

ASSESSMENT OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS
OF IMABORO RIVER AT ANKPA, KOGI STATE,
NIGERIA

BY

MELIGA SALIFU

DEPARTMENT OF BIOLOGICAL SCIENCES
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA.

JUNE, 2015.

ASSESSMENT OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS
OF IMABORO RIVER AT ANKPA, KOGI STATE,
NIGERIA

BY

Meliga SALIFU, B.Sc (Ed) BIOLOGY (ABU) 2001
M.Sc/SCIE/08051/2010-2011

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF
MASTER OF SCIENCE DEGREE IN EDUCATIONAL BIOLOGY

DEPARTMENT OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

JUNE, 2015.

DECLARATION

I declare that the work in the thesis entitled “**Assessment of Physico-chemical and Biological Parameters of Imaboro River at Ankpa, kogi State**” has been performed by me in the Department of Biological Sciences under the supervision of Prof. J.A. Adakole and Dr. Matthias A. Chia. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

Meliga SALIFU

Signature

Date

CERTIFICATION

This thesis entitled “**ASSESSMENT OF PHYSICO-CHEMICAL AND BIOLOGICAL PARAMETERS OF IMABORO RIVER AT ANKPA, KOGI STATE**” by **Meliga SALIFU** meets the regulations governing the award of degree of Master of Science (Educational Biology) of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

Prof. J.A. Adakole
Chairman, Supervisory Committee
Department of Biological Sciences,
Ahmadu Bello University, Zaria.

Signature

Date

Dr. Matthias A. Chia
Member, Supervisory Committee
Department of Biological Sciences,
Ahmadu Bello University, Zaria.

Signature

Date

Prof. A. K. Adamu
Head of Department
Department of Biological Sciences,
Ahmadu Bello University, Zaria.

Signature

Date

Prof. A. Z. Hassan
Dean, School of Postgraduate Studies
Ahmadu Bello University, Zaria.

Signature

Date

ACKNOWLEDGEMENT

I give my creator God the glory for His guidance, protection, provision and wisdom throughout the time this program lasted. Lord, you made it happen. I lack words to fully appreciate the efforts of my supervisors, Prof. J. A. Adakole and Dr. M. A. Chia. I am so glad to have worked under your supervision and with the kind of persons you are, I know there is still hope for our educational system. Thank you for all your efforts that made this work successful. I appreciate the staff of Hydrobiology Laboratory, Department of Biological Sciences, Ahmadu Bello University, Zaria for their cooperation. I say a big thank you to my H.O.D., Mr. S. J. Abuh, Kogi State College of Education, Ankpa for his support, encouragement and release of the Departmental Laboratory and equipment for this work.. Special thanks to Mr. S.O Ameh, of Chemistry Laboratory., Kogi State College of Education, Ankpa for his contributions.

DEDICATION

I dedicate this work to my beloved father, late Salifu Ogbaje for his desire to give me sound education and to my darling wife and children for understanding with me throughout the time this programme lasted.

ABSTRACT

This study was set to determine the seasonal variations in the physical and chemical parameters of Imaboro River as well as the plankton, periphytic algae and macrobenthic invertebrate community structure and dynamics of the river. Sample collection was done monthly from October, 2012 to September, 2013 (one year). The physico-chemical and biological parameters were analysed according to standard methods. Water temperature, pH and electrical conductivity were determined on the field. Dissolved oxygen (DO), biological oxygen demand (BOD), TDS, TSS and TS were determined at Chemistry Laboratory, Kogi State College of Education, Ankpa. Other analyses were done at Department of Biological Sciences Hydrobiology Laboratory, Ahmadu Bello University, Zaria. The study showed that temperature ranged between 23.24 ± 0.39 and $28.36 \pm 0.19^{\circ}\text{C}$, transparency between 39.80 ± 9.16 and 59.30 ± 9.41 cm, TSS between 100.00 ± 68.24 and 300.00 ± 0.00 mg/l, TDS between 40.00 ± 24.49 and 820.00 ± 335.26 mg/l, velocity between 0.17 ± 0.05 and 0.17 ± 0.05 m/s. pH ranges between 5.75 ± 0.11 and 6.19 ± 0.17 , EC between 17.80 ± 3.54 and 34.60 ± 10.27 $\mu\text{S}/\text{cm}$, DO between 2.96 ± 0.17 and 4.62 ± 0.45 mg/l, total hardness between 18.40 ± 2.40 and 48.00 ± 8.10 mg/l, alkalinity between 4.75 ± 0.95 and 13.20 ± 3.18 mg/l, $\text{NO}_3\text{-N}$ between 7.200 ± 73 and 24.80 ± 1.39 mg/l and $\text{PO}_4\text{-P}$ between 1.00 ± 0.07 and 2.34 ± 0.04 mg/l. The study revealed that the physico-chemical parameters vary significantly between stations and months of study. The community structure of the biological parameters studied showed no significant difference between stations and months. The canonical correspondent analysis (CCA) of the biological parameters showed a strong positive correlation between the species and the physico-chemical parameters. The dynamics of Imaboro river is a complex one showing some elements of organic pollution resulting from anthropogenic activities

although most of the physico-chemical parameters studied fell within the tolerable limit. It was recommended that people should be sensitized on the danger of dumping refuse inside the river, molecular techniques be adopted for accurate identification of organisms, and further research be conducted to determine the heavy metal content of the river.

