natron Ramsar Site

To avoid bias, random sampling technique was used to obtain respondents from area alongside PR. The total number of about 60 respondents, 30 males and 30 females were engaged during the course of the data collection. Determination of sample size was achieved by using Yamane formula (Yamane, 1964)

$$n = \frac{N}{1 + N(e)^2}$$

n = Sample size

N = Population of the study which was 5322

e = Margin of error and in this case, e = 12.8% (chosen by researchers)

1 = Constant

$$n = \frac{5322}{1 + 5322 (0.128)^2} = 60$$

The study used structured questionnaires as the main method for primary data collection. These structured questionnaires comprising of open and closed questions that were equally distributed to all selected respondents. The target respondents were key informants, pastoralist, farmers and village executive officer. The questionnaires items included general information of the respondents and the kind of anthropogenic activities taking place along Lake Natron Ramsar Site catchments. Furthermore, the study used a checklist of questions to collect information from key informants. A key informant in this study is defined as a person knowledgeable in a scientific area of specialization.



Figure 2: Assessment of Anthropogenic activities taking place around LNRS

2.2.2. Physicochemical Water Quality Parameters

2.2.2.1 Water sample collection

Sampling was carried out during wet and dry seasons at selected sampling sites (upstream, midstream and downstream) following Crosby and Patel (1995). The sampling location was recorded using the global positioning system (GPS) (Hisseien et al., 2015). A total of 3 water samples from upstream, midstream and downstream sampling sites respectively were collected depth-wise using 2-litres water sampler and kept into half liter labeled plastic bottles. The water sample was then stored in a cool

box at 4°C and transported immediately to the laboratory in Arusha Technical College for analysis.

2.2.2.2 Sample Preparation and Analysis

In the laboratory water samples were filtered using 0.45 µm size filter membrane and stored at 4°C before analysis. Unfiltered water samples were tested for alkalinity using titrimetric method with 0.1N HCl and the result was expressed as HCO₃⁻ (mg/l) as explained by APHA et al. (1998). EC, DO, pH, turbidity and TDS were measured in-situ at each sampling site using potentiometric method.

In the Laboratory, 360 ml of water sample were measured into the BOD bottle. The water sample in the BOD bottle were mixed with ten drops of Allyl Thiourea (ATH inhibitor), magnetic stirring rod, and three drops of 45% of potassium hydroxide solution in seal gasket. After mixing water in a BOD bottles, the BOD bottles were tightly closed and the BOD incubator with temperature about 20°C was used to incubate the samples for five days. After five days the BOD values were recorded.

For COD analysis, 2.5 ml of distilled water were measured into the COD test tube as blank sample. 2.5 ml of filtered water sample was measured into another COD test tube. Again, 1.5 ml of 0.5 M of potassium dichromate (digestion solution) were added to each test tube and then heated. 3.5 ml of sulphuric acid (catalyst solution) were added into the hot test tubes. The tongs were used to shake the hot contents to ensure complete mixing. The samples were transferred into the COD block digester and heated for 2 hours at 150°C. The samples were cooled and titrated with 0.1 M Ferrous Ammonium Sulphate (FAS) using ferroin indicator. At the end of titration reddish brown colour was observed.

$$\text{COD in mg/L} = \frac{(A - B) \times M \times 8000 \times df}{V}$$

Where A = Volume of FAS used for blank titration

B = Volume of FAS used for sample titration

M = Molarity of FAS

df = dilution factor (if the sample has diluted)

V = Volume of water sample taken (2.5ml)

For phosphate analysis, the HACH DR/2700 machine was switched on. The user program clicked and numbers of parameters were appeared. Phosphate was selected by clicking on it. Distilled water was poured into the cuvette up to the mark. The cuvette was inserted into the cuvette holder and protective cover was closed. The zero button were clicked to show 0 mg/L PO_4^{3-} . One powder pillow of PhosVer 3 reagent was poured into the cuvette. The filtered water sample was added to the mark and shaken to dissolve. The reaction completed after two minutes and the timer beeped. The read button was clicked to show the value of phosphate obtained.

For nitrate analysis, the HACH DR/2700 machine was switched on. The user program clicked and numbers of parameters were appeared. Nitrate was selected by clicking on it. Distilled water was poured into the cuvette up to the mark. The cuvette was inserted into the cuvette holder and protective cover was closed. The zero button was clicked to show 0 mg/L NO_3^- . One powder pillow of NitraVer 5 reagent was poured into the cuvette. The filtered water sample was added to the mark and shaken to dissolve. The reaction completed after two minutes and the timer beeped. The read button was clicked to show the value of nitrate obtained.



Figure 3: Onsite and laboratory analysis of physicochemical parameters

2.3. Data Analysis

2.3.1. Anthropogenic Activities Around Lake Natron Ramsar Site

Statistical Package for Social Science (SPSS) version 26 was used to explore the extent of dominant anthropogenic activities carried out within the catchments/watersheds. Responses from respondents were coded, entered and

analyzed through descriptive statistical analysis to obtain frequency and percentages. Thereafter, Microsoft Excel was used to draw figures. For information obtained through informal, face to face interviews and verbal discussion, content analysis and structural function analysis was employed for supplementing information obtained through household questionnaire surveys (Ostrom, 1990; 1993).

2.3.2. Physicochemical Water Quality Parameters

The statistical package for social science (SPSS) version 26 was used in the analysis of physico-chemical data which was plotted in Microsoft Excel. The values were compared with Tanzania drinking water quality standard (TBS, 2008) and World Health Organization guideline (WHO, 2008) for drinking water/irrigation water. The comparison was done in order to check whether the measured values are within both national and international required standard limits. These standards were used to categorize the status of the river as to guide the allowable required standard limits of each selected water parameters in Pinyinyi River. One-way ANOVA on other hand was used to determine whether there was significant difference between sampling sites (upstream, midstream and downstream) while Tukey multiple comparisons test was performed to reveal specific differences. Differences were deemed significant at $P \leq 0.05$.

