

## ORIGINAL RESEARCH ARTICLE

## Assessment of Surface Water Physicochemical Variables and Macrophytes Diversity in Sokoto and Rima Rivers, Nigeria

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### ABSTRACT

The Sokoto and Rima Rivers are vital water bodies in Nigeria, supporting local ecosystems and communities. This study aimed to investigate various physical and chemical parameters of the water, as well as the diversity of macrophytes present in the Sokoto and Rima Rivers. Standard methods of determining physicochemical parameters and surveys of macrophytes were adopted. Results obtained revealed that temperature and depth were found to be the most influential factors on macrophytes distribution. In Sokoto River, average temperature ranged from 27.00°C to 27.30°C, and average depth from 285 to 295 meters at both stations A and B. In Rima River, average temperature varied from 25.85°C to 26.50°C, and average depth ranged from 730 to 735 meters at both stations A and B. Emergent species were dominant among the 20 identified macrophyte species, with 18 species, while free-floating and submerged species each represented one species. This research contributes to understanding the ecological health of the Sokoto and Rima Rivers, guiding conservation efforts, informing water resource management, and identifying potential impacts on human activities in these areas. Ultimately, the goal is to support sustainable development and protect these valuable natural resources for the long term.

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### KEYWORDS

Diversity, Macrophytes, Physicochemical Parameters, Rima, Sokoto

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### INTRODUCTION

Aquatic macrophytes have been identified as submerged or floating plants that grow in or near water (Adigun, 2005; Gijo and Alagoa, 2022; Munyai and Dalu, 2023). These macrophytes could comprise a diverse group of organisms including angiosperms, ferns, mosses and liverworts (Lacoul and Freedman, 2006). Aquatic macrophytes are normally found growing in association with both standing and flowing water whose level is at or above the surface of the soil (Keddy, 2010). They can also be defined as plants that have adapted to living in aquatic environments, both in fresh waters or in salt waters (Sculthorpe, 1985). The most common adaptation is aerenchyma, but floating leaves are finely dissected leaves which are also common (Hutchinson, 1975). They are very important parts of the food chain where they serve as food for fish and maintain balance in nutrient cycle of aquatic bodies (Thomaz *et al.*, 2008). The spread and occurrence of these macrophytes on some Nigerian waterways were earlier reported by Kio and Ola (1987) where they generated high national interests. A lot of environmental factors other than

nutrient concentrations could explain some of the observed variations in macrophyte species distribution and composition (Wetzel, 2001). However, these plants are highly productive and play important structuring roles in aquatic environments (Jeppesen *et al.*, 2000). Therefore, ecological studies carried out in aquatic environments are not complete if aquatic macrophytes' communities are not as essential components for ecosystem functioning and aquatic biodiversity conservation, as well as the physical parameters that influence or affect their growth.

Furthermore, aquatic macrophytes have the physiological potential to remediate heavy metals from polluted water bodies thereby regarded as the corner stone of aquatic environments (Chukwuka and Uka, 2007). Changes in physicochemical parameters can affect the growth and distribution of submerged macrophytes and other macrophytes (Strand and Weisner, 2001), and the structure of communities (Wantzen *et al.*, 2008). For example, the reported effects of water depth on the growth of the submerged species *Myriophyllum spicatum*

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(Strand and Weisner, 2001; Zhu *et al.*, 2012; Zhu *et al.*, 2015), *Potamogeton pectinatus* (Bucak *et al.*, 2012), *Potamogeton maackianus* and *Potamogeton malaianus* (Zhu *et al.*, 2012; Zhu *et al.*, 2015), and on the community composition of submerged macrophytes (Dong *et al.*, 2014) demonstrate that water depth plays a vital role in aquatic ecosystems. Light, which is one of the most important variables for photosynthesis during the growth of submerged plants, can be strongly influenced by the characteristics of the water column in an aquatic ecosystem (Bornette and Puijalon, 2011). Water transparency can be affected by coloured dissolved organic matter (CDOM) and the concentrations of both suspended solids and plankton in water (Kirk, 1994). As is true of all organisms, the distribution and abundance of aquatic plants are influenced by variations in environmental factors. This fact can be used to identify species and communities that are reliable indicators of important changes in their ecosystem, including ones that may serve as gauges of ecological integrity (Fennessy *et al.*, 1998; Mack *et al.*, 2000; Aznar *et al.*, 2002). The high density of water makes aquatic organisms more buoyant, so aquatic plants invest fewer resources in supporting tissues, than terrestrial plants (Oyediji and Abowei, 2012). Because macrophytes are in water, water loss is not a problem.

Thus, submerged aquatic macrophytes lack the structural and productive structures produced by terrestrial plants (Oyediji and Abowei, 2012). Emergent aquatic macrophytes are defined as plants that are rooted in shallow water with vegetative parts emerging above the water surface (Westlake *et al.*, 1998). Many species of aquatic macrophytes are invasive species and as such make particularly good weeds because they reproduce vegetatively from fragments (Oyediji and Abowei, 2012). Macrophytes constitute the primary producers of aquatic ecosystems. They convert the incident radiating energy of the sun to chemical energy in the presence of nutrients like iron, nitrogen, manganese, molybdenum, phosphorous and zinc. In the aquatic environment, phytoplanktons are the foundation of the food web, providing a nutritional base for zooplankton and subsequently for other invertebrate shellfish and finfish (Emmanuel and Onyema, 2007). The productivity of any water body is determined by the amount of planktons it contains as they are the major primary and secondary producers (Davies *et al.*, 2009).

Water level fluctuations can affect the growth, distribution, and the survival of submerged macrophytes (Sousa *et al.*, 2010; Zhu *et al.*, 2012) both directly and indirectly (Raulings *et al.*, 2010; Zhang Liu *et al.*, 2014). Hyacinth is not new in the ecological history of man (Chukwuka and Uka, 2007). Its extensive growth and multiplication have created problems associated with navigation, irrigation and fishing, among others (Chukwuka and Uka, 2007).

The floating mat of vegetation covers available sunlight from the water surface. The direct effect of this is the low production of natural fish food (phytoplankton and

zooplankton species) thus resulting in overall low fish productivity (Chukwuka and Uka, 2007). The bloom of vegetation also results in massive fish kills due to high oxygen demand and competition for nutrients available. These invasive aquatic weeds affect both biodiversity and water quality (Chukwuka and Uka, 2007). The effect of the presence of aquatic weeds in water bodies on water loss through evapotranspiration is a subject of controversy but most experimental data indicate an increase in water loss from surfaces covered by aquatic weeds (Obot and Mbagwu, 1988).