TABLE OF CONTENTS

	Page
Cover page.....	i
Title page.....	ii
Declaration.....	iii
Approval page.....	iv
Acknowledgement.....	v
Dedication.....	vi
Abstract.....	vii
Contents.....	viii
List of Tables.....	xiii
List of Figures.....	xiv
List of plates.....	xvi
List of Appendices.....	xvii
1.0 INTRODUCTION.....	1
1.1 Background of the study.....	1
1.2 Statement of Research Problem.....	5
1.3 Justification.....	6
1.4 Aim of the Study.....	6
1.5 Objectives of the Study.....	6
1.6 Research Hypotheses.....	7
2.0 LITERATURE REVIEW.....	8
2.1 River Monitoring.....	8
2.2 Physico-chemical Parameters of Water.....	9

2.2.1 Water temperature.....	9
2.2.2 Water transparency.....	10
2.2.3 Total solids.....	10
2.2.4 Total suspended solids	11
2.2.5 Total dissolved solids.....	12
2.2.6 Water depth.....	12
2.2.7 Water velocity	13
2.2.8 Water pH.....	14
2.2.9 Total hardness.....	15
2.2.10 Electrical conductivity.....	16
2.2.11 Nitrate-Nitrogen.....	17
2.2.12 Phosphate- phosphorus.....	17
2.2.13 Water alkalinity.....	19
2.2.14 Dissolved oxygen.....	19
2.3 Biological Monitoring of Water.....	20
2.3.1 Phytoplankton.....	21
2.3.2 Zooplankton.....	21
2.3.3 Macro benthic fauna.....	22
2.3.4 Periphyton.....	23
3.0 MATERIALS AND METHOD.....	25
3.1 Study Area.....	25
3.2 Sampling Stations.....	25
3.3 Sampling Procedure.....	27

3.4 Physical and Chemical Parameters Determinations.....	27
3.4.1 Water temperature.....	27
3.4.2 Water transparency.....	28
3.4.3 Water velocity.....	28
3.4.4 Water depth.....	28
3.4.5 Water width.....	29
3.4.6 Water pH.....	29
3.4.7 Electrical conductivity (EC).....	29
3.4.8 Total dissolved solids (TDS).....	29
3.4.9 Total suspended solids (TSS).....	30
3.4.10 Total solids (T S).....	30
3.4.11 Nitrate-nitrogen (NO ₃ -N).....	30
3.4.12 Phosphate-phosphorus (PO ₄ -P)	31
3.4.13 Total hardness.....	31
3.4.14 Total alkalinity.....	31
3.4.15 Dissolved oxygen (DO).....	32
3.4.16 Biological oxygen demand (BOD).....	33
3.5 Biological Parameters.....	33
3.5.1 Plankton sampling and analysis.....	33
3.5.2 Periphyton.....	34
3.5.3 Macrobenthic fauna.....	34
3.6 Statistical Analysis of Data.....	35
4. 0 RESULTS.....	37
4.1 Water Temperature.....	37

4.2 Water Transparency.....	42
4.3 Total Suspended Solids (TSS).....	42
4.4 Total Dissolved Solids (TDS).....	42
4.5 Total Solids (TS).....	45
4.6 Water Depth.....	45
4.7 Water Width.....	49
4.8 Water Velocity.....	49
4.9 Water pH.....	51
4.10 Electrical Conductivity.....	54
4.11 Dissolved Oxygen (DO).....	54
4.12 Biological Oxygen Demand (BOD).....	57
4.13 Total Hardness.....	57
4.14 Total Alkalinity.....	60
4.15 Nitrate-Nitrogen (NO₃-N).....	60
4.16 Phosphate-Phosphorus (PO₄-P).....	63
4.17 Macrobenthic Fauna.....	63
4.18 Phytoplankton.....	66
4.19 Zooplankton.....	73
4.20 Non–Diatom. Periphytic Algae.....	77
4.21 Periphytic Diatom.....	80
5.0 DISCUSSION.....	93
5.1 Physico-chemical Parameters.....	93
5.2 Biological Parameters.....	96
6.0 SUMMARY, CONCLUSION AND RECOMMENDATION.....	102

6.1 Summary.....	102
6.2 Conclusion.....	103
6.3 Recommendations.....	103
REFERENCES.....	104
APPENDICES.....	111

List of Tables

Table 4.1: Comparison of Physico-chemical Parameters between Months of the Study Period.....	38
Table 4.2: Comparison of Physico-chemical Parameters Between Stations.....	39
Table 4.3: Comparison of Physico-chemical Parameters Between Seasons of the Study Period.....	41
Table 4.4 Macrobenthic Fauna Community of Imaboro River, Kogi State.....	67
Table 4.5: Shannon-Weiner's Diversity Index for Benthos of Imaboro River.....	69
Table 4.6: phytoplankton Community of Imaboro River, Kogi State.....	70
Table 4.7: Shannon-Weiner's Diversity Index for Phytoplankton of Imaboro River, Kogi State	72
Table 4.8: Zooplankton Community of Imaboro River, Kogi State	75
Table 4.9: Shannon-Weiner's Diversity Index for Zooplankton of Imaboro River, Kogi State.....	78
Table 4.10: Non- diatom Periphytic Algae of Imaboro River, Kogi State.....	81
Table 4.11: Shannon-Weiner's Diversity Index for Non-diatom Periphyton of Imaboro River, Kogi State.....	83
Table 4.12: Periphytic Diatoms of Imaboro River, Kogi State.....	85
Table 4.13: Shannon-Weiner's Diversity Index for Periphytic Diatoms of Imaboro River, Kogi State.....	87
Table 4.14: Range of Physico-chemical Parameters of Imaboro River and Selected National and International Water Quality Standard Guidelines.....	101