3. Results

3.1 Anthropogenic Activities Around Lake Natron Ramsar Site

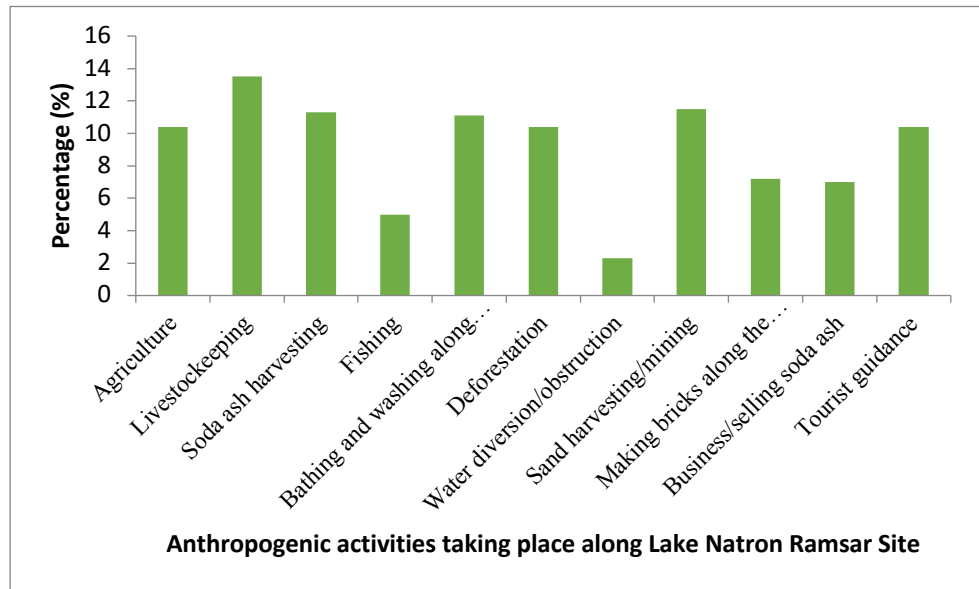


Figure 4: Anthropogenic activities taking place along LNRS.

The anthropogenic activities undertaken by the respondents were 46 (10.4%) were involved in agricultural activities, 60 (13.5%) livestock keeping, 50 (11.3%) soda ash harvesting, 22 (5.0%) fishing, 49 (11.1%) bathing and washing along the catchments, 46 (10.4%) deforestation, 10 (2.3%) water obstruction, 51 (11.5%) sand mining, 32 (7.2%) making bricks, 31 (7%) business and 46 (10.4%) tourist guidance (Figure 4).

3.2 Physicochemical Water Quality Parameters

Table 1: Physicochemical water quality parameters of Pinyinyi River

Parameters	Sampling sites	Seasons		Average mean \pm SD	WHO	TBS
		Wet (Mean \pm SD)	Dry (Mean \pm SD)			
COD, mg/l	Upstream	192 \pm 16	149 \pm 18.47	170.67 \pm 28.02 ^a	60	60
	Midstream	288 \pm 16	181.33 \pm 18.47	234.67 \pm 60.43 ^b		
	Downstream	244 \pm 16	106.67 \pm 18.47	165.33 \pm 66.099		
	Average mean	234.67 \pm 44.54	145.78 \pm 36.17	^a		
BOD, mg/l	Upstream	94 \pm 9.54	72.67 \pm 6.81	83.33 \pm 13.84 ^e	10	2-6
	Midstream	141.67 \pm 6.51	91.67 \pm 5.86	116.67 \pm 27.94 ^d		
	Downstream	115.67 \pm 12.50	51.33 \pm 7.57	83.50 \pm 36.43 ^e		
	Average mean	117.11 \pm 22.35	71.89 \pm 18.44			
DO, mg/l	Upstream	0.31 \pm 0.01	0.297 \pm 0.01	0.302 \pm 0.01 ^q	8-10	5-7
	Midstream	0.29 \pm 0.04	0.27 \pm 0.02	0.28 \pm 0.03 ^r		
	Downstream	0.27 \pm 0.02	0.32 \pm 0.02	0.297 \pm 0.03 ^s		
	Average mean	0.289 \pm 0.03	0.296 \pm 0.03			
EC, μ s/cm	Upstream	158.33 \pm 0.58	231.00 \pm 1.00	194.67 \pm 39.81 ^k	<1500	1000
	Midstream	158.00 \pm 1.00	239.67 \pm 1.12	198.83 \pm 44.74 ^l		
	Downstream	164.67 \pm 1.53	221.00 \pm 1.00	192.83 \pm 30.88		
	Average mean	160.33 \pm 3.39	230.56 \pm 8.14	^m		
Nitrate, mg/l	Upstream	0.32 \pm 0.03	0.13 \pm 0.06	0.225 \pm 0.11 ^z	30	30
	Midstream	0.80 \pm 0.00	0.10 \pm 0.00	0.45 \pm 0.38 ^h		
	Downstream	0.40 \pm 0.00	0.20 \pm 0.00	0.30 \pm 0.11 ^c		
	Average mean	0.51 \pm 0.224	0.144 \pm 0.052			
Phosphate, mg/l	Upstream	0.30 \pm 0.00	0.00 \pm 0.00	0.150 \pm 0.16 ^y	6	6
	Midstream	0.40 \pm 0.00	0.10 \pm 0.00	0.25 \pm 0.16 ^g		
	Downstream	0.30 \pm 0.00	0.100 \pm 0.00	0.20 \pm 0.11 ^p		
	Average mean	0.333 \pm 0.05	0.067 \pm 0.05			
pH, Unit	Upstream	8.63 \pm 0.252	8.20 \pm 0.10	8.42 \pm 0.293 ^x	6.5-8.5	6.5-8.5
	Midstream	7.61 \pm 0.12	8.00 \pm 0.10	7.81 \pm 0.234 ^w		
	Downstream	7.58 \pm 0.165	8.17 \pm 0.153	7.87 \pm 0.3497 ^w		
	Average mean	7.94 \pm 0.543	8.122 \pm 0.139			
TDS, mg/l	Upstream	78.67 \pm 0.58	119.00 \pm 1.00	98.83 \pm 22.104 ^f	500	1000
	Midstream					

Key	Downstream	79.33 ±0.58	128.67 ±1.53	104.00 ±27.041		
	Average mean	82.00 ±1.00	111.33 ±1.53	96.67 ±16.108		
		80.00 ±1.66	119.67 ±7.62			
Turbidity, NTU	Upstream	6.00 ±0.46	19.20 ±0.82	12.60 ±7.25 ⁿ	5	25
	Midstream	5.80 ±0.46	18.73 ±0.252	12.27 ±7.092 ⁿ		
	Downstream	6.13 ±0.31	44.67 ±0.52	25.4 ±21.393 ^t		
	Average mean	5.98 ±0.39	27.53 ±13.15			

n

Key: Means sharing the same letter are not significant different at 0.05 significance level.

