The Influence Of Land-use Patterns in The Ruvu River Watershed on Water Quality in the River System

Elizabeth Ngoye[1] and John F. Machiwa[2]

[1]Department of Zoology and Marine Biology, University of Dar es Salaam, P. O. Box 35064, Dar es Salaam, Tanzania.

[2]Department of Aquatic Environment and Conservation, University of Dar es Salaam, P.O. Box 35064, Dar es Salaam, Tanzania.

[1]ngoye@chem.udsm.ac.tz

Abstract

This work assessed the variational impacts of land-use patterns in the Ruvu river basin on water quality in the river system. Seasonal changes in water quality parameters were also investigated. Ten sampling stations were selected and samples were subsequently subjected to standard analytical procedures. Physico-chemical water quality parameters observed were pH (up to 8.07 ± 0.23), temperature (up to 31.1 ± 0.4 °C), EC (up to 48,734 ± 306 µS/cm), TDS (up to 24,367 ± 152.9 mg/l), turbidity (up to 840 ± 69.3 FAU) and DO (up to 16.78 mg/l). The results for nutrients included NO_3-N (up to 0.62 ± 0.3 mg/l), NH_4-N (up to 16.2 ± 0.5 mg/l), PO_4-P (up to 1.75 ± 0.2 mg/l) and TP (up to 3.56 ± 0.38 mg/l). Generally, water samples from stations with forested catchments had high levels of DO and low levels of nutrients (low levels of NH_4-N and NO_3-N) compared to those from farm land, industrial, residential and market places. There were clear seasonal variations with an increase in the concentrations of nutrients during rainy season. The results show obvious anthropogenic impacts on the water quality of the river. Continuous monitoring and surveillance to ensure protection of water resources is recommended.

Introduction

Rivers and the surrounding land drained by them (watersheds) are very important part of our natural heritage. The river itself is used by human beings and animals as source of water for their daily needs and also provides the environment for fish, plants and animals, while the banks and nearby land support living organisms such as man. Rivers provide water for agriculture, industry and domestic use. They sustain ecosystems that provide economic, recreational, aesthetic, social and cultural benefits. Rivers have been utilized by mankind over the centuries to the extent that, very few, if any, are now in their natural condition (Wetzel, 2001). Cunningham and Saigo (1999) have reported that, between 1985 and 1990 there was a decrease in the total length of rivers and canals in England and Wales having top quality water. Of concern nowadays is the fast declining availability of useable fresh water in terms of water quality and quantity as a result of poor land-use practices in the catchment areas (Calder, 1993).

Water quality in rivers is generally linked with land-use in the catchment which can affect the amount and quality of runoff during and following rainfall. Forestry, agriculture, industrialization and urbanization modify watershed cover characteristics that influence runoff quality and quantity (Richards and Host, 1994). Many problems of water pollution are caused by changes in land-use patterns on catchment areas as population pressure and economic activity increase (Lee and Bastemeijer, 1991). The main factors affecting the water quality of most water resources are pollution by industrial waste products, pesticides and fertilizer contamination and domestic sewage pollution. Environmental degradation and deforestation also have the influence on the quality of many water resources (Calder, 1993). The major concern in urban areas is the lack of sanitation facilities and refuses disposal systems. Surface water sources are generally affected more directly than groundwater sources by land-use changes in the catchment area.

Presently, there is a growing awareness of the importance of watershed and landscape-scale influences on the quality and quantity of water in the receiving water body (Richards and Host, 1994).

The spatial analysis of land-use patterns on the catchment area and their influence on the stream quality and biological assemblages is important. Ruvu is among the rivers threatened by pollution as a result of changes in land-use patterns on the catchment.

This paper presents the results of the study on impacts of land-use patterns on water quality in the Ruvu river system. The main objective of this study was to assess the influence of farming and urbanization in the Ruvu river watershed as well as seasons on water quality in the river. The quality of water from forested areas (upcountry/coastal including mangrove) was also assessed.