List of Figures

Fig 3.1: Study Area Showing Imaboro River and the Sampling Points.....	26
Fig 4.1: Mean Monthly Variations in Temperature of Imaboro River,Kogi State....	40
Fig 4.2: Mean Monthly Variations in Transparency of Imaboro River, Kogi State..	43
Fig 4.3: Mean Monthly Variations in TSS of Imaboro River, Kogi State.....	44
Fig 4.4: Mean Monthly Variations in TDS of Imaboro River, Kogi State	46
Fig 4.5: Mean Monthly Variations in TS of Imaboro River, Kogi State.....	47
Fig 4.6: Mean Monthly Variations in Depth of Imaboro River, Kogi State.....	48
Fig 4.7: Mean Monthly Variations in Width of Imaboro River, Kogi State.....	50
Fig 4.8: Mean Monthly Variations in Velocity of Imaboro River, Kogi State.....	52
Fig 4.9: Mean Monthly Variations in pH of Imaboro River, Kogi State.....	53
Fig 4.10: Mean Monthly Variations in Electrical Conductivity of Imaboro River, Kogi State.....	55
Fig 4.11: Mean Monthly Variations in DO of Imaboro River, Kogi State.....	56
Fig 4.12: Mean Monthly Variations in BOD of Imaboro River, Kogi State.....	58
Fig 4.13: Mean Monthly Variations in Total Hardness of Imaboro River, Kogi State.....	59
Fig 4.14: Mean Monthly Variations in Alkalinity of Imaboro River, Kogi State....	61
Fig 4.15: Mean Monthly Variations in NO ₃ -N of Imaboro River, Kogi State.....	62
Fig 4.16: Mean Monthly Variations in PO ₄ -P of Imaboro River, Kogi State.....	64
Fig. 4.17: Principal Component Analysis (PCA) of the Physico-chemical Parameters of Imaboro River, Kogi State.....	65
Fig 4.18: Mean Monthly Variations in Macrobenthic Fauna of Imaboro River per Station.....	69
Fig. 4.19: Mean Monthly Variations in Phytoplankton of Imaboro River Per Station.....	71
Fig 4.20: Cannonical Correspondence Analysis (CCA) of Phytoplankton of Imaboro River, Kogi State.....	74

Fig 4.21: Mean Monthly Variations zooplankton of Imaboro River per station.....	77
Fig 4.22: Cannonical Correspondence Analysis (CCA) of Zooplankton of Imaboro River, Kogi State.....	79
Fig 4.23: Mean Monthly Variations in Non diatom Periphytic algae of Imaboro River per station	82
Fig 4.24: Cannonical Correspondence Analysis (CCA) of Non-diatom Periphyton of Imaboro River, Kogi State.....	84
Fig 4.25: Mean Monthly Variations in Periphytic diatoms of Imaboro River per station	86
Fig 4.26: Cannonical Correspondence Analysis (CCA) of Periphytic diatom of Imaboro River, Kogi State.....	89

List of Plates

Plate 4.1: Sample Micrograph of Phytoplankton of Imaboro River, Kogi State.....	90
Plate4. 2: Sample Micrograph of Zooplankton of Imaboro River, Kogi State.....	91
Plate 4.3: Sample Micrograph of Periphytic Diatom of Imaboro River.....	92

List of Appendices

Appendix I: Mean Monthly Phytoplankton Population of Imaboro River per station	111
Appendix II: Mean Monthly Zooplankton Population of Imaboro River per station.....	112
Appendix III: Benthos community of Imaboro River,Kogi State.	113
Appendix IV: Comparison of Phytoplankton, Zooplankton and Benthos Between Seasons.....	114
Appendix V: Non-diatom Periphytic Community of Imaboro River, Kogi State....	115
Appendix VI: Monthly Periphytic diatom community of Imaboro River per station.....	116
Appendix VII: Periphytic diatoms of Imaboro River showing the Families.....	117
Appendix VIII: Periphytic Diatoms of Imaboro River showing the Families Continued.....	118
Appendix IX: Periphytic diatoms of Imaboro River showing the Families Continued.....	119
Appendix X: ANOVA of Biological Parameters per Month, Station and Station/Month.....	120
Appendix XI: Summary of PCA of Physico-chemical Parameters and CCA of Biological Parameters of Imaboro River	121
Appendix XII: Phytoplankton Families and Species Identified in Imaboro River, Kogi State.....	122
Appendix XIII: Non-diatom Periphyton Families and Species Identified in Imaboro River, Kogi State	124
Appendix XIV: Number of Benthos Family Identified at Each Station of a stretch of Imaboro River.....	126
Appendix XV: Number of Zooplankton Species Identified at Each Station of a stretch of Imaboro River.....	127
Appendix XVI: Number of Phytoplankton Species Identified at Each Station of a Stretch of Imaboro River.....	128

Appendix XVII: Number of Non-diatom Periphyton Species Identified at Each Station of a stretch of Imaboro River.....,,.....	130
Appendix XIII: Number of Periphytic Diatom Species Identified at Each Station of a Stretch of Imaboro River.....	132

CHAPTER ONE

1.0

INTRODUCTION

1.1 Background of the Study

Access to safe water is a fundamental need and basic human right (WHO, 2000). Water is an indispensable component of the human body. Water also plays an important role in many industries (cosmetics, food, pharmaceutical). It is also a good solvent and the main transporter of a wide variety of chemical substances in aquatic ecosystems. Unfortunately, these properties heighten water's exposure to various kinds of pollution. It is therefore important to constantly protect and control the quality of water, particularly in regions with a deficiency of freshwater; for example, in Africa and Nigeria, where freshwater quality is a major concern (WHO, 2000, Chia *et al.*, 2009, Lobanga *et al.*, 2009, Chigor, 2012). Even when water is in abundance, it is reasonable to verify the quality of drinking water, due to its impact on the health of aquatic ecosystems and humans as well.

Surface water bodies which are the most important sources of water for human activities has unfortunately been under severe environmental stress and are being threatened as a consequence of human developmental activities (Yogendra and Puttaiah, 2008). Availability of safe and reliable sources of water is an essential prerequisite for sustained development (Adakole *et al.*, 2008). This availability of safe and reliable sources of water has in recent times, been affected by climate change which results from global warming. Climate change directly affects the water cycle. It also affects the quantity and quality of water resources available to meet human and environmental demands. It can lead to both floods and drought. Rising sea levels have a serious effect on coastal aquifers, a major source of urban and regional water supply

systems, and higher water temperatures can exacerbate many forms of water pollution (UNESCO-WWAP, 2009). Water supply reliability, health, agriculture, energy and aquatic ecosystems – all will feel the impact of these changes to the water cycle. The demand for water to meet these needs is also affected by climate change.

In recent times however, Nigerian freshwater bodies have been subjected to various forms of degradation due to pollution. Sources of this pollution include industrial effluents, domestic wastes, agricultural run-offs, oil spillage and obnoxious fishing methods (Njoku and Keke, 2003; Chia *et al.*, 2011).