Aquatic macrophytes form an important part of the biota of the littoral zones of lakes and reservoirs and are considered one of the most productive communities on Earth (Ondiviela *et al.*, 2014). Many ecological functions have been assigned to them (Jeppesen *et al.*, 1998; Kotta *et al.*, 2014). These mainly include: their role as primary producers in trophic food chains; the source of habitats and refuges for algae, periphyton, zooplankton, invertebrate and vertebrate species; their role in nutrient cycling in aquatic systems; their influence on microclimate and hydrochemical processes in littoral zones; and their influence on the sediment dynamics of freshwater ecosystems. Besides these, many macrophyte species have been regarded as sites of carbon sequestration and they potentially support carbon dioxide (CO<sub>2</sub>) mitigation (Marba *et al.*, 2015). Generally, a certain level of water depth can provide the opportunity for plant growth (Gafny and Gasith, 1999), which is clearly conducive to the maintenance of stable macrophyte communities (Geest *et al.*, 2005). However, extremely low or high water levels that are beyond the suitable water depth range of certain species are both unfavourable for the growth of this aquatic vegetation (Coops *et al.*, 2003; O'Farrell *et al.*, 2011; Zhu *et al.*, 2012). Therefore, there is a need for adequate assessment of the effects of some physico-chemical parameters on the diversity of macrophytes. The present study aims to investigate the status of some physico-chemical parameters and their influences on the distribution of macrophytes in seasonal wetland ecosystem in the River Rima and River Sokoto of Sokoto State, Nigeria.

## MATERIALS AND METHODS

### Description of the Study Area

River Rima is situated in the North-Western region of Sokoto State, Nigeria. The area is located between longitude 4°E and 6°54'E and latitude 12°N and 13°54'N (Mamman, 2000). Rainy season is usually between May/June to early October/November (Umar and Ipinjolu, 2001). The Rima River is a river in the northern part of Nigeria. At its northernmost point, it is joined by the Goulbi de Maradi River. It runs southwest and joins the Sokoto River near Sokoto, then continues south to the Niger River. The upper Rima is a seasonal river and flows only during the rainy season (Umar and Ipinjolu, 2001). The Zauro polder project, a major irrigation scheme, has been planned for many years. It would irrigate 10,572

hectares (26,120 acres) of farmland in the Rima floodplain between Argungu and Birnin Kebbi (Tosin, 2009).

River Sokoto (formerly known as Gulbin Kebbi) is a river in North-West Nigeria and a tributary of the River Niger. The river's source is near Funtua in the south of Katsina State, some 275 kilometers (171 mi) in a straight line from Sokoto. It flows north-west passing Gusau in Zamfara State, where the Gusau Dam forms a reservoir that supplies water (Akané and Jurgen, 2005). Further downstream, the river enters Sokoto State where it passes by Sokoto and is joined by the River Rima, then turns south and flows through Birnin Kebbi in Kebbi State. About 120 kilometers (75 mi) south of Birnin Kebbi, it reaches its confluence with the Niger River. The plains around the rivers are widely cultivated and the water is used as a source of irrigation. The rivers are also used as a

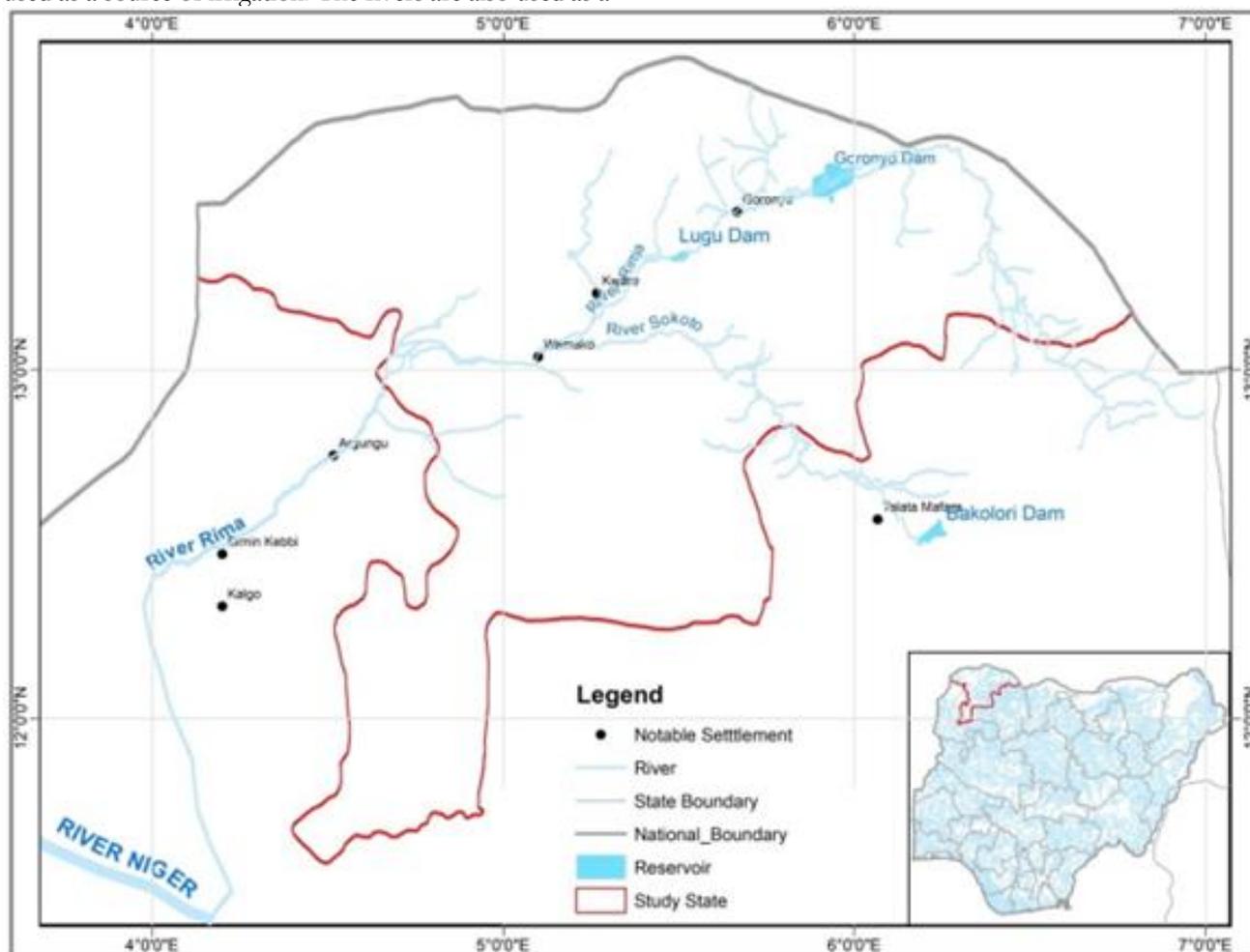
source of transportation. Bakalori Dam, about 100 kilometers (62 mi) upstream from Sokoto is a major reservoir on the Sokoto River. It has had a significant impact on downstream floodplain cultivation (Akané and Jurgen, 2005).