Materials and Methods

Study Area

The study was conducted in the Ruvu river basin (Figure 1) which is located in the Coast and Morogoro Regions. The basin has an area of about 17,900 km^2, and lies between latitude 6°05' and 7°45' South and longitude 37°15' and 39°00' East (URT, 1995). The Ruvu River originates in the Uluguru Mountains and flows into undulating highlands in the middle reaches. It finally discharges into the Indian Ocean near the town of Bagamoyo about 70 km northwest of Dar es Salaam. Generally, annual rainfall ranges between 800 and 2,700 mm with the average annual basin rainfall amount of 1,081mm (URT, 1995).

Land cover on the catchment adjacent to Ruvu River basin is of various types with most of the area covered with natural vegetation. The principle types of vegetation in the basin are mangrove forest at the mouth of the river, thickets, woodlands, tropical evergreen and semi-deciduous forests along the river and its tributaries, and mountain forest. Another type of vegetation is that induced by cultivation, which is the main land-use activity in the basin. The main crops cultivated in the basin include maize, paddy, cassava, cashew, sisal, vegetables and citrus. Therefore, of the 17,900 km^2 of the total catchment area, arable land accounts for only 10% (JICA, 1994), the rest comprises of forest, steep slope area, floodplain, water bodies and a very small area is utilized for human settlement ranging from small towns to villages.