Water quality could be described as the chemical, physical and biological characteristics of water, normally in respect to its suitability for a particular purpose (Howard, 2011). In towns, chemical pollutants have been detected in streams, endangering plant and animal life (Chia *et al.*, 2009) and run-off containing pollutants from roads and parking lots have affected the water quality of urban streams (Howard, 2011). Water quality assessment is of immense importance to practices involving the use of water bodies such as in the management of fisheries, water supply, pollution control, irrigation and sewage reservoir and impoundment (Adakole *et al.*, 2008; Chigor *et al.*, 2012).

Many methods and criteria are available to assess aquatic ecosystems. A physico-chemical approach to monitor water pollution is most common and lots of information is available on these aspects. Physical parameters define those characteristics of water that appeal to the sense of sight, touch, taste or smell (Ramachandra and Malvikaa, 2007). Suspended solids, turbidity, colour, taste, odour and temperature fall under this category. Chemical parameters are related to the solvent capabilities of water. Total dissolved solids, alkalinity, hardness, fluorides, metals, organics, and nutrients are

chemical parameters of concern in water-quality management (Ramachandra and Malvikaa, 2007). Such data is valuable and necessary but does not provide all the information required in the assessment of the quality of the waterbody. Physical and chemical parameters undergo marked changes in relation to seasonal changes and location.

Traditionally, water quality monitoring actions have focused on physical and chemical measurements. It is widely recognised that the use of other indicators, in addition to traditional chemical and physical water quality monitoring techniques, can greatly enhance the assessment and management of aquatic ecosystems (Ramachandra and Malvikaa, 2007). In this regard, biological monitoring or biomonitoring has proved to be an important tool in assessing the condition of aquatic ecosystems. Biological methods used for assessing the water quality include the collection, counting, and identification of the aquatic organisms (Ramachandra and Malvikaa, 2007).

Bio - indicators of pollutants are useful in predicting the level and degree of pollution before the effects of the pollutants start (Pai, 2002). Qualitative and quantitative analysis of different groups of organisms have led to establishment of bio-indicators, indices and systems which can be used to assess the pollution and trophic status of water bodies. Presently, bio-monitoring and indices have become integral part of water quality assessment (Mahadev *et al* 2005, Kannel *et al.*, 2007) and forms part of many water quality studies (Pramila *et al.*, 2007).

Indices of biotic integrity and other similar multimetric concepts have been developed since the 1970's as methods to quantitatively assess environmental conditions through habitat indicators. Biological indicators are currently used and promoted by numerous

conservation agencies as a means to monitoring and assessing human impacts on environments, including the World Conservation Union (IUCN), World conservation Monitoring Center (UNEP), U.S. Environmental Protection Agency (US EPA), as well as the Nature Conservancy, World Wide Fund for Nature (WWF), Friends of the Earth (FOE), and Greenpeace (IUCN, 1989; US EPA, 2002; UNEP, 2002). It has been established that environmental disturbances induce changes in the structure and function of biological systems.

The benthic community structure represents an integral measure of autotrophic and heterotrophic process in lakes, and reflects disturbances in these processes. A better understanding of the effects of pollution is obtained when biological data are correlated with the physical and chemical parameters. However, biological indicator evaluation provides direct evidence of the effects of pollution, whereas physical and chemical data provide only indirect evidence. No single species by itself will indicate the full scope of potential hazards coincident with the various uses of water or provide all the information for an adequate evaluation (Ramachandra and Malvikaa, 2007).

Plankton, particularly phytoplankton, has long been used as indicators of water quality. They flourish both in highly eutrophic waters while a few others are very sensitive to organic and/or chemical wastes. Some species have also been associated with noxious blooms sometimes creating offensive tastes and odours or toxic conditions. Because of their short life cycles, planktons respond quickly to environmental changes and hence, the standing crop and species composition indicate the quality of the water mass in which they are found. They strongly influence certain non-biological aspects of water quality such as pH, colour, taste, odour and in a very practical sense, they are a part of the water quality. The species assemblage of

zooplankton is also used in the assessment of water quality. As benthic macroinvertebrates tend to remain in their original habitat, they are affected by local changes in water quality. Some are capable of tolerating higher loads of pollution than others. Thus if the pollution is severe, or is moderate but sustained over time, the whole community structure may be simplified in favor of tolerant species. By assessing indicator species, diversity, and functional groups of the benthic macroinvertebrate community, it is possible to determine water quality (Ramachandra and Malvikaa, 2007). Diatoms have been used as indicators of environmental change in flowing waters and lakes. Periphytic diatoms of lakes respond to eutrophication. The relative abundance of diatom species is used as the most valuable characteristics of diatom assemblages for bioassessment of river health (Jacob, 2012).

1.2 Statement of Research Problem

Rivers serve as sinks to most wastes that result from anthropogenic activities (Adeloye, 2004). As human population increases, more pressure is put on available water resources in meeting human water needs and for waste disposal. Imaboro river had in recent times come under stress as a result of rapid urbanization. All the domestic and industrial wastes as well as sewage from all parts of the town are washed into the river during run-off. The topography of the town slopes into the river and drainage channels are constructed emptying into the river. This situation may eventually lead to pollution of the river which might have dire consequences on the ecosystem.

The physico – chemical and biological parameters of rivers vary temporally and spatially depending on the nature and quantity of effluents they receive seasonally and

at points along their courses (Howard, 2011). Imaboro river may show the same trend making the water hazardous for use at some points or times.

1.3 Justification

There is scanty information on the physico-chemical and biological parameters of Imaboro River. This study was deemed necessary to provide baseline information on some aspects of physico-chemical and biological parameters of Imaboro River. There is also the potential benefits of this research for conservation purposes and the detection of pollution on this river.

Since water pollution in many instances is a biological phenomenon, it would appear logical that it ought to be measured biologically (Ramachandra *et al.*, 2005). To this end, biological parameters were used in this study.

1.4 Aim of the Study

The aim of this study is to evaluate the quality of a stretch of Imaboro river water in Ankpa using planktonic, periphytic algae and benthic macro invertebrate diversity of the river.