**Sampling Points**

In River Rima and River Sokoto, there are two sampling points A and B which were studied based on the differences in their partition by bridge overhead.

Sampling Point A: The right hand side of the rivers as partitioned by the bridge.

Sampling Point B: The left hand side of the rivers as partitioned by the bridge.



**Plate 1: A Map Showing River Rima and River Sokoto**

**Sample Size Determination**

The sample size requirements were estimated using resampling techniques as described by Quist *et al.* (2007). The presence and relative abundance of the macrophytes were estimated along each transect. The relative abundance of the macrophytes was recorded as the percentage cover of the macrophyte per species above the substrate when viewed from above (Environmental

Protection (Water) Policy EPP 2009 – Monitoring and Sampling Manual, 2018).

**Macrophytes Sampling Techniques**

Two (2) methods were adopted for the macrophytes sampling in this study: point sampling method and transect sampling method (Madsen, 1999; Kolada *et al.*, 2009). The point sampling method was employed in

shallow regions of the Rivers where the vegetation cover was very high. The belt transect method was employed in this study according to the procedure described by Environmental Protection (Water) Policy EPP 2009 – Monitoring and Sampling Manual (2018). Belt transects were randomly selected (without replacement) from both Rivers.

### Location and Frequency of Macrophytes Sampling

The macrophytes community was collected from River Rima and River Sokoto for the period of 2 weeks in the month of August at each sampling point i.e. sampling points A and B in both Rivers Sokoto and Rima as partitioned by the bridge.

### Sample Collection and Determination of Physico-Chemical Parameters

Water samples were collected from the rivers in 60 cl capacity sample bottles in the hours of 08:00 a.m. to 09:00 a.m. and were taken to laboratory for physico-chemical analysis. The samples (for both physico-chemical and biological analyses) were collected for a period of two weeks in the month of August. The physico-chemical parameters measured at the field were Temperature (Adeyemo *et al.*, 2008), Turbidity (Cole, 1994) and Depth, as well as Dissolved Oxygen (Huang *et al.*, 2017), Nitrate (NO<sub>3</sub>) (SMEWW, 1999), Phosphate (PO<sub>4</sub>) (Niemi *et al.*, 1990), pH and Biochemical Oxygen Demand (BOD) (Huang *et al.*, 2017), while biological analysis which includes identification of macrophytes was conducted at both field and laboratory.

### Macrophytes Counting and Identification

The macrophytes community was collected from River Rima and River Sokoto for the period of 2 weeks at each sampling point i.e. sampling points A and B in both Rivers Sokoto and Rima as partitioned by the bridge. Macrophytes species were identified on the field while unidentified species were collected in a leather bag and transported to the laboratory for identification. Based on their morphological features, the collected samples were sorted and identified by comparing with identification charts (African glossary), plates and preserved macrophytes in the Biological Science Herbarium, Usmanu Danfodiyo University, Sokoto, Nigeria.

### Statistical Analysis

Means and standard deviation were calculated for the physicochemical parameters for all the sampling points. Analysis of variance (ANOVA) was employed to determine the variability between means of the measured physicochemical parameters. Tukey's Honestly Significant

Difference (HSD) Test was also employed to separate means where significant differences exist ( $P < 0.05$ ). Version 20 of Statistical Package for the Social Sciences (SPSS) software was used to aid the statistical analysis. Tables were used to depict the average physicochemical parameters and list of macrophyte species for the two Rivers. Pie chart was used to show the percentage of occurrence of macrophytes in both Rivers.

## RESULTS

### Surface Water Physicochemical Variables

The results of the analysis of the surface water physicochemical variables of the Sokoto and Rima Rivers are presented in Table 1 and 2. In Sokoto River, average temperature ranged from 27.00°C to 27.30°C, and average depth from 285 to 295 meters at both stations A and B. In Rima River, average temperature varied from 25.85°C to 26.50°C, and average depth ranged from 730 to 735 meters at both stations A and B. The results obtained in this study revealed that temperature and depth were found to be the most influential factors on macrophytes distribution.

Table 1 and 2 shows the values for weekly variation in physicochemical parameters in relation to sampling points of River Sokoto and River Rima from week one to the second week. There was fluctuation within the weeks between the sites in average Temperature, Depth, Turbidity, Nitrate, pH, DO, BOD<sub>5</sub> and Phosphate from 27.00 - 27.30 °C, 285 - 295 cm, 26.50 - 30.00 NTU, 1.10 - 1.40 mg/L, 6.85 - 6.88, 4.80 - 5.70 mg/L, 22.70 - 25.05 mg/L and 0.238 - 0.243 mg/L in River Sokoto and from 25.85 - 26.50 °C, 730 - 735 cm, 31.50 - 32.00 NTU, 1.20 - 1.55 mg/L, 6.81 - 6.82, 4.35 - 5.50 mg/L, 23.50 - 25.35 mg/L and 0.214 - 0.215 mg/L in River Rima, respectively.

### Diversity of Macrophytes

The diversity of macrophytes in both River Sokoto and River Rima as shown in Table 3, emergent life forms occurred the most with 18 emergent species while free floating and submerged species are identified as one each.

Figure 1 illustrates the percentage of life forms of macrophytes where emergent species occurred the most with 90% occurrence while free floating and submerged species have 5% occurrence each.