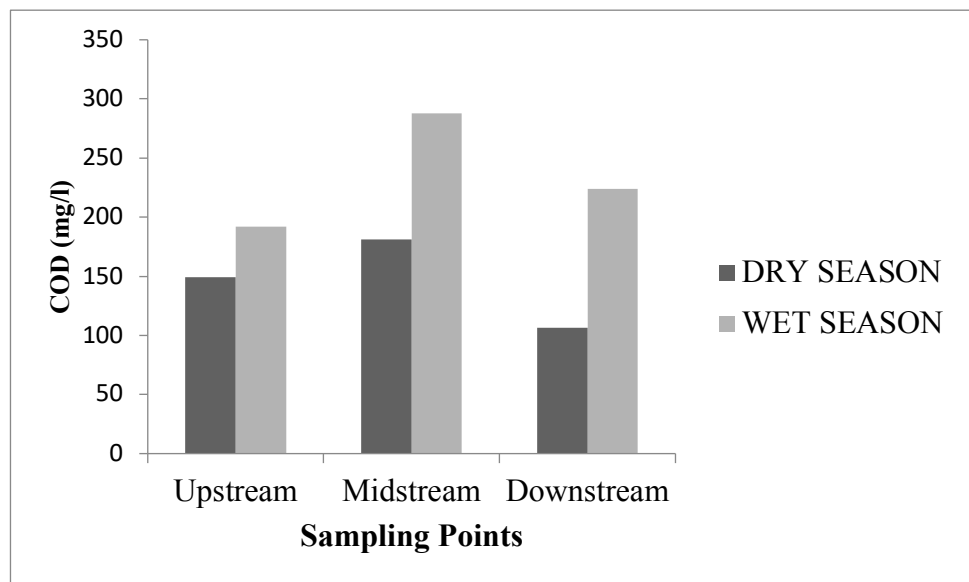


Figure 5: Variation of COD at Pinyinyi River sampling sites during dry and wet seasons

Figure 5 shows the variation of COD at Pinyinyi River. The average concentration of COD of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 170.67, 234.67 mg/L and 165.33 mg/L respectively (Table 1). The maximum COD values were recorded during wet season (234.67 ±44.54 mg/L) and minimum COD values were recorded during dry season (145.78 ±36.17 mg/L) (Table 1).

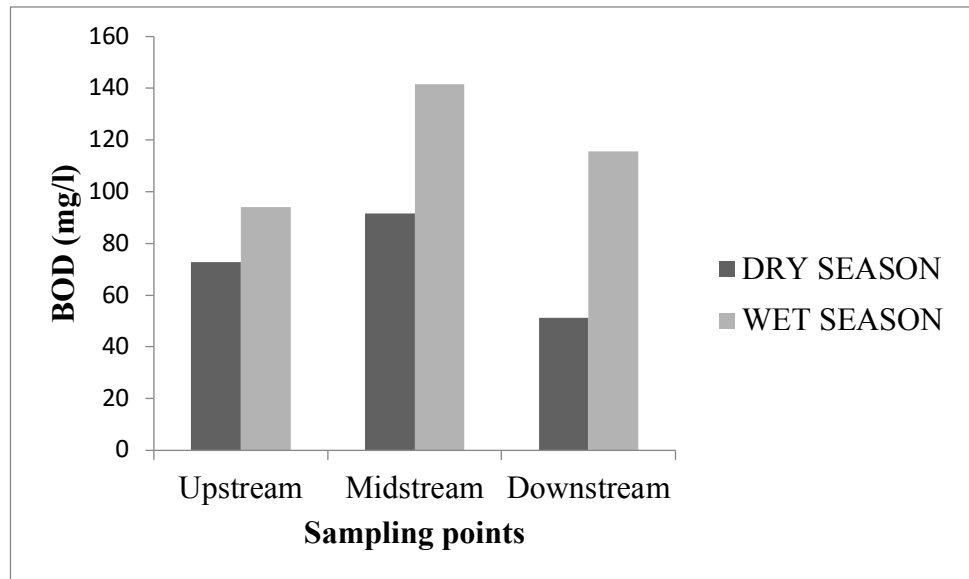


Figure 6: Variation of BOD at Pinyinyi River sampling sites during dry and wet seasons

Figure 6 and Table 1 show the variation of BOD at Pinyinyi River. The average concentration of BOD of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 83.33 ± 13.84 , 116.67 ± 27.94 and 83.50 ± 36.43 mg/L. The maximum values of BOD were recorded in all sampling site during dry and wet seasons.

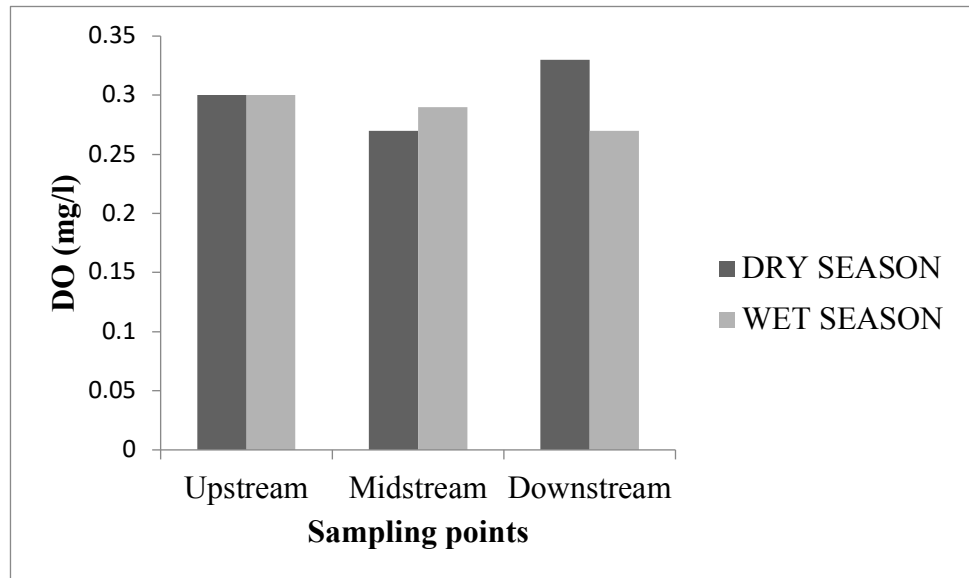


Figure 7: Variation of DO at Pinyinyi River sampling sites during dry and wet seasons