1.5 Objectives of the Study

The objectives of the study are as follows:

- (i) To determine the temporal and spatial variations in the physical and chemical parameters in relation to the water quality of Imaboro river.
- (ii) To determine the temporal and spatial variations in plankton, periphytic algae and macro benthic invertebrate community structure and dynamics of Imaboro river.

- (iii) To relate the temporal and spatial changes of plankton, periphytic algae and macro benthic invertebrate community structure to the physicochemical parameters and water quality of Imaboro river.

1.6 Research Hypotheses

- (i) There is no significant difference in the temporal and spatial variations of the physicochemical parameters of Imaboro River.
- (ii) The temporal and spatial variations of the plankton, periphyton and macro benthic invertebrate community structure of Imaboro river are not significant.
- (iii) There is no significant relationship between the biological community structures of Imaboro river with the physicochemical parameters.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 River Monitoring

The fate and transport of many anthropogenic pollutants are determined by not only hydrological cycles, but also physico-chemical processes (Bellingham, 2012). Rivers are vital and vulnerable freshwater ecosystems that are critical for the sustenance of all life. However, the declining water quality of these ecological systems threatens their sustainability and is therefore a matter of serious concern (Ugwu and Wakawa, 2012). Rivers are waterways of strategic importance across the world, providing main water resources for domestic, industrial and agricultural purposes (Jain, 2009). Untreated discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial wastewaters, agricultural run-off and other sources all can have short term and long term effects on the quality of a river system (Singh, 2007). It is a common practice for people living along river catchments to discharge their domestic waste as well as sewage into rivers. Wild and Domestic animals using same drinking water can also contaminate the water through direct defecation and urination (Best *et al.*, 1998; Jain, 2009).

Water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions. A regular monitoring of water bodies with required number of parameters in relation to water quality prevents the outbreak of diseases and occurrence of hazards (Ugwu and Wakawa, 2012).

Bellingham (2012) explained that in order to mitigate the impact human societies have on natural waters, it is becoming increasingly important to implement

comprehensive monitoring regimes. He further highlighted that monitoring water resources will quantify water quality, identify impairments and help policy makers make land use decisions that will not only preserve natural areas, but improve the quality of life.

Chia (2007) maintained that the quality of a given water body is governed by the physical, chemical and biological factors all of which interact with one another and greatly influence its productivity.

Bio-monitoring in conjunction with physical and chemical observation of water quality is potentially useful in assessing water bodies. Chemical data measure concentration of pollutants in the water body, and the ecosystem imbalances are measured by biological information (Ramachandra and Malvikaa, 2007). Biological and chemical data are essential in understanding the ecosystem integrity.

2.2 Physico-Chemical Parameters of Water

Physical parameters define those characteristics of water that respond to the sense of sight, touch, taste or smell. Suspended solids, turbidity, colour, taste, odour and temperature fall under this category. Chemical parameters are related to the solvent capabilities of water. Total dissolved solids, alkalinity, hardness, fluorides, metals, organics, and nutrients are chemical parameters of concern in water-quality management (Ramachandra and Malvikaa, 2007).

2.2.1 Water temperature

Temperature exerts a major influence on the biological activities and growth. Many aquatic organisms are sensitive to changes in water temperature (Bellingham, 2012). Bellingham (2012), also noted that water bodies will naturally show changes in

temperature seasonally and daily; however, man-made changes to stream water temperature will affect fish's ability to reproduce. To a certain point the increase in temperature leads to greater biological productivity, above and below which it falls and it also governs the kind of organisms (species composition). At elevated temperatures, metabolic activity of organism increases, requiring more oxygen but at the same time the solubility of oxygen decreases, thus accentuating the stress (Boulton, 2012). Temperature influences water chemistry, e.g. DO, solubility, density, pH, and conductivity. Water holds lesser oxygen at higher temperatures (Akin-Oriola, 2003; AWQA, 2012). Some compounds are more toxic to aquatic organisms at higher temperatures. Additionally temperature of drinking water has an influence on its taste (Ramachandra and Malvikaa, 2007).

2.2.2 Water transparency

Transparency is a characteristic of water that varies with the combined effect of colour and turbidity (Ramachandra and Malvikaa, 2007). It measures the light penetrating through the water body. Clear water lets light penetrate more deeply into the river than murky water. This light allows photosynthesis to occur and oxygen to be produced (Allison *et al.*, 2007). Pollution tends to reduce water clarity. Transparency values are expressed in cm or mm. Secchi disc, a metallic disc of 20 cm diameter with four quadrats of alternate black and white on the upper surface is used to measure transparency (Ramachandra and Malvikaa, 2007).

2.2.3 Total solids (TS)

Solids refer to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. Total solids are the term applied to the material left in the vessel after evaporation of a sample and its subsequent drying in

the oven at a defined temperature (Sheila, 2007). Total solids include total suspended solids, the portion of total solids retained by a filter, and total dissolved solids, the portion that passes through the filter (APHA, 1998). Total solids can be measured by evaporating a water sample in a weighed dish, and then drying the residue in an oven at 103 to 105° C. The increase in weight of the dish represents the total solids. Total solids are expressed as mg/l of water.

2.2.4 Total suspended solids (TSS)

Total Suspended Solids are solids in water that can be trapped by a filter. TSS can include a wide variety of materials, such as silt, decaying plant and animal matter, industrial wastes and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways (Sheila, 2007). Waters high in suspended solids may be aesthetically unsatisfactory especially for purposes such as bathing. To measure TSS, the water sample is filtered through a pre-weighed filter. The residue retained on the filter is dried in an oven at 103 to 105°C until the weight of the filter no longer changes. The increase in weight of the filter represents the total suspended solids.

2.2.5 Total dissolved solids (TDS)

Total Dissolved Solids (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in water (Sheila, 2007). This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life (Sheila, 2007). If TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur. Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature. Waters with high dissolved solids generally are of inferior palatability. A limit of 500 mg/l TDS is desirable for drinking waters (Sheila, 2007). Total dissolved solid or mineral in the natural waters is a useful parameter in describing the chemical density as a fitness factor and as a general measure of edaphic relationship that contributes to productivity within the water body (Abolude, 2007). Total dissolved solids can be measured using a meter and the total solids and total suspended solids can be weighed in the laboratory by evaporation.