Figure 2 and 3 depicts the density of macrophytes occurrence in both stations A and B of River Sokoto. Station A was seen to have higher species richness of 14 compared to Station B with 11 species richness. *Eichhornia crassipes*, *Cymbopogon schoenanthus*, *Mimosa pigra*, *Rottboellia cochinchinensis*, *Ricinus communis*, *Amaranthus viridis*, *Corchorus olitorius*, *Commelina* spp., *Pennisetum purpureum*, *Paspalum*

*scrobiculatum* and *Digitaria debilis* all occurred the most throughout the study weeks at 8% while *Alcea rosea*, *Triumfetta cordifolia* and *Dicoma tomentosa* all occurred the least throughout the weeks of the study at 4% in station A of River Sokoto. *Eichhornia crassipes*, *Cymbopogon schoenanthus*, *Mimosa pigra*, *Rottboellia cochinchinensis*, *Pennisetum purpureum*, *Paspalum scrobiculatum*, *Digitaria debilis* and *Zea mays* occurred the most throughout the study weeks in station B of River Sokoto at 10.5% of occurrence while *Cynodon dactylon*, *Commelina* spp. and *Corchorus olitorius* occurred the least throughout the weeks of the study with 5.3% of occurrence in station B of River Sokoto.

Figure 4 and 5 depicts the density of macrophytes occurrence in both stations A and B of River Rima. Station

A was seen to have higher species richness of 17 compared to Station B with 11 species richness. *Oryza sativa*, *Eichhornia crassipes*, *Cymbopogon schoenanthus*, *Rottboellia cochinchinensis*, *Cleome viscosa*, *Mimosa pigra*, *Alcea rosea*, *Amaranthus viridis*, *Triumfetta cordifolia*, *Corchorus olitorius*, *Commelina* spp., *Pennisetum purpureum*, *Paspalum scrobiculatum*, *Digitaria debilis*, *Pennisetum glaucum*, *Spinacia oleracea* and *Cynodon dactylon* all have 5.88% of occurrence in station A while *Oryza sativa*, *Cymbopogon schoenanthus*, *Cleome viscosa*, *Alcea rosea*, *Triumfetta cordifolia*, *Corchorus olitorius*, *Paspalum scrobiculatum*, *Pennisetum glaucum*, *Spinacia oleracea* and *Cynodon dactylon* all have 9.52% of occurrence and *Eichhornia crassipes* has 4.76% of occurrence in station B of River Rima.

**Table 1:** Weekly Variation of Physicochemical Parameters of River Sokoto

Parameters	Site A		Site B	
	Week 1	Week 2	Week 1	Week 2
Temperature (°C)	26.00	27.00	28.00	27.60
Depth (cm)	300	300	290	270
Turbidity (NTU)	26.00	30.00	27.00	30.00
Nitrate (mg/L)	1.00	1.40	1.20	1.40
pH	6.83	6.85	6.87	6.90
DO (mg/L)	4.40	5.10	5.20	6.30
BOD <sub>5</sub> (mg/L)	23.60	20.20	26.50	25.20
Phosphate (mg/L)	0.229	0.245	0.257	0.231

**Key:** °C = Degree Celsius; cm = Centimeter; NTU = Nephelometric Turbidity Scale; mg/L = Milligrams per Liter

**Table 2:** Weekly Variation of Physicochemical Parameters of River Rima

Parameters	Site A		Site B	
	Week 1	Week 2	Week 1	Week 2
Temperature (°C)	25.40	26.00	26.30	27.00
Depth (cm)	750	750	720	710
Turbidity (NTU)	29.00	32.00	34.00	32.00
Nitrate (mg/L)	1.00	1.30	1.40	1.80
pH	6.80	6.79	6.82	6.85
DO (mg/L)	5.00	5.90	3.70	5.10
BOD <sub>5</sub> (mg/L)	21.60	24.20	25.40	26.50
Phosphate (mg/L)	0.230	0.215	0.199	0.213

**Table 3:** List of Macrophytes Found in Both River Sokoto and River Rima during the Study Period

S/N	Scientific Name	Common Name	Local Name	Family	Life Form (Group)
1	<i>Oryza sativa</i>	Rice	Shinkaafa	Poaceae	Emergent
2	<i>Eichhornia crassipes</i>	Water Hyacinth	Kainuwa	Pontederiaceae	Free Floating Leaves
3	<i>Cymbopogon schoenanthus</i>	Lemon Grass	Dangaye	Poaceae	Emergent
4	<i>Cleome viscosa</i>	Asian Spiderflower	Yarunguwi	Cleomaceae	Emergent
5	<i>Rottboellia cochinchinensis</i>	Itchgrass	Daawadawa	Poaceae	Emergent
6	<i>Mimosa pigra</i>	Giant Sensitive Tree	Gumbii	Fabaceae	Emergent
7	<i>Commelina</i> spp.	Dayflowers	Balaasayaa	Commelinaceae	Emergent
8	<i>Pennisetum glaucum</i>	Pearl Millet or Bulrush Millet	Hatsi/Dauroo	Poaceae	Emergent
9	<i>Alcea rosea</i>	Hollyhock	Garmagami	Malvaceae	Emergent
10	<i>Amaranthus viridis</i>	Pig Weed	Halifa/Rukubu	Amaranthaceae	Emergent
11	<i>Spinacia oleracea</i>	Spinach	Alayyahuu	Amaranthaceae	Emergent
12	<i>Digitaria debilis</i>	Finger-Grass	Harkiyaa	Poaceae	Emergent
13	<i>Ricinus communis</i>	Castor Bean or Castor Oil Plant	Zuruman	Euphorbiaceae	Emergent
14	<i>Corchorus olitorius</i>	Nalta Jute, Jute Mallow or Bush Okra	Laalo	Malvaceae	Emergent
15	<i>Dicoma tomentosa</i>	Woolly Dicoma	Daudawa	Asteraceae	Emergent
16	<i>Zea mays</i>	Maize	Masaraa/Bagwariiyaa	Poaceae	Emergent
17	<i>Triumfetta cordifolia</i>	Burbark	Dangeree	Malvaceae	Emergent
18	<i>Paspalum scrobiculatum</i>	Rice Grass, Kodo Millet or Koda Millet	Tumbin Jaakki	Poaceae	Emergent
19	<i>Pennisetum purpureum</i>	Elephant Grass, Napier Grass or Uganda Grass	Ciyaawar Giwaa	Poaceae	Emergent
20	<i>Cynodon dactylon</i>	Bermuda Grass, Dog's Tooth Grass, Dubo or Bahama Grass	Tsarkiyar Damoo	Poaceae	Submerged

From the table (Table 3) above, emergent species of macrophytes occurred the most (18) out of 20 species,

while submerged and free-floating only have one species each.