Figure 7 shows the variation of DO at Pinyinyi River. The average concentration of DO of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 0.302 ± 0.01 , 0.28 ± 0.03 and 0.297 ± 0.03 mg/L respectively (Table 1). The maximum DO values were recorded at upstream sampling point during wet season 0.31 ± 0.01 mg/L and at downstream during dry seasons 0.32 ± 0.01 mg/L (Table 1). The minimum value of DO were recorded at all sampling site during dry and wet seasons.

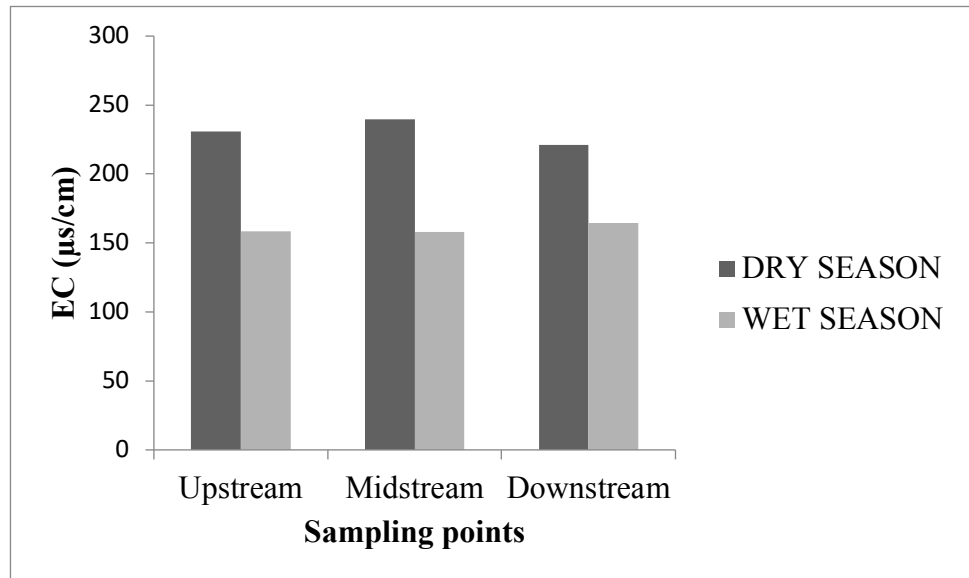


Figure 8: Variation of EC at Pinyinyi River sampling sites during dry and wet seasons

Figure 8 shows the variation of EC at Pinyinyi River. The average EC of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 194.67 ± 39.81 , 198.83 ± 44.74 and 192.83 ± 30.88 $\mu\text{s/cm}$ respectively (Table 1). The maximum EC values were recorded during the dry season, 230.56 ± 8.14 $\mu\text{s/cm}$ and minimum EC were recorded during the wet season, 160.33 ± 3.39 $\mu\text{s/cm}$ (Figure 8).

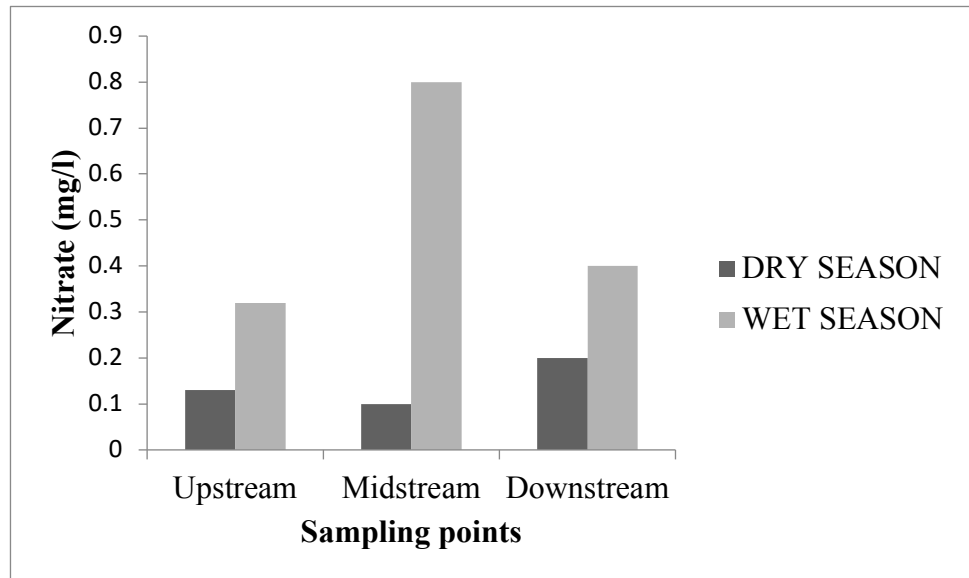


Figure 9: Variation of Nitrate at Pinyinyi River sampling sites during dry and wet seasons

Figure 9 shows the variation of nitrate at Pinyinyi River. The highest value of nitrate was recorded during wet season, 0.51 ± 0.224 mg/L while the lowest was obtained during the dry season, 0.144 ± 0.052 mg/L (Table 1). The average concentration of nitrate of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 0.225 ± 0.11 , 0.45 ± 0.38 and 0.30 ± 0.11 mg/L respectively (Table 1).