2.2.6 Water depth

The depths of the ocean have been charted since the early days of sailing using a method called sounding (<http://www.dosits.org/pe...tion/tomeasurewaterdepth/#>). A sounding line (a rope that has a weight attached) is lowered over the side of the ship. When the weight hits the seafloor, the line goes slack, and is marked at the water's surface. The weight is pulled back up and the distance from the surface mark to the weight is measured. This length equals the depth of the ocean at that point. This

method of seafloor mapping is very time consuming, especially when charting deep water. (<http://www.geography-site.co.uk>).

The invention of sonar changed the way that the seafloor is mapped. A combined transmitter and receiver, called a transducer, send a sound pulse straight down into the water. The pulse moves down through the water and bounces off the ocean bottom. The transducer is able to pick up the reflected sound. Computers precisely measure the time it takes for the sound pulse to reach the bottom and return. In shallow water the sound waves will return very fast and in deeper water it will take more time to receive the echoes. The depth of the ocean is calculated by knowing how fast sound travels in the water (approximately 1,500 meters per second). This method of seafloor mapping is called echosounding (<http://www.geography-site.co.uk>).

Water depth has a profound effect on the temperature and dissolved oxygen concentration of the water body. The water temperature usually falls with depth, because less sunlight will penetrate the water at greater depth. Oxygen levels, like temperature, also decrease with depth (www.lenntech.com/water-ecology-faq.htm).

2.2.7 Water velocity

The velocity of a river is the speed at which water flows along it. The velocity will change along the course of any river, and is determined by factors such as the gradient (how steeply the river is losing height), the volume of water, the shape of the river channel and the amount of friction created by the bed, rocks and plants (<http://www.geography-site.co.uk>). Velocity of the water surface can be measured using a stop watch capable of timing in seconds, something to float on the water and a measuring tape. Velocity of the water below the surface is measured by velocity

meter. Flow vanes measure velocity both at the water surface and below the water surface (<http://www.geography-site.co.uk>).

2.2.8 Water pH

The pH of natural water can provide important information about many chemical and biological processes and provides indirect correlations to a number of different impairments (Bellingham, 2012). pH – potential of hydrogen, is the measure of the concentration of hydrogen ions. It provides the measure of the acidity or alkalinity of a solution and is measured on a scale of 0 – 14. The pH of water is 7, which is neutral, and lower than 7 is acidic, while higher than 7 is alkaline. The closer pH gets to 1, the more acidic while the closer pH gets to 14, the more basic (Kelly-Addy *et al.*, 2004). The pH of water determines the solubility and biological availability of certain chemical nutrients such as phosphorus, nitrogen, carbon and heavy metals like lead, copper, cadmium, etc (Bellingham, 2012). pH determines how much and what form of phosphorus is most abundant in water. It also determines whether aquatic life can use the form available. In the case of heavy metals the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble in acidic waters. pH of natural waters would be around 7, but mostly basic. pH of seawater is around 8.5. pH of natural water usually lies in the range of 4.4 to 8.5 (Bellingham, 2012). In unpolluted or pure waters, the pH is governed by the exchange of carbon dioxide with the atmosphere. Carbon dioxide is soluble in water and the amount of CO₂ that will dissolve in the water will be a function of temperature and the concentration of CO₂ in the air. As the gaseous CO₂ becomes aqueous, the CO₂ will be converted into H₂CO₃ which will acidify the water to a pH of about 6. If any alkaline earth metals such as sodium are present, the

carbonates and bicarbonate formed from the solubilization of CO₂ will interact with sodium increasing the alkalinity shifting the pH up over 7 (Bellingham, 2012).

Lower values in pH are indicative of high acidity, which can be caused by the deposition of acid forming substances in precipitation. A high organic content will tend to decrease the pH because of the carbonate chemistry. As microorganisms break down organic material, the by-product will be CO₂ that will dissolve and equilibrate with the water forming carbonic acid (H₂CO₃). Other organic acids such as humic and fulvic acid can also result from organic decomposition (Bellingham, 2012).

pH is typically monitored for assessments of aquatic ecosystem health, recreational waters, irrigation sources and discharges, live stock, drinking water sources, industrial discharges, intakes, and storm water runoff.

2.2.9 Total hardness

Water hardness is the traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to lather. Hardness is generally caused by the calcium and magnesium ions (bivalent cations) present in water (Ramachandra and Malvikaa, 2007). Polyvalent ions of some other metals like strontium, iron, aluminium, zinc and manganese are also capable of precipitating the soap thus contributing to hardness. However, the concentration of these ions is very low in natural waters therefore hardness is generally measured as concentration of only calcium and magnesium, which are far higher in quantities over other hardness producing ions (Ramachandra and Malvikaa, 2007). Hardness is measured in terms of mg/L using standard methods involving reagents.

2.2.10 Electrical conductivity

Electrical conductivity (EC) in natural waters is the normalized measure of the water's ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Most dissolved inorganic substances in water are in the ionised form and hence contribute to conductance. Thus, measurement of conductivity also gives a rapid and practical estimate of the dissolved mineral contents of water. Conductivity is highly dependent on temperature and therefore is reported normally at 25°C to maintain comparability of data from various sources (Ramachandra and Malvikaa, 2007). Conductivity is reported in mmho or μ mhos/cm, though the recent unit of conductivity has been named Siemens/cm (S) instead of mho. Most freshwater sources will range between 0.001 and 0.100 S/cm (Bellingham, 2012). Conductivity meter is used to measure conductivity. The source of EC may be an abundance of dissolved salts due to poor irrigation management, minerals from rain water run-off, or other discharges. EC is also the measure of the water quality parameter "Total Dissolved Solids" (TDS) or salinity. At about 0.3 S/m is the point at which the health of some crops and fresh water aquatic organisms will be affected by the salinity.