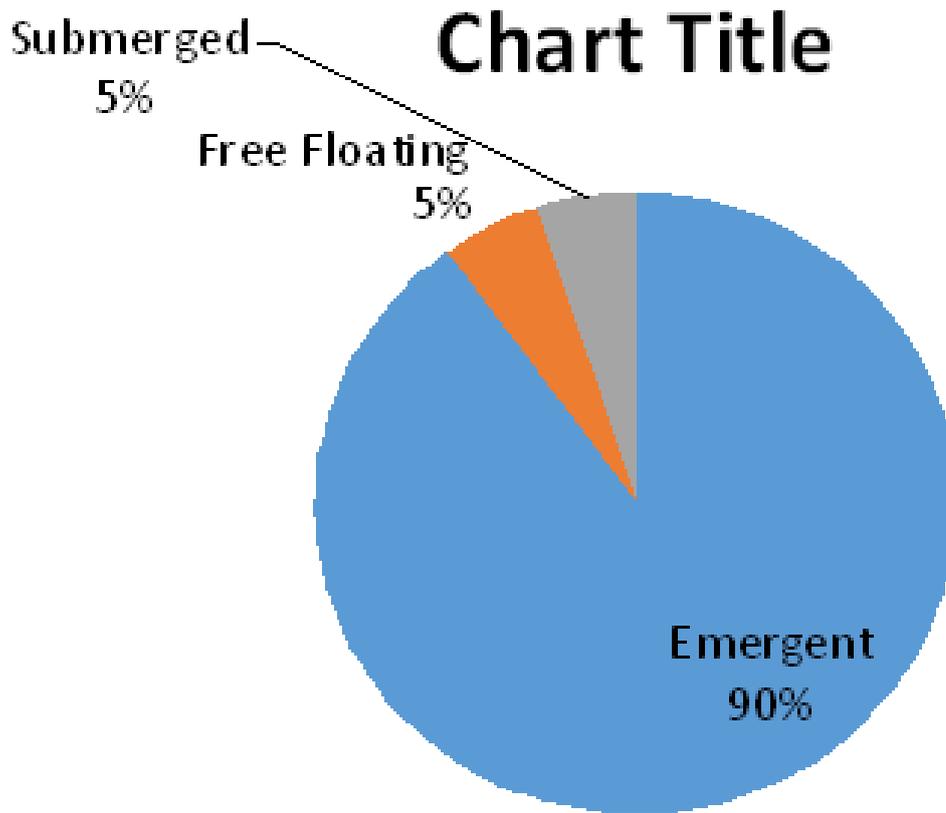


Figure 1: Pie Chart Showing the Percentage of Macrophytes Live Forms during the Study Period