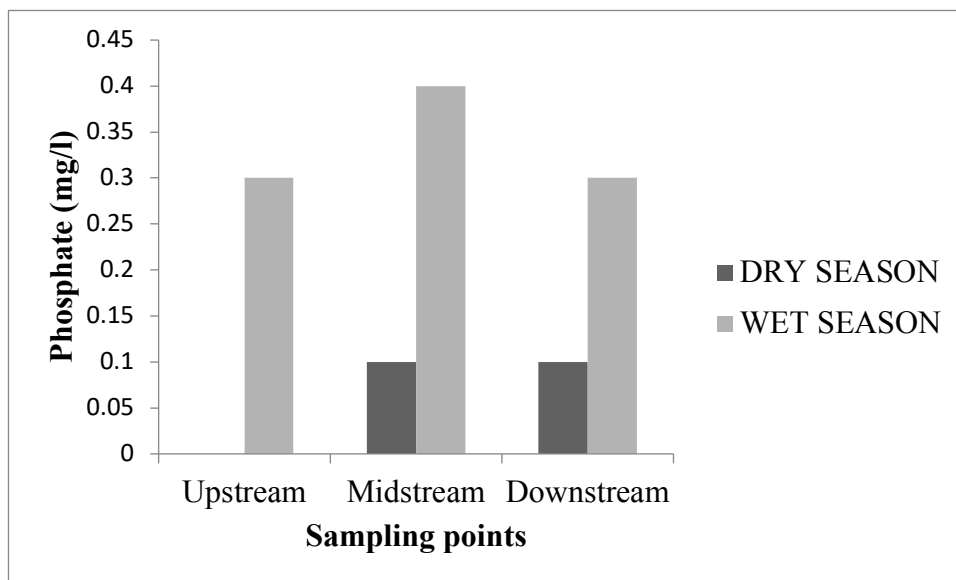


Figure 10: Variation of Phosphate at Pinyinyi River sampling sites during dry and wet seasons

Figure 10 shows the variation of inorganic phosphate at Pinyinyi River. The average concentration of inorganic phosphate in Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 0.150 ± 0.16 , 0.25 ± 0.16 and 0.20 ± 0.11 mg/L respectively (Table 1). The maximum inorganic phosphate values were recorded during wet season, 0.333 ± 0.05 mg/L and minimum inorganic phosphate were recorded during dry seasons, 0.067 ± 0.05 mg/L (Table 1).

4. Discussion

4.1. Anthropogenic Activities Around Lake Natron Ramsar Site

Agriculture activities and livestock keeping were the most dominant anthropogenic activities at Pinyinyi and Monic villages. Harvesting and selling of Soda ash and firewood were dominated at Engaresero village as their source of income. Selling firewood and construction of slums were associated with deforestation resulted to a loss of riparian vegetation at Pinyinyi River. Bathing and washing, sand mining, making bricks and water obstruction were also contributed to Pinyinyi River water pollution, changed the turbidity, EC, TDS and pH of water (Figure 4). Some of these activities such as agriculture,

livestockkeeping, washing and bathing generate organic pollutants released into the river. Decomposition of these organic pollutants lowers the level of oxygen and increase the level of COD and BOD.

4.2 Physicochemical Water Quality Parameters

According to Adeyemo et al. (2008) and Lalika et al. (2015) the maximum values of COD are attributed to pesticides, herbicides and insecticides from agricultural activities. In this study, the maximum value of COD recorded from upstream, midstream and downstream during wet season and dry season could be due to organic pollutants from agricultural activities, washing, bathing, livestockkeeping, pesticides, herbicides, Industrial fertilizers and insecticides. In all sampling sites, values of COD above the permissible limit (TBS, 2008; WHO, 2008). The statistical analysis at 95% confidence level showed that, there was a significant difference between upstream and midstream, midstream and upstream, midstream and downstream, downstream and midstream ($P = 0.05$), also there was no significant different between upstream and downstream, downstream and upstream ($P = 0.858$).

BOD measures the quantity of oxygen required by bacteria for breaking down of complex organic pollutants to simpler substances of the decomposable organic matter present in water (Suthar et al., 2010). BOD is an important parameter in the aquatic ecosystem since it shows the status of pollution (Mbaruku, 2016). The greater the BOD, the more rapidly oxygen is depleted in the water body, because microorganisms are using up DO. The consequences of high BOD are the same as those of low DO where aquatic organisms become frazzled suffocate and die (Mbaruku, 2016). The permissible range of BOD is 2 mg/L – 6 mg/l (WHO, 2008; TBS, 2008). According to Al-badii et al. (2013) and Tyagi. (2015) the maximum value of BOD are attributed to organic pollutants from agricultural activities. In this study the maximum value of BOD recorded from upstream, midstream and downstream during wet season could be due to organic pollutants from agricultural activities, deforestation, livestockkeeping, washing, bathing and influx of pollutants from pit latrines whereas maximum BOD recorded from upstream, midstream and downstream during dry season is due to bathing, washing and livestock keeping. BOD from upstream, midstream and downstream were above the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis at 95% confidence level showed that,

there was a significant difference between upstream and midstream, midstream and upstream, midstream and downstream, downstream and midstream ($P = 0.05$), also there was no significant different between upstream and downstream, downstream and upstream ($P = 0.999$).

DO is the quantity of gaseous oxygen dissolved in an aqueous solution. Suitable dissolved oxygen is necessary to withstand aquatic biota. Oxygen content is important for the direct need of many organisms and affects the solubility of many nutrients and periodicity of aquatic ecosystem (Mustapha et al., 2013). In summertime dissolved oxygen decreases due to upturn in temperature and increased microbial activities. The lowest acceptable dissolved oxygen concentration for aquatic life, range from 6 mg/L in warm water to 9.5 mg/L in cold water (WHO, 2008). DO play a role of regulator of metabolic activities of organisms and thus manages metabolism of the biological community as a whole and used as an indicator of tropical status of the water (Suthar et al., 2010). Low DO is an indication that, the aquatic ecosystem is degraded and some organisms that use aerobic conditions will not be able to survive due to lack of oxygen (Mbaruku, 2016). The permissible limit of DO is 5 mg/L – 7 mg/L (TBS, 2006) and 8-10 mg/L (WHO, 2008). According to Pearl et al. (2014), Lalika et al. (2015) and Mгимwa et al. (2021) the minimum value of DO are attributed to bathing, washing and organic pollutants from agricultural activities. In this study the minimum value of DO recorded from upstream, midstream and downstream during dry and wet season could be due to organic pollutants from agricultural activities, bathing, washing, faeces from pit latrines, deforestation and livestock keeping.

The statistical analysis at 95% confidence level showed that, there was no significant different between upstream and midstream, midstream and upstream ($P = 0.193$), there was no significant different between upstream and downstream, downstream and upstream ($P = 0.917$), also there was no significant different between midstream and downstream, downstream and midstream ($P = 0.343$).