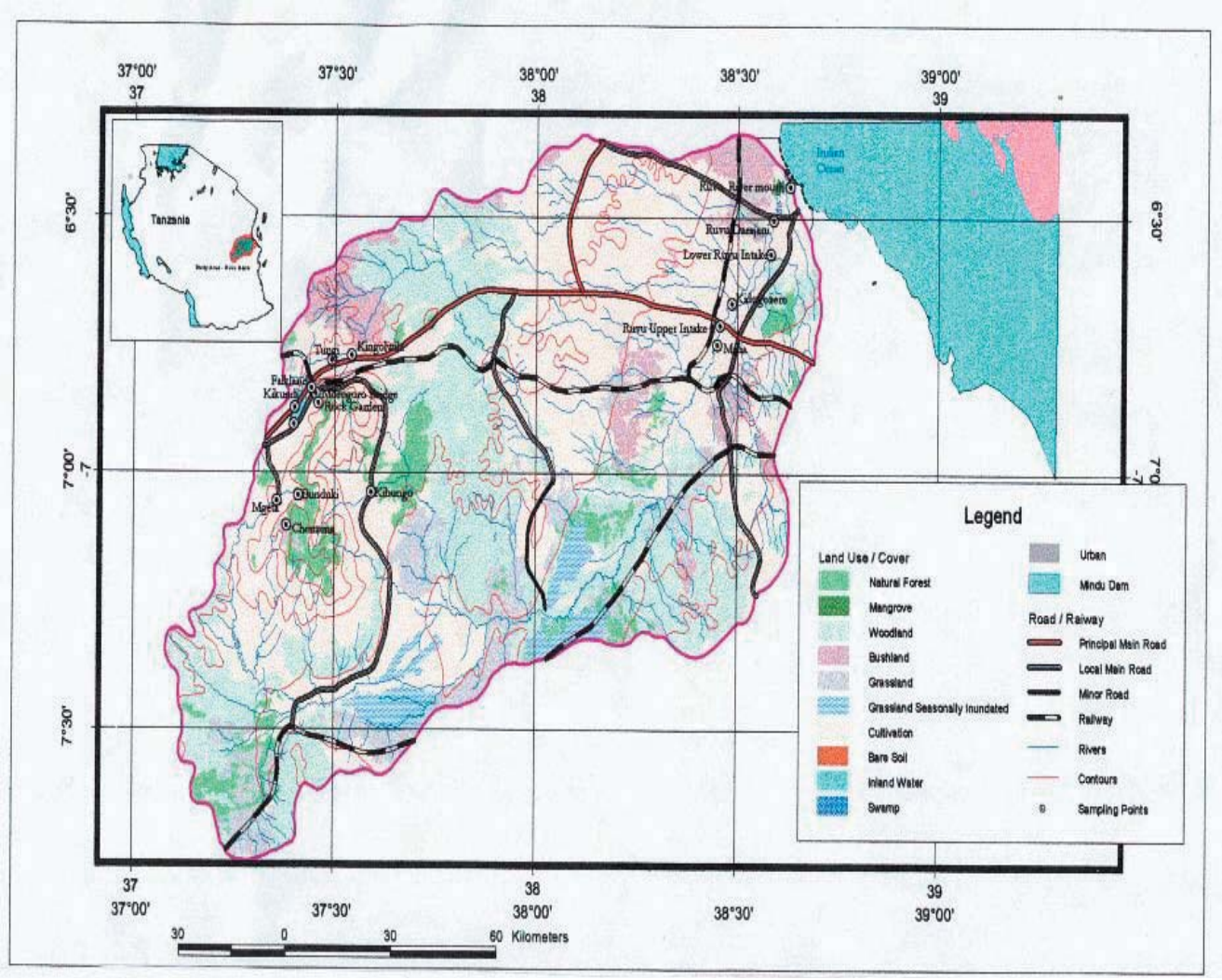


Figure 1: Map of Ruvu river basin showing drainage system, major land-use, types of land cover and sampling points.

Sample Collection and Analysis

Water samples were taken from the main river and tributaries during dry and rainy seasons. Ten sampling stations were chosen namely: 1). Tchenzema, 2). Kibungo, 3). Mgeta, 4). Mindu dam, 5). Kikundi, 6). Morogoro bridge, 7). Tungi 8). Msua, 9). Ruvu darajani and 10). Ruvu mouth (Figure 1). Samples were collected in polythene containers which had been washed with phosphorus free detergents, rinsed with distilled water and left to stand overnight in 1 M HCl. They were rinsed again with distilled water and thrice with sample water on site and transported in a cool box to the Chemistry laboratory at the University of Dar es Salaam. Following sampling, river water samples were analysed according to standard methods (APHA, 1992). The analysed parameters include pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), soluble reactive phosphorus (SRP), total phosphorus (TP), nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NO_4-N).

The pH of water was measured on site using a pH meter (RS model). Measurement of temperature, EC and TDS was done using Hatch EC/TDS meter (Hatch, No. 940600013692). Turbidity was determined on site as Formazin Attenuation Unit (FAU) method using a portable datalogging spectrophotometer (HATCH, DR/2010). In the laboratory, DO was determined using the iodometric titrimetric method, a procedure based on the oxidizing property of DO.

SRP and TP were determined using ascorbic acid method. SRP was determined on filtered water samples by reacting with ammonium molybdate and potassium antimonyl tartarate in an acid medium and then reduced using ascorbic acid to yield an intense blue colour. The colour intensity was determined colorimetrically at 880 nm. Total phosphorus was determined from unfiltered water samples using the same method. Ammonia was determined by treating the river water samples in an alkaline citrate medium with sodium hypochlorite and phenol in the presence of sodium nitroprusside which acts as a catalyser. The blue indophenol colour formed with ammonia was measured spectrophotometrically at 640 nm. Nitrate-N was determined using cadmium reduction method followed by diazotisation with sulphanilamide and coupling with N-(1 naphthl)-ethylenediamine to form a highly coloured azo dye that is measured colorimetrically.

Analysis of variance (ANOVA) was used to compare variations in water quality at different land-uses and the post hoc test (Tukey) was used to compare differences among means. Student t-test was used to compare the quality of water between seasons (Zar, 1986).

Results and Discussion

Physical Quality of Water in the Ruvu River System

The levels of various parameters at different seasons at each

sampling station i.e. the variation of pH, temperature, EC, TDS, DO and turbidity are illustrated in Figure 2a - h.