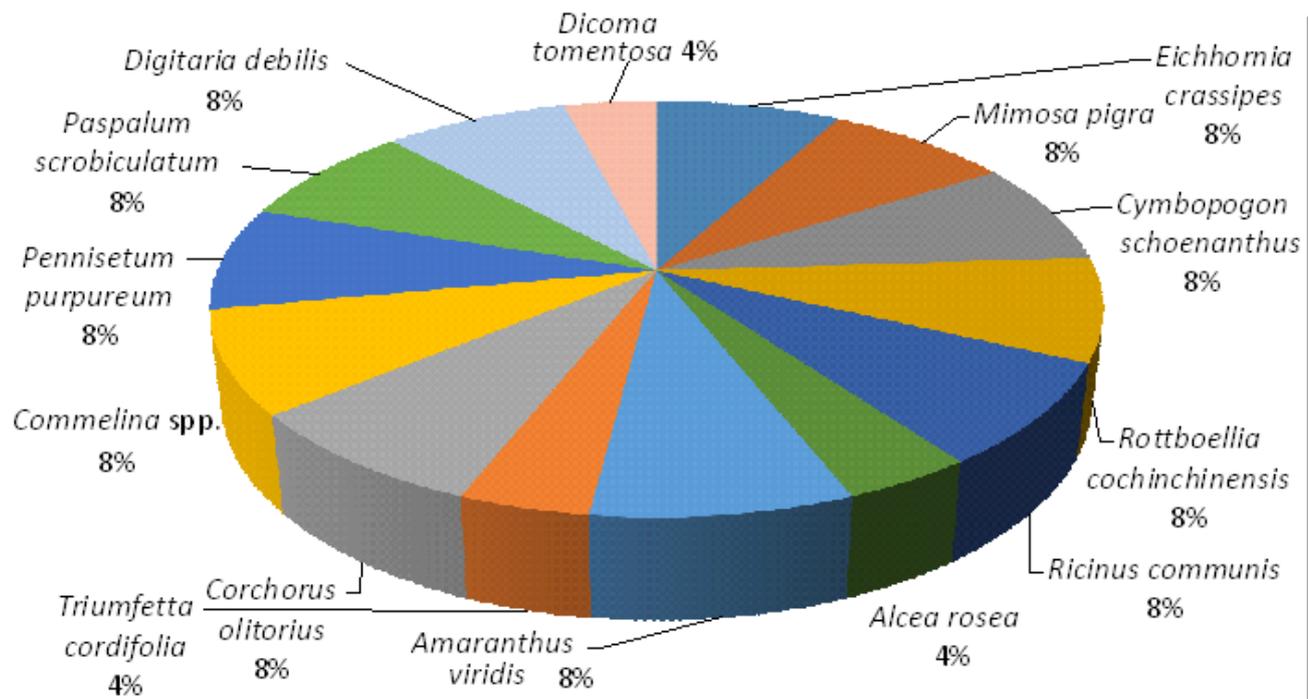
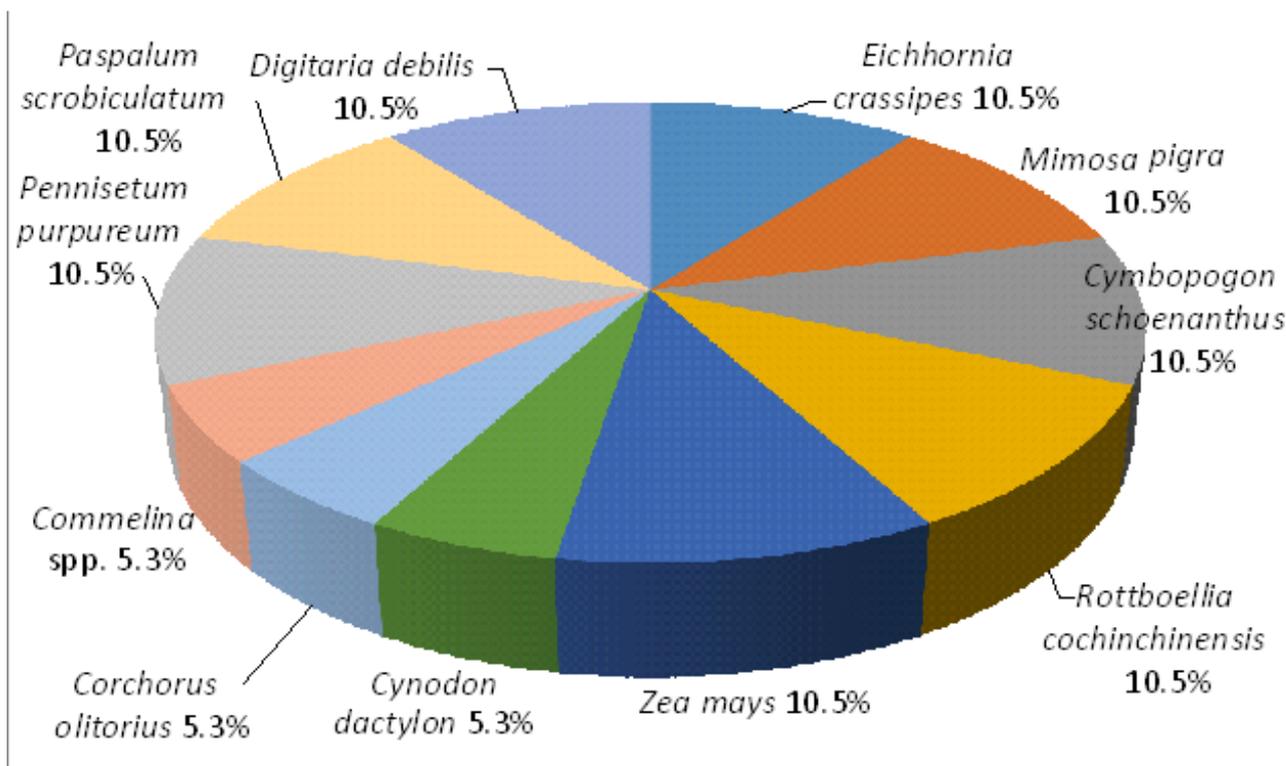
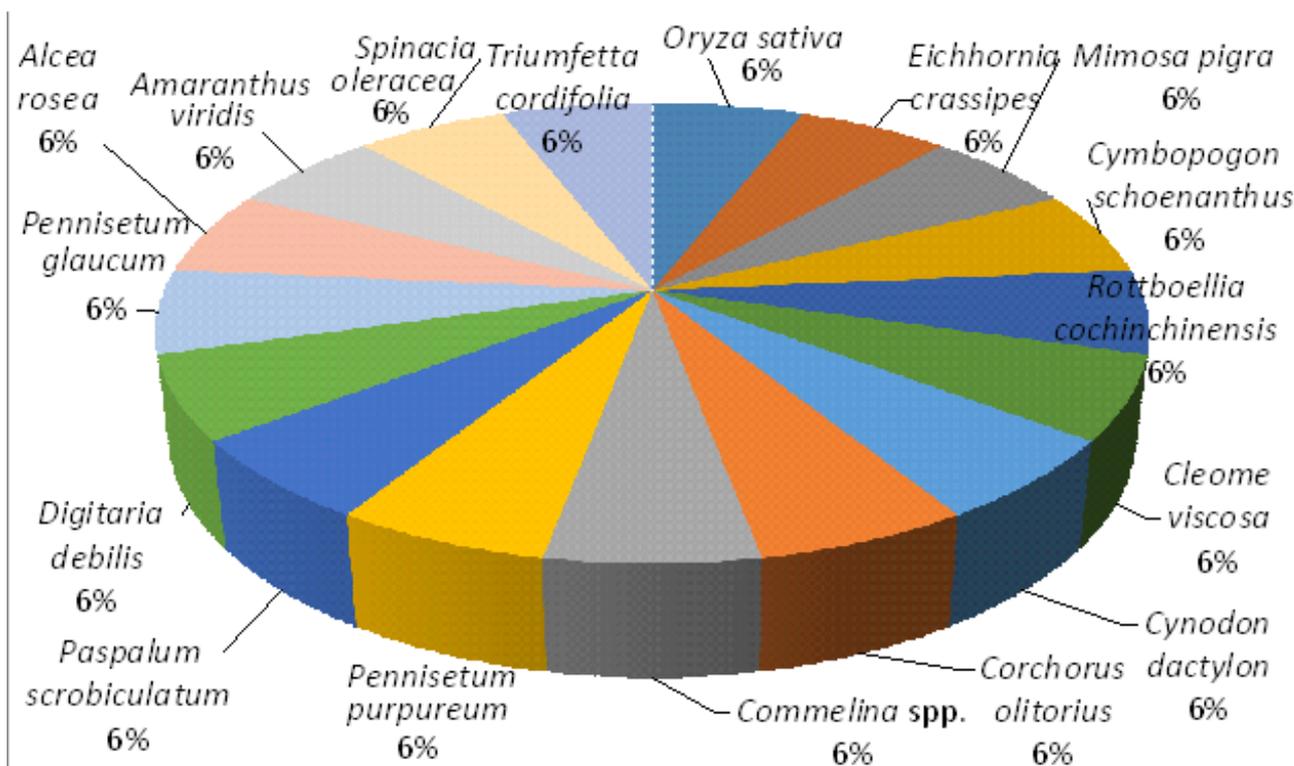