Field measurements of EC reflect the amount of total dissolved solids (TDS) in natural waters. The relationship between TDS and EC can be described by the equation;

$$\text{TDS (mg/l)} \approx \text{EC } (\mu\text{S/cm}) \times 640 \text{ (Bellingham, 2012).}$$

2.2.11 Nitrate-nitrogen (NO₃-N)

Nitrate ion (NO₃⁻) is the common form of nitrogen in natural waters. Nitrite (NO₂⁻) will oxidize into nitrate after entering an aerobic regime. Similarly, plants and microorganisms will reduce nitrate into nitrite but nitrite ion will quickly oxidize back into nitrate once it reenters the water. Natural sources of nitrate are igneous rock, plant decay and animal debris. Nitrates are measured in terms of mg/l and are measured in the laboratory using reagents. Nitrate levels over 5 mg/l in natural waters normally indicates man made pollution, 200 mg/l is an extreme level (Bellingham, 2012). Man made sources of NO₃-N include fertilizers, livestock, urban run-off, septic tanks, and waste water discharges. In general, nitrates are less toxic to people than ammonia or nitrite however at high levels nitrate will become toxic especially to infants. Methemoglobinemia is nitrate poisoning where high levels of nitrate enter in hemoglobin will oxidize the ferric iron II into ferrous iron III inhibiting the blood's ability to carry oxygen (Bellingham, 2012). WHO has imposed a limit of 10mg/L nitrate as nitrogen on drinking water to prevent the disorder of methemoglobinemia.

In the environment, nitrate will become toxic to fish at about 30 mg/l (Bellingham, 2012). Nitrate pollution will cause eutrophication of a stream where algae and aquatic plant growth will consume the oxygen and increase the TSS of the water. Eutrophication is usually the result of nitrate and phosphate contamination and is a significant reduction of water quality.

2.2.12 Phosphate-phosphorus (PO₄-P)

Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates and organically bound phosphates. They occur in solution, in particles or detritus or in the bodies of aquatic

organisms. Orthophosphate is the phosphorus form that is directly taken up by algae, and the concentration of this fraction constitutes an index of the amount of phosphorus immediately available for algal growth (Ramachandra & Malvikaa, 2007).

Unlike total ammonia, phosphates are less soluble and less volatile, therefore, phosphates will form salts with sodium and calcium and fall out of solution to accumulate in the sediment. Phosphates ions in natural waters will exist in solution in its ionized form, as salts, in organic form or as a particulate species. Higher concentrations rarely occur, because after it enters a water system, it will be rapidly taken up by plants (Bellingham, 2012). In general, phosphorous is an essential nutrient to living organisms. In unpolluted waters, phosphorous can enter a water system from the weathering of phosphorous-bearing rocks and minerals. In areas of high volcanic activity, phosphorous may be naturally abundant in the soils.

Man made sources of phosphate in the environment include domestic and industrial discharges, agricultural runoff where fertilizers are used, and changes in land use in areas where phosphorous is naturally abundant in the soil. In general, phosphates are not very toxic to people or other living organisms. Like nitrogen containing compounds, the main environmental impact associated with phosphate pollution is eutrophication. High levels of phosphorus will be quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidities. These impairments will kill or harm fish and other aquatic organisms (Bellingham, 2012).

2.2.13 Water alkalinity

The alkalinity of water is a measure of its capacity to neutralise acids. The alkalinity of natural waters is due to the salts of carbonates, bicarbonates, borates, silicates and phosphates along with the hydroxyl ions in free states. However, the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate and bicarbonate, which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in wastewater treatment processes, particularly in coagulation, softening and operational control of anaerobic digestion. Alkalinity is expressed as mg/l (Ramachandra and Malvikaa, 2007).

2.2.14 Dissolved oxygen (DO)

Sources of oxygen in water are by diffusion of oxygen from the air into the water, photosynthetic activity of aquatic autotrophs and inflowing streams. DO is a very important parameter for the survival of fishes and other aquatic organisms. Diffusion of oxygen or transfer of oxygen in these organisms is efficient only above certain concentrations. Too low concentrations of oxygen may not be enough to sustain life. Oxygen is also needed for many chemical reactions that are important to lake functioning (oxidation of metals, decomposition of dead and decaying matter, etc.). Measurement of DO can be used to indicate the degree of pollution by organic matter. DO is expressed as mg/L. DO concentrations of below 5 mg/L may adversely affect the functioning and survival of biological communities. Below 2 mg/L may lead to fish mortality (Ramachandra and Malvikaa, 2007).

2.3 Biological Monitoring of Water

Bio-monitoring is a valuable assessment tool that is receiving increased use in water quality monitoring programs of all types (Kennish, 1992). Bio-monitoring involves the use of biotic components of an ecosystem to assess periodic changes in the environmental quality of the ecosystem. Bio-monitoring of aquatic communities can be subdivided into bio-assessments, toxicity bioassays, behavioural bioassays, bioaccumulation studies and fish health studies (Ramachandra and Malvikaa, 2007).

Bio-monitoring involves the use of indicators, indicator species or indicator communities. An indicator signals messages, potentially from numerous sources, in a simplified and useful manner. An indicator may reflect biological, chemical or physical attributes of ecological condition. The primary uses of an indicator are to characterise current status and to track or predict significant changes. An ecological indicator has been used to identify major ecosystem stress through their presence, condition, and numbers of the types of fish, insects, algae, amphibians and plants (Ramachandra and Malvikaa, 2007). These types of plants and animals are called biological indicators or bio-indicators. The fundamental principle behind biological indicator theory is that organisms provide information about their habitats.

Bio-indicators are evaluated through presence/absence, condition, relative abundance, reproductive success, community structure (i.e. composition and diversity), community function (i.e. trophic structure), or any combination thereof (Hellawell, 1986, Landres et al. 1988). The presence or absence of the indicator or of an indicator species or indicator community reflects the environmental conditions of the water body under study.