The pH of water between station 1 and 10 varied between 6.95 ± 0.09 and 8.07 ± 0.23. During both seasons (dry and rainy), the analysis of variance (ANOVA) test showed significant difference in the pH values at areas of different land-uses. The mean pH values along the Ruvu river system conform to typical river water values (4.5 – 8.5) as described by **McCutcheon *et al*., 1992**. The pH values were also within the World Health Organization (WHO) and Tanzania Temporary Standards (TTS) for drinking water quality (6.5 -9.5). The temperature of Ruvu river water varied between 14.00 ± 0.6 and 31.1 ± 0.4 °C touching the lower in rainy season (Figure 2). The values were lower in the forested areas and higher in the lower plains where the air temperatures were higher. The mean temperature values were generally within the range and typical values for river water quality in all stations during both dry and rainy seasons except for station 8 and 9 which had high temperature values during dry season. Temperature at stations 1, 2, 3, 4, 5, and 6 falls within the WHO recommended values (25 °C) for drinking water quality while at stations 7, 8, 9 and 10 temperature values were higher than the WHO standards for drinking water quality because are located in lower coastal plains and turbidity levels are higher. High temperature affects the amount of oxygen dissolved in water and hence the sensitivity of aquatic organisms to toxic wastes, parasites and diseases is also affected.

The conductance value station 1 and 10 varied between 39.8 ± 0.8 and 48,734 ± 305.5 µS/cm while TDS varied between 19.9 ± 0.38 and 24367 ± 152.9 mg/l (Figure 2). EC and TDS were lower in the forested areas with higher levels recorded at the river mouth in both seasons.

sea water which have high levels of dissolved ions. The higher values of EC are usually associated with high concentrations of dissolved ions in water This may be attributed by the mixing