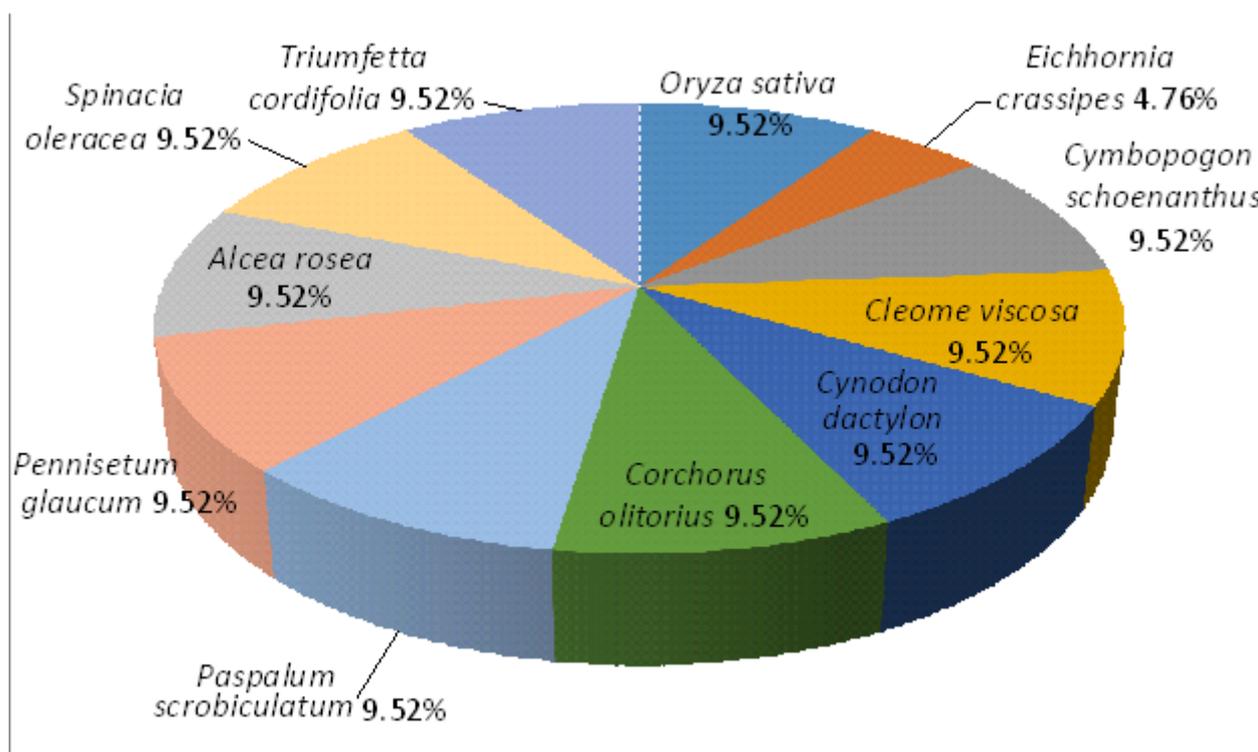
Figure 2: Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Sokoto Partition A during the Study Period



**Figure 3:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Sokoto Partition B during the Study Period



**Figure 4:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Rima Partition A during the Study Period



**Figure 5:** Pie Chart Showing the Percentage of Occurrence of Macrophytes in River Rima Partition B during the Study Period

## DISCUSSION

There are six major ecological factors that are important to the life of aquatic organisms (macrophytes). They include water, temperature, pH, light, oxygen and salinity (Sleigh, 1991). Water quality is of paramount importance for an aquatic ecosystem as it maintains all the ecological processes which support biodiversity. The growth and productivity of the aquatic organisms depend on the physicochemical characteristics of the water body (Verma *et al.*, 2012).

The temperature ranges of River Rima and River Sokoto are within the range of 16 - 30 °C as reported by Chapman (1992) (Tables 1 and 2). This indicates fluctuation in water temperature within the study period (from week one to week two) in the two Rivers. Adeniyi and Ovie (1982) reported that temperature range for the survival and optimum growth of aquatic organisms (macrophytes) is between 22 °C and 31 °C which corresponds to the range of temperature reported in all the sampling points of both River Sokoto and River Rima. Also, the observed result of water temperature in the Rivers was within FEPA (1991) and WHO (1999) standard maximum limits. But, works by Inuwa (2007) and Mustapha (2008a & b) agreed with the result obtained in this study, that shows fluctuation in the water temperature within the Rivers (Tables 1 and 2).

The importance of water pH to the survival of aquatic macrophytes is great. In river, pH fluctuates based on the metabolic activities as well as the amount of decomposition of organic matter by the microbes. The pH obtained in the current study falls within the FEPA (1991),

WHO (1999) and Ragnar (2004) standard range for water quality (Tables 1 and 2). Therefore, the results of the pH obtained in this study are within the limits to support aquatic life for favourable and successful thriving of fish, shrimp and other aquatic organisms as suggested by Deekae *et al.* (2010). It was also in congruence with the findings of Inuwa (2007) and Mustapha (2008a & b). However, it somehow disagreed with the findings of Gijo and Alagoa (2022) who reported a pH range of 7.86 to 8.03 from the three (3) sampled stations.

The DO concentration observed in this study fluctuated throughout the period of sampling in the two Rivers, in which low DO was recorded in the first week in River Sokoto and first week in River Rima which falls below the normal range stated by FEPA (1991). This result agrees with the reports of Inuwa (2007) and Ibrahim *et al.* (2009), which showed that river system that contain high level of inorganic and organic pollutants tend to have low DO (Tables 1 and 2).

BOD<sub>5</sub> in this study disagrees with the FEPA (1991) and findings of Ragnar (2004), where the lowest BOD<sub>5</sub> was recorded in week two in River Sokoto and second week in River Rima (Tables 1 and 2).

According to Gijo and Alagoa (2022), nitrate is an indispensable factor for water quality assessment in surface water whose presence depend majorly on the activities of nitrifying bacteria, stream currents and catchment characteristics in lotic water systems. The highest nitrate level was in site B of River Rima and site B of River Sokoto (Tables 1 and 2). This result is in

agreement with the finding of Gijo and Alagoa (2022) who reported a nitrate concentration that ranged from 0.92 mg/L to 1.62 mg/L from the sampled locations. The high nitrate concentrations could be attributed majorly to anthropogenic activities taking place in the water systems (Gijo and Alagoa, 2022). These anthropogenic activities include water runoff from agricultural farms, discharge of municipal and household refuse and sewage from public places such as markets and schools, and other effluents that contain nitrogen. However, the nitrate concentration result reported in this study is below the permissible limit of 50mg/L in comparison with international and national standards. Although, high nitrate values always signify eutrophication which usually result in the depletion of dissolved oxygen in the receiving water systems (Gijo and Alagoa, 2022).