Another parameter that was determined is EC, which is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts (Mezgebe et al., 2015). The intensification in land use practices in the catchments influences higher TDS, which contribute to higher EC.

Higher EC is an indication of salts in water that are not acceptable to macroinvertebrates, because some cannot tolerate salinity conditions (Mbaruku, 2016). The permissible limit of EC is $< 1500 \mu\text{S}/\text{cm}$ (WHO, 2008) and $1000 \mu\text{S}/\text{cm}$ (TBS, 2008). According to Nyairo et al. (2015) the maximum value of EC during dry season are attributed to high rate of evaporation, dissolution of rocks, pesticides, herbicides and insecticides from agricultural activities. In this study, the maximum value of EC recorded from upstream, midstream and downstream during dry season could be due to high rate of evaporation, dissolution of rocks, deforestation, water diversion and pesticides from agricultural activities (Figure 8). The EC recorded from upstream to downstream were within the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis at 95% confidence level showed that, there was a significant difference between upstream and midstream, midstream and upstream, midstream and downstream, downstream and midstream ($P = 0.05$), also there was significant different between upstream and downstream, downstream and upstream ($P = 0.031$).

Nitrate is one of the essential nutrients in aquatic ecosystem for plants growth and limits algal growth (Bwalya, 2015). According to Bwalya, (2015) nitrogen containing elements are crucial for all biotic processes in the aquatic environment. The increase of nitrate concentration in rivers is due to anthropogenic activities. During floods, the run off from agricultural activities conveys fertilizers to the rivers causing pollution of water bodies. The upturn of nitrate causes excessive algal growth, up on decomposition too much algal growth lowers oxygen levels and thus some aquatic organisms cannot stand anaerobic condition (Mbaruku, 2016). High nitrate levels noted in surface water originate from human activities such agricultural activities and livestock keeping (Palmer et al., 2007; Lalika et al., 2015). High nitrate concentration observed in many river systems may be due to drawn-out sources from urban and agricultural runoff and to point discharge from sewage treatment plants (Mbaruku, 2016). The permissible limit of nitrate is $50 \text{ mg}/\text{L}$ (WHO, 2008) and $30 \text{ mg}/\text{L}$ (TBS, 2008). The minimum values of nitrate recorded from upstream to downstream could be due to short residence times in the water column after entering the river, primarily due to uptake by phytoplankton (Melaku et al., 2007). The nitrate recorded from upstream, midstream and downstream was within the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis

at 95% confidence level showed that, there was significant different between upstream and midstream, midstream and upstream, midstream and downstream, downstream and midstream ($P = 0.05$), also there was significant different between upstream and downstream, downstream and upstream ($P = 0.001$)

Phosphate is the most important nutrient for plants growth, phosphorus can occur in a variety form in aquatic ecosystem namely: as mineral phosphorus, inorganic phosphorus and organic phosphorus (Phosphorus bound up with carbon and oxygen in plant matter) and as dissolved soluble reactive orthophosphate (PO_4^{3-}) (Mbaruku, 2016). In aquatic ecosystems if phosphorus outstrips the acceptable limit, affects aquatic ecosystem by dwindling the oxygen after excess algal growth (Bwalya, 2015). Fertilizers, after being used for agricultural activities are splashed down to the water bodies bringing in great loads of phosphorus (Bwalya, 2015). The permissible limit of phosphate is 6 mg/L (WHO, 2008) and 6 mg/L (TBS, 2008). The minimum values of inorganic phosphate recorded from upstream, midstream and downstream during dry season could be due to adsorption to particulate matter and subsequent sedimentation (Melaku et al., 2007). The maximum values of inorganic phosphate recorded from upstream to downstream during wet season are due to agricultural activities and livestock keeping (Bwalya, 2015; Melaku et al., 2007). The inorganic phosphates recorded from upstream, midstream and downstream during wet season were within the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis at 95% confidence level showed that, there was significant different between all three sampling sites ($P = 0.05$).

pH indicates the strength of the acidic or alkalinity character of a solution and is controlled by the dissolved chemical compounds and biochemical progressions in the solution (Mezgebe et al., 2015). The pH is most important parameter in determining the corrosive nature of water. The lower the pH value the higher the corrosive nature of water (Mbaruku, 2016). Low pH increases the solubility of metals and nutrients such as nitrates and phosphates making them available for uptake by plants and animals (Mbaruku, 2016). It is usually monitored for assessment of water ecosystem health, irrigation and drinking water, industrial discharge and surface water run-off (Mezgebe et al., 2015). The recommended pH is 6.5 to 8.5 (WHO, 2008; TBS, 2008). Water which has pH value of more than 9 or less than 4.5 becomes unfitting for domestic use like drinking. Higher pH at upstream sampling site could be due to bicarbonate and carbonate of calcium and magnesium in water and the main sources of such chemicals could be due livestock keeping, bathing and washing in River water course (Suthar et al., 2010). The pH recorded from upstream to downstream was within the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis at 95% confidence level showed that, there was significant different between upstream and midstream, upstream and downstream, downstream and upstream, ($P = 0.05$) and there was no

significant different between midstream and downstream, downstream and midstream ($P = 0.725$).

TDS indicates the ability of water to dissolve various inorganic and some organic minerals or salts like sulphates, magnesium, chlorides, bicarbonate, sodium, calcium and potassium (Mbaruku, 2016). High levels of TDS reduce algal productivity and growth and give a picture of the poor water quality (Mezgebe et al., 2015). Irrigation with high TDS results in soil salinization and a drop in macro-porosity but did not decrease farm yield (Adeyemo et al., 2008). The permissible limit of TDS is 500 mg/L (WHO, 2008) and 1000 mg/L (TBS, 2008). Water containing more than 1000 mg/L of TDS is not considered as desirable for drinking because it is harmful for human and aquatic life. According to Lalika et al. (2015) the maximum value of TDS during dry season are attributed to high rate of evaporation, dissolution of rocks, pesticides, herbicides and insecticides from agricultural activities. In this study, the maximum value of TDS recorded from upstream, midstream and downstream during dry season could be due to high rate of evaporation, water diversion, deforestation, dissolution of rocks and pesticides from agricultural activities (A. 2). The TDS recorded from upstream to downstream during dry and wet seasons were within the permissible limit (WHO, 2008; TBS, 2008). The statistical analysis at 95% confidence level showed that, there was significant different between upstream and midstream, midstream and upstream, midstream and downstream, downstream and midstream ($P = 0.05$), also there was significant different between upstream and downstream, downstream and upstream ($P = 0.014$).