Biological indicators are currently used and promoted by numerous conservation agencies as a means to monitoring and assessing human impacts on environments. These agencies include the World Conservation Union (IUCN), World Conservation Monitoring Centre (UNEP), U.S. Environmental Protection Agency (USEPA), as well as the Nature Conservancy, World Wide Fund for Nature (WWF), Friends of the Earth (FOE), and Greenpeace (IUCN 1989, UNEP 2002, USEPA 2002).

2.3.1 Phytoplankton

Phytoplankton (microscopic algae) usually occurs as unicellular, colonial or filamentous forms and is mostly photosynthetic and is grazed upon by the zooplankton and other organisms occurring in the same environment. Phytoplankton has long been used as indicators of water quality. Because of their short life spans, plankton responds quickly to environmental changes.

They flourish both in highly eutrophic waters while a few others are very sensitive to organic and/or chemical wastes. Algal assemblages could be used as indicators of clean water or polluted water. Clean water would support a great diversity of organisms, whereas polluted water would yield just a few organisms, with one or few dominant forms (Trainor, 1984). In this context, the micro algae have great potential for monitoring and evolving the water quality of the waterbodies (Venkataraman *et al.*, 1994).

2.3.2 Zooplankton

Zooplankton principally comprise of microscopic protozoans, rotifers, cladocerans and copepods. The species assemblage of zooplankton also may be useful in assessing water quality. Most zooplankton occupies an intermediate, second or the third trophic

level of aquatic food webs feeding on algae and bacteria and in turn being eaten by numerous invertebrates and fish. Therefore, any adverse effect to them will be indicated in the health of the fish populations. Using zooplankton as indicators for the assessment of water quality is advantageous because zooplankton are microscopic but and easy to identify. They can be handled in large numbers within a limited space and samples can be collected easily and processed rapidly. Their reproductive cycle is short enough to enable the study through several generations in a relatively short time. Some of the commonly occurring species like *Daphnia*, *Cyclops*, *Brachionus* and *Moina* can be easily cultured to ensure constant supply for experimental purposes, and they respond more rapidly to environmental changes than fishes, which have been traditionally used as indicators of water quality (Ramachandra and Malvikaa, 2007).

2.3.3 Macrobenthic fauna

Aquatic invertebrates live in the bottom parts of water bodies. They are also called benthic, Macro-invertebrates, or benthos, (benthic = bottom, macro = large, invertebrate = animal without a backbone). Examples of some macro-invertebrates are nymphs of stonefly, mayfly, caddisfly larvae, snails, mussels, crustaceans, rat-tailed maggot, etc. Macro-invertebrates convert and transport nutrients from one part of the water body to another, influencing nutrient cycling. They ingest organic matter such as leaf litter and detritus and in turn become food for higher aquatic organisms such as fish, forming a basic link between organic matter and higher aquatic animals in the food web. They are sensitive to changes in habitat and pollution, especially to organic pollution (Ramachandra *et al.*, 2005)

Benthos are preferred indicators of watershed health because they live in the water for all or most of their life, are easy to collect, differ in their tolerance to amount and

types of pollution, are easy to identify in a laboratory. They also have limited mobility and are integrators of environmental condition (Ramachandra and Malvikaa, 2007).

2.3.4 Periphyton

A fundamental part of lotic ecosystems is the periphyton community assemblages whose diversity increases as anthropogenic influences on the system increases (Round, 1991). These assemblages have important implications for ecosystem processes in lotic environments as they establish ecological balance (Rocha, 1993), purify water by absorbing many impurities and are sites of the breakdown of bacterial and other organic matter contamination, respond rapidly to degradation of water quality (Biggs and Kilroy, 2000; Doung *et al.*, 2007) and also play an important role in global cycling of silica and carbon (Mann, 1999).

A major part of the periphyton assemblage is made up of diatoms which are various microscopic one-celled or colonial members of the algal division Bacillariophyta, of the class Bacillariophyceae, having cell walls of silica consisting of two interlocking valves.

The relationship between diatoms and environmental variables are robust and quantifiable making diatoms appropriate quantitative indicators of ecological conditions in lotic systems (Olivera *et al.*, 2001). They represent outstanding bio-indicators for different degrees of pollution and provide excellent indicators of water quality. Benthic diatoms have also been deemed excellent organisms for biological monitoring because they lie at the base of aquatic food webs and are among the first organisms to respond to environmental changes (Lavoie *et al.*, 2008). They also have a short life cycle allowing rapid response to environmental stress especially

eutrophication, providing detailed information on nutrient changes (Sonneman *et al.*, 2001; Lobo *et al.*, 2004; Billinger *et al.*, 2006; Resh, 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Imaboro river is the largest river in Ankpa L.G.A of Kogi state which is used majorly to supply water to Ankpa, the local government headquarters, and the surrounding villages. Ankpa is located within latitude $7^{\circ}24'16''\text{N}$ and longitude $7^{\circ}37'50.6''\text{E}$ at the eastern part of Kogi State (Fig. 3.1). The town has an area of approximately 1200km^2 and a population of 267,353 in the 2006 population census (National Population Commission).

Most of the town's landscape slopes to the river so that run-off from the town finally ends in the river. Commercial and agricultural activities predominate in the area.

Imaboro River passes through Ankpa in Ankpa L.G.A. to Olamaboro L.G.A. before joining Ofu river in Ofu L.G.A to form Anambra river that flows to river Niger. The river flows throughout the year. The river is used mostly for domestic purposes- washing, bathing, cooking and drinking. There is also little fishing activities.

3.2 Sampling Stations

Five sampling stations were selected based on a preliminary survey of the river. The first station (Station I) is located at the point of entrance of the river to the town with no visible evidence of surface run-off from the town. It has an elevation of 304.49 m above the sea level and a coordinate of $07^{\circ}24'40.3''\text{N}$ $07^{\circ}38'47.0''\text{E}$ (GPS). Station II is located immediately after Saint Charles's college, where the first major drainage channel that brings run-off from the town into the river is located. It has an elevation of 295.96 m above the sea level and a coordinate of $07^{\circ}24'17.9''\text{N}$ $07^{\circ}38'28.0''\text{E}$ (GPS). Station III is located at the bridge along Otukpo road and receives effluents