According to Gijo and Alagoa (2022), phosphate regulates the production of phytoplanktons in the presence of nitrogen which therefore serves as the first limiting nutrient for freshwater plants. In natural waters, it is usually available in the form of phosphate which generally occurs in low and moderate concentrations. Increasing the  $PO_4^{3-}$  pollution in water system depends largely on certain activities such as agriculture runoff containing phosphate fertilizers (NPK) and the waste water containing detergents, et cetera. In this study, mean of phosphate level of the Rivers is relatively similar weekly but there was variation in phosphate level at all sampling points in River Sokoto and River Rima (Tables 1 and 2). Therefore, low phosphate values were observed in this study which are inconsistent with the result obtained by Gijo and Alagoa (2022) who reported higher phosphate level which varied from 2.19 mg/L to 10.68 mg/L. However, in comparison with the standard phosphate values, the result obtained in this study is slightly above the permissible limits of 0.1 mg/L indicating that the Rivers are partially polluted by phosphate compounds.

The result of turbidity showed disparate fluctuations of concentrations with respect to location (site) in which site B had the highest turbidity in River Sokoto which is within maximum limits stated by Pandey (1997) (Tables 1 and 2). While the highest turbidity recorded for River Rima was in site B (Tables 1 and 2). The result recorded for turbidity in the two Rivers during the course of this study is also in agreement with that reported by Mustapha (2008a & b) and Wakawa (2008) while studying Challawa River.

In the present study, higher depth value at Site A of River Sokoto and Site A of River Rima may be linked with the abundance of rainfall within the period of study and also because they are the respective inlets of each of the Rivers (Wakawa, 2008) (Tables 1 and 2).

Macrophytes perform many ecosystem functions in aquatic ecosystems and provide services to human society. One of the important functions performed by macrophytes is uptake of dissolved nutrients (Nitrate and Phosphate) from water. These nutrients may be harmful to humans but in turn useful to aquatic macrophytes

(Vymazal, 2013), which may be the reason why lower nitrate and phosphate levels were recorded in all sampling sites of the two Rivers during this study (Tables 1 and 2). Aquatic macrophytes are phylogenetically well dispersed across the angiosperms, with at least 50 independent origins, although they comprise less than 2% of the angiosperm species (Pennisi, 2018) (Table 3). Due to their underwater environment, aquatic submerged macrophytes have limited access to carbon and experience reduced light levels (Pederson *et al.*, 2013). This may be the reason why the emergent species of macrophytes are dominant in distribution during this study (Table 3). Due to their aquatic surroundings and depth of water, the macrophytes are not at risk of losing water through the stomata and therefore, face no risk of dehydration (Shtein *et al.*, 2017) (Tables 1 and 2). As according to van der Valk (2006), in the classification of macrophytes, emergent species are the most abundant and highly distributed throughout the study period both in River Sokoto and River Rima sampling sites with 90% percentage of occurrence (Figure 1). Submerged macrophytes completely grow under water with roots attached to the substrate (e.g. *Cynodon dactylon*) or without any root system (Beentje *et al.*, 2001) (Table 3). Free-floating macrophytes are aquatic plants that are found suspended on water surface with their roots not attached to substrate, sediment, or bottom of the water body. They are easily blown by air and provide breeding ground for mosquitoes. Example include: water lettuce, water cabbage and water hyacinth (Bornette *et al.*, 1998) (Table 3).

According to Westlake *et al.* (1998) Amphiphytes (can live in water or land) were found during the study period but Helophytes (rooted to the bottom and leaves are above the waterline) were the most widely distributed in both River Sokoto and River Rima (Table 3). Habitat complexity provided by macrophytes tends to increase diversity and density of both fish and invertebrates (Thomaz *et al.*, 2007). Mean of temperature in River Sokoto (Table 1) shows why they have lesser macrophytes species distribution of 14 species in the highest site compared to River Rima with lesser temperature (Table 2) which have up to 17 species in site A. However, effects of temperature on macrophytes' growth and distribution depends on the species of the macrophytes (Kotta *et al.*, 2014). With respect to each sites of the respective Rivers, this study agrees with Wrona *et al.* (2006) and Riis *et al.* (2012) that temperature can increase the growth of macrophytes as respiration and photosynthesis increases, this is in favour of emergent species and thus increase by 25% (Buschmann *et al.*, 2004; Heikkinen *et al.*, 2009; Rothausler *et al.*, 2011). This may be the reason why emergent species are more distributed compared to submerged species. In a nutshell, warming will favour growth of few species. Hence, the diversity and species richness of macrophytes will decrease (Feuchtmayr *et al.*, 2010) (Table 3).

Both Rivers are turbid due to suspension of solids, silts, clays and wastes from various sources and contributories of the Rivers. This results in turbidity of the majority of

the water body with transparencies recorded in River Sokoto and River Rima, hence suppressing growth of macrophytes by limiting light (Riis *et al.*, 2012). In turbid situations, only floating plants and emergent communities dominate (Table 3). pH of the two Rivers from this study is slightly neutral throughout the weeks and sampling sites during the study period.

## CONCLUSION

This research contributes to understanding the ecological health of the Sokoto and Rima Rivers, guiding conservation efforts, informing water resource management, and identifying potential impacts on human activities in these areas. Ultimately, the goal is to support sustainable development and protect these valuable natural resources for the long term.

## RECOMMENDATIONS

Based on the results obtained in this study, the following recommendations were drawn:

- i. Efficient management system is recommended to reduce the rate of water pollution caused by human activities on water bodies of the Rivers.
- ii. Sensitization and public education of local people as well as general public on the effect of anthropogenic activities on the water bodies as well as the resultant effect on ecosystem of the Rivers should be encouraged.
- iii. Further studies of the two Rivers should be conducted for a longer period in order to obtain more detailed information about the activities taking place around the water and factors that lead to fluctuations of physicochemical parameters of the Rivers.
- iv. It is recommended that private agencies contribute to management system of the Rivers or further form synergy with Government agencies to reduce the pollution of the Rivers and reduce anthropogenic activities taking place.
- v. Constant monitoring is recommended to avoid depositions of toxic solids from the sources.

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