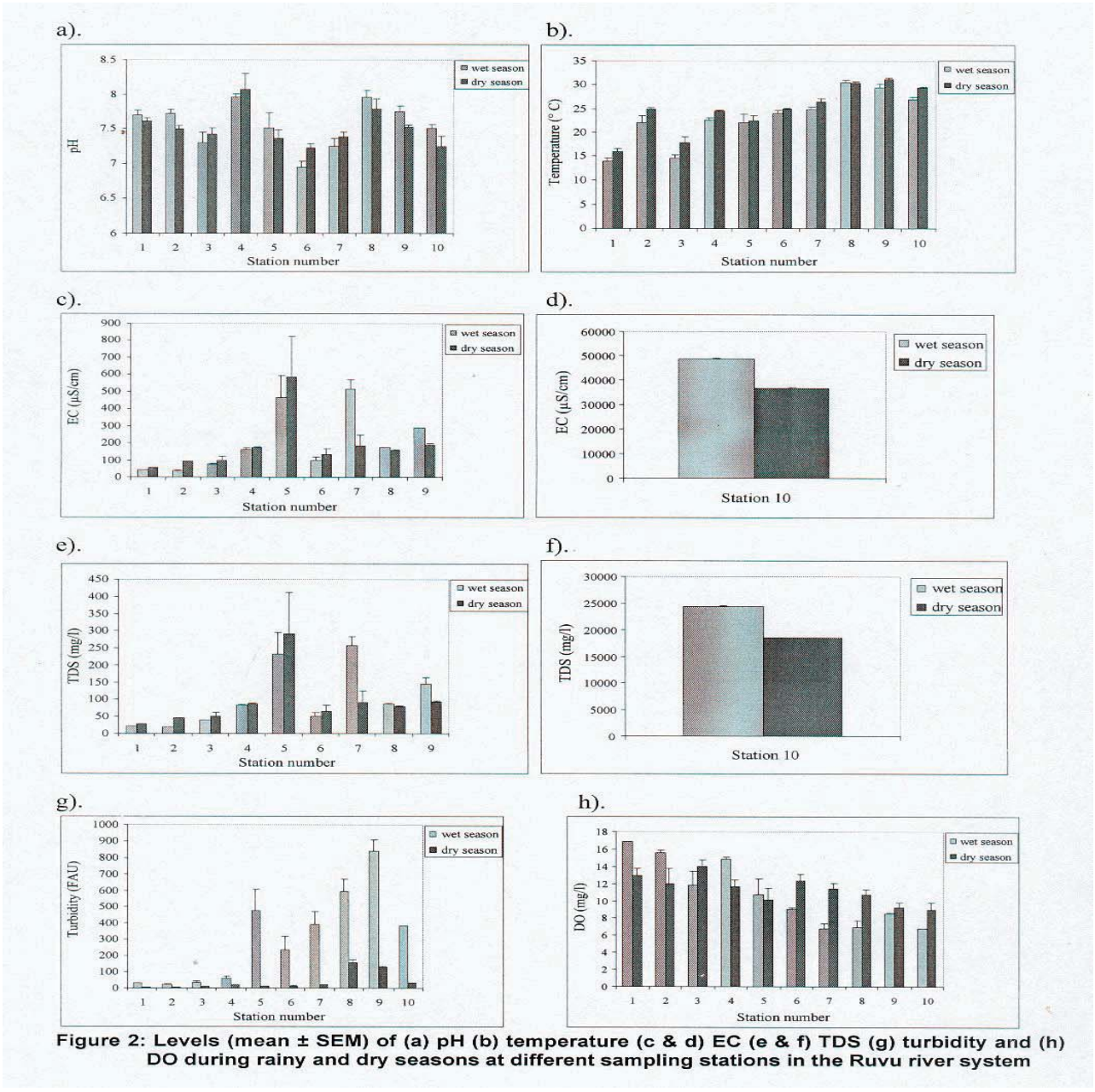


Figure 2: Levels (mean ± SEM) of (a) pH (b) temperature (c & d) EC (e & f) TDS (g) turbidity and (h) DO during rainy and dry seasons at different sampling stations in the Ruvu river system

up of the river water and **(McCutcheon *et al*., 1992; Allanson, 2001).** Stations adjacent to urban and agricultural areas also had higher amounts of EC and TDS due to higher inputs of salts from urban and agricultural areas in the catchment. At any of the stations and in both seasons the EC and TDS values were within the recommended range for river water quality for direct abstraction to supply (40 – 1500 µs/cm and 5 – 317 mg/l respectively) and WHO and TTS limits (2000 µs/cm and 1500 mg/l respectively) except for water at the river mouth (station 10) where the EC was higher than the recommended limits.

Turbidity of river water ranged from 3.0 ± 0.6 and 840 ± 69.3 FAU touching higher values during rainy season (Figure 2). High values of turbidity were recorded in agricultural areas (station 8 and 9) during dry and rainy season. The lowest value of turbidity was recorded at station 2 found in the forested areas both during dry (3.0 ± 0.58 FAU) and wet (24 ± 0.76 FAU) seasons due to little erosion of the land. Generally, turbidity increased as the river flows towards the mouth. The ANOVA test indicated that, the variation of turbidity was significantly different between different stations both in dry and rainy seasons. Turbidity values were above the range values for river water quality (0 – 3 FAU) and WHO/TTS maximum levels (25/30 FAU respectively) for drinking water quality at all stations except for station 1 and 2 adjacent to forested land where turbidity values fell within the typical concentration for river water quality during both seasons.

The dissolved oxygen varied widely ranging from 6.8 ± 0.02 to 16.8 ± 0.04 mg/l during the study period. The lowest values were recorded at the river mouth during both dry and rainy seasons. Mangrove forest is located at this area. Oxygen levels are generally low in mangrove waters **(Shunula and Ngoile, 1989; Walsh, 1967).**

Low DO concentrations were also recorded at stations 5, 6 and 7 probably due to discharge of domestic and industrial wastes (mainly raw sisal wastes) into the river. The organic wastes cause depletion of DO in receiving waters due to oxygen consumption as a result of decomposition of organic load in the water **(Nana-Amankwaah and Bosque-Hamilton, 2001).** The concentration of DO were above the WHO recommended levls of 5 mg/l at all the stations.