Turbidity is a measure of how clear the water is (Mezgebe et al., 2015). Turbidity in most water is due to colloidal and extremely fine dispersion. Turbidity is influenced either naturally by rainfall run off or anthropogenic activities such as industrial activities. In many aquatic systems such as Rivers and Lakes water clarity is determined by the abundance of suspended algae which reduce water clarity and increase its color (Mezgebe et al., 2015). Turbidity water affects photosynthesis because it limits permeation of light (Mbaruku, 2016). The permissible limit of turbidity is 5 NTU (WHO, 2008) and <25 NTU (TBS, 2008). In extreme cases, turbid water can harm animals and deposit heavy sediment on leaves reducing photosynthesis. Turbid water also affects how well disinfection techniques including ultraviolet light and chlorination work and slows the establishment of vegetables (Mezgebe et al., 2015). According to Mezgebe et al. (2015), Khatri and Tyagi (2014), the maximum value of turbidity attributed to sand mining, making bricks and deforestation. In this study, the maximum value of turbidity recorded from downstream during dry season could be due to sand mining, livestockkeeping, fishing, bathing, agriculture, water

diversion, washing and deforestation (A. 3). The statistical analysis at 95% confidence level showed that, there was a significant different between upstream and downstream, midstream and downstream, downstream and upstream, downstream and midstream ($P = 0.05$), also there was no significant different between upstream and midstream, midstream and upstream ($P = 0.966$).

5. Conclusions

The study revealed that agricultural activities, livestock keeping, deforestation, soda ash harvesting, bathing and washing, sand harvesting and tourist guidance are most dominant anthropogenic activities around LNRS. Phosphate, pH, EC, TDS and nitrate are within the permissible limit. DO, BOD, COD and turbidity on Pinyinyi River are above the permissible limit. The study revealed that, agricultural activities, bathing, washing, sand mining, livestock keeping and deforestation significantly affect the water quality of Pinyinyi River. The study therefore proposed that watershed management using nature-based solutions such as afforestation of riparian vegetation. Additionally, education on environmental conservation and awareness for Pinyinyi river ecosystem sustainability through sustainable agriculture and livestock practices along Pinyinyi river. Moreover, further analysis of physicochemical and bacteriological of Pinyinyi river are required.

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Apendices

Appendix 1: Questionnaire for respondents

I am Omary Rajabu R. MSc Environmental Science Management and Technology from Sokoine University of Agriculture, department of geography and environmental studies. I'm conducting a research on **the use of physico-chemical parameters to assess the impacts of anthropogenic activities on River water quality around Lake Natron Ramsar Site**, I request you to assist in getting the information that will be used for academic purpose only and not otherwise.

Section A: General information of the respondents

- 1. Respondent number.....
- 2. Age of the respondent.....
- 3. Village.....
 - 4. Ward.....
 - 5. Sex. Tick (√) appropriate.
 - a) Male []
 - b) Female []
 - 4. Marital status. Tick (√) appropriate.
 - a) Single
 - b) Married []
 - c) Widow
 - d) Separated
 - 5. Education level. Tick (√) appropriate
 - a) Primary level []
 - b) Secondary level []
 - c) College /University []
 - d) Not at all []
 - 6. Occupations Tick (√) appropriate.
 - a) Agriculture []
 - b) Business []
 - c) Pastoralist []
 - d) Fishing []
 - e) Others

M

- d)
- e)
- 26. What do you think should be done to ensure the continual existence of Pinyinyi River and other catchments.....
.....
.....
- 27. How do you perceive the idea of leaving Pinyinyi River untouched.....
.....
.....
- 28. What methods are being used in ensuring conservation of Pinyinyi River?
a)
- b)
- c)
- 29. Is there any organization that motivates you in water conservation around Pinyinyi River? a) Yes b) No []
- 30. If yes in the question above what action do they take to help the conservation of Pinyinyi River?
a)
- b)
- c)
- 31. If no in the question above explain why,
a)
- b)

Thank you for your attention and cooperation

Section D: Checklist for nature Tanzania/key informant

Date of the interview

Name:

Contact:

Section/Dept:

Position:

1. What are the main rivers that drain to Lake Natron Ramsar Site?
2. What are the main anthropogenic conducts/influences associated with each river before emptying its water to Lake Natron Ramsar Site?
3. How far have these rivers been affected by the named influences?
4. Which River is most affected?

5. What is the current ecological/conservation status of most affected river?
6. Is there any biomonitoring work that has been previously done?
7. a) If there, what was the outcome and its implication?
b) If Not, how is the monitoring done, what are the strategies used to assess the status of the most affected river with change in time?
8. Is there any ongoing strategy to act on the anthropogenic changes in relation to most affected rivers?
9. Is there any plan to restore the most affected river? Please elaborate clearly if any.

Appendix 2

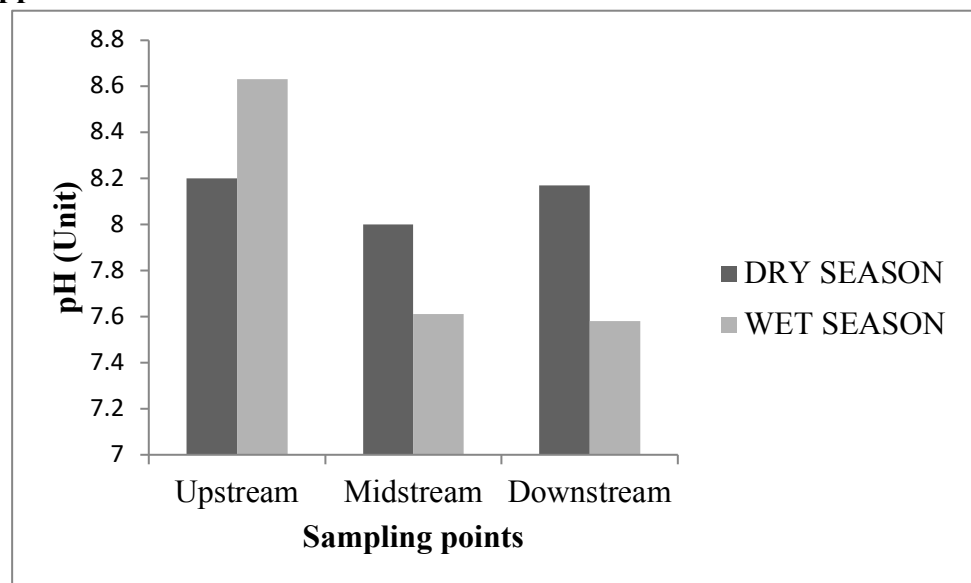


Figure A. 1: Variation of pH at Pinyinyi River sampling sites during dry and wet seasons