Levels of Nutrients in the Ruvu River System

The concentration of nutrients i.e. NO_3-N, NH_4-N, SRP and TP are illustrated in Figure 3 a - d. The concentrations of nutrients were generally higher in urban and agricultural areas due to higher input of wastes into the river system. The highest level of NO_3-N was recorded at station 5 both during dry (0.50 ± 0.22 mg/l) and rainy (0.62 ± 0.26 mg/l) season (Figure 3a). Station 5, is adjacent to a residential area and a market place. The area has poor sanitation and generally lack waste management facilities. Run-off from village and market place end up in the Kikundi River, a tributary of the Ruvu River. Station 5 also has higher levels of NH_4-N (up to 16.244 ± 5 mg/l during rainy season) (Figure 3b). Areas used for agricultural purposes (stations 8 and 9) also had higher concentrations of NO_3-N probably due to application of fertilizers in farms which eventually end up in the river system due to runoff. The levels of NO_3-N conform to the WHO (45 mg/l) and TTS (100 mg/l) recommended values for drinking water at any the station. Stations 8 and 9 had high levels of NH_4-N levels (up to 2.6 ± 0.6 and 1.3 ± 0.7 mg/l respectively) due to increased fertilizer application in farms which are scattered around these stations.

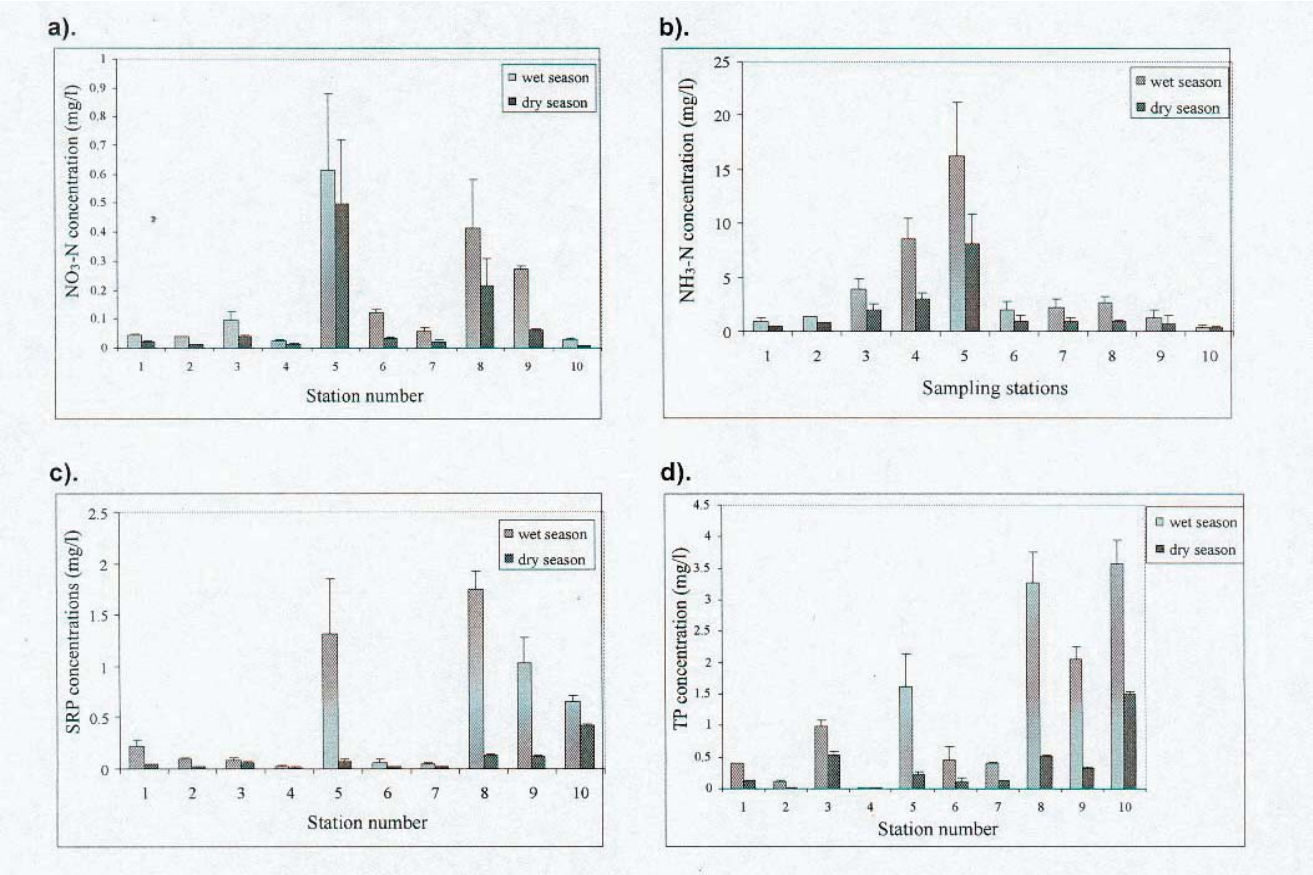


Figure 3: Mean (± SEM) concentrations (mg/l) of (a) NO_3-N (b) NH_4-N (c) SRP and (d) TP in river water at different sampling stations.

Lower concentrations of NO_3-N and NH_4-N at the river mouth may probably be due to dilution, sedimentation of organic loads and uptake by mangroves. The concentrations of NH_4-N were within the range and typical concentrations for water quality in rivers in both seasons except for locations of the river close to human settlements (station 5). NH_4-N concentrations were generally lower than the WHO recommended levels (0.05 – 0.5) mg/l at most of the stations except where land-use in the adjacent area included human settlement (station 5) and agricultural activities (stations 8 and 9).

Soluble reactive phosphorus (SRP) and total phosphorus (TP) were lower in the upstream forested areas (Figure 3c & d) due to little influences by human activities. However the levels were higher in urban, agricultural and mangrove areas. The water samples from urban areas (station 5 and 6) had relatively high concentrations of phosphorus that may be contributed by input of wastewater from diary farms and diffuse sources such as washing in the river. A study conducted by **Sundblad (1994)** revealed that soluble phosphorus concentrations in Bierun River were high, 0.5 – 1.0 mg/l, due to considerable input from sewage discharge in urban areas. High levels of SRP and TP were found at stations 8 and 9 especially during wet season. These high levels may be attributed to the application of phosphorus fertilizers in the adjacent rice farms that eventually end up in the river through runoff. The concentration of SRP and TP decreased from station 8 downstream to the river mouth due to dilution along the river flow.

During both seasons, the concentration of SRP at all the stations lied within the typical and range concentrations for river water quality except for station 4 (Mindu dam) which had SRP concentration below the typical and range concentrations for river water in both seasons. The TP concentrations were far above the WHO acceptable standards at any of the stations along the Ruvu river system except for stations 2 and 4 (located within mountainous forested area and Mindu dam) during rainy season and 1, 2, 4, and 7 (mainly within forested, industrial and dam areas) during dry season.

Conclusions and Recommendations

The present study shows that, segregates of the river water in forested areas had lower levels of nutrients compared to areas close to human activities. The most affected areas are those close to human settlements. Agricultural areas also contribute to higher levels of nutrients concentrations in the Ruvu river system. The contribution of industries to river water pollution is not significant due to low number of industries along the river. Industries are only found in Morogoro town.

It is recommended that, water pollution prevention strategies should be implemented in heavily populated and unsanitary sections of the river system. The strategies could include land-use planning, capacity building for water resources management and enforcement on water control. Treated potable water should be provided for people in these areas to save them from the danger from mismanaged catchment areas.

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