Figure A. 1 shows the variation of pH at Pinyinyi River. The average concentration of pH of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 8.42 ± 0.293 , 7.81 ± 0.234 and 7.87 ± 0.3497 unit respectively (Table 1). The maximum pH values at upstream sampling point were recorded during wet and dry season, 8.42 ± 0.293 units and minimum pH were recorded at midstream and downstream during dry and wet seasons, 7.81 ± 0.234 and 7.87 ± 0.3497 unit respectively (Table 1).

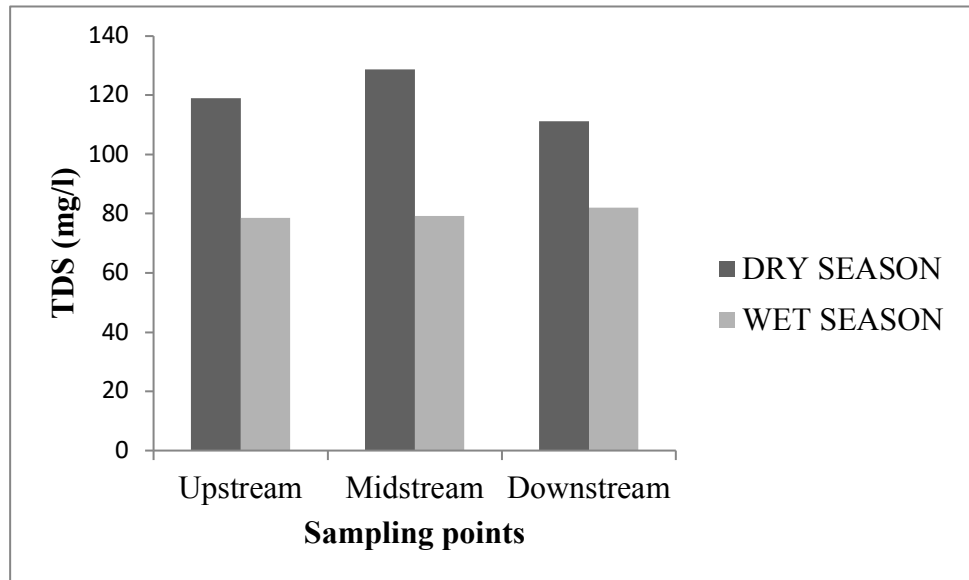


Figure A. 2: Variation of TDS at Pinyinyi River sampling sites during dry and wet seasons

Figure A. 2 shows the variation of TDS at Pinyinyi River. The average concentration of TDS of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 98.83 ± 22.104 , 104.00 ± 27.041 and 96.67 ± 16.108 mg/L respectively (Table 1). The maximum TDS values were recorded during the dry season in all sampling sites, average mean TDS, 119.67 ± 7.62 mg/L and minimum TDS were recorded during wet season in all sampling points, average mean TDS, 80.00 ± 1.66 mg/L (Table 1).

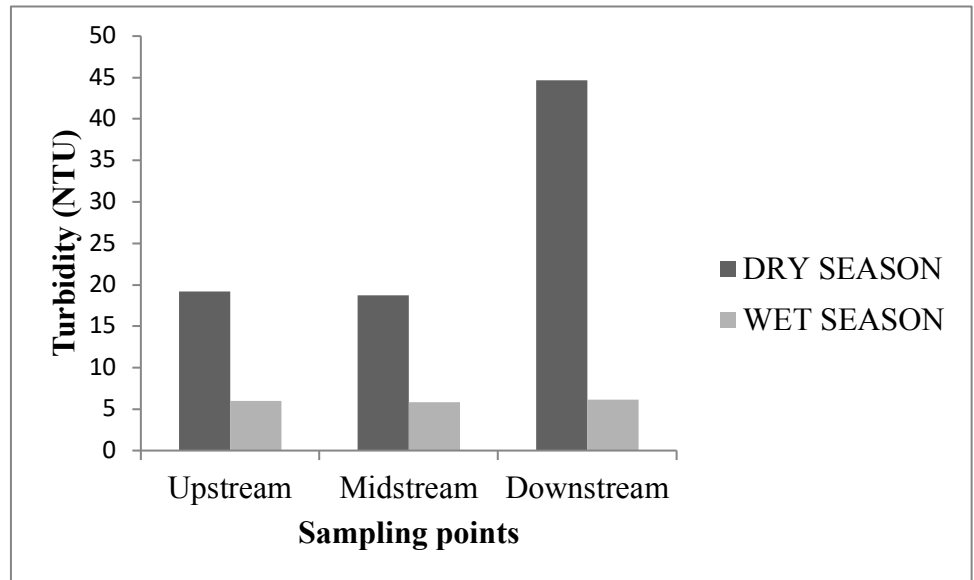


Figure A. 3: Variation of Turbidity at Pinyinyi River sampling sites during dry and wet season

Figure A. 3 shows the variation of turbidity at Pinyinyi River. The average concentration of turbidity of Pinyinyi River at upstream, midstream and downstream during wet and dry seasons were 12.60 ± 7.25 , 12.27 ± 7.092 and 25.4 ± 21.393 NTU respectively (Table 1). The maximum turbidity values were recorded during dry season in all sampling sites, average mean turbidity, 27.53 ± 13.15 NTU and minimum turbidity were recorded during wet season in all sampling points, average mean, 5.98 ± 0.39 NTU (Table 1). The turbidity recorded at downstream during dry season (44.67 ± 0.52 NTU) were not within the permissible limit (Table 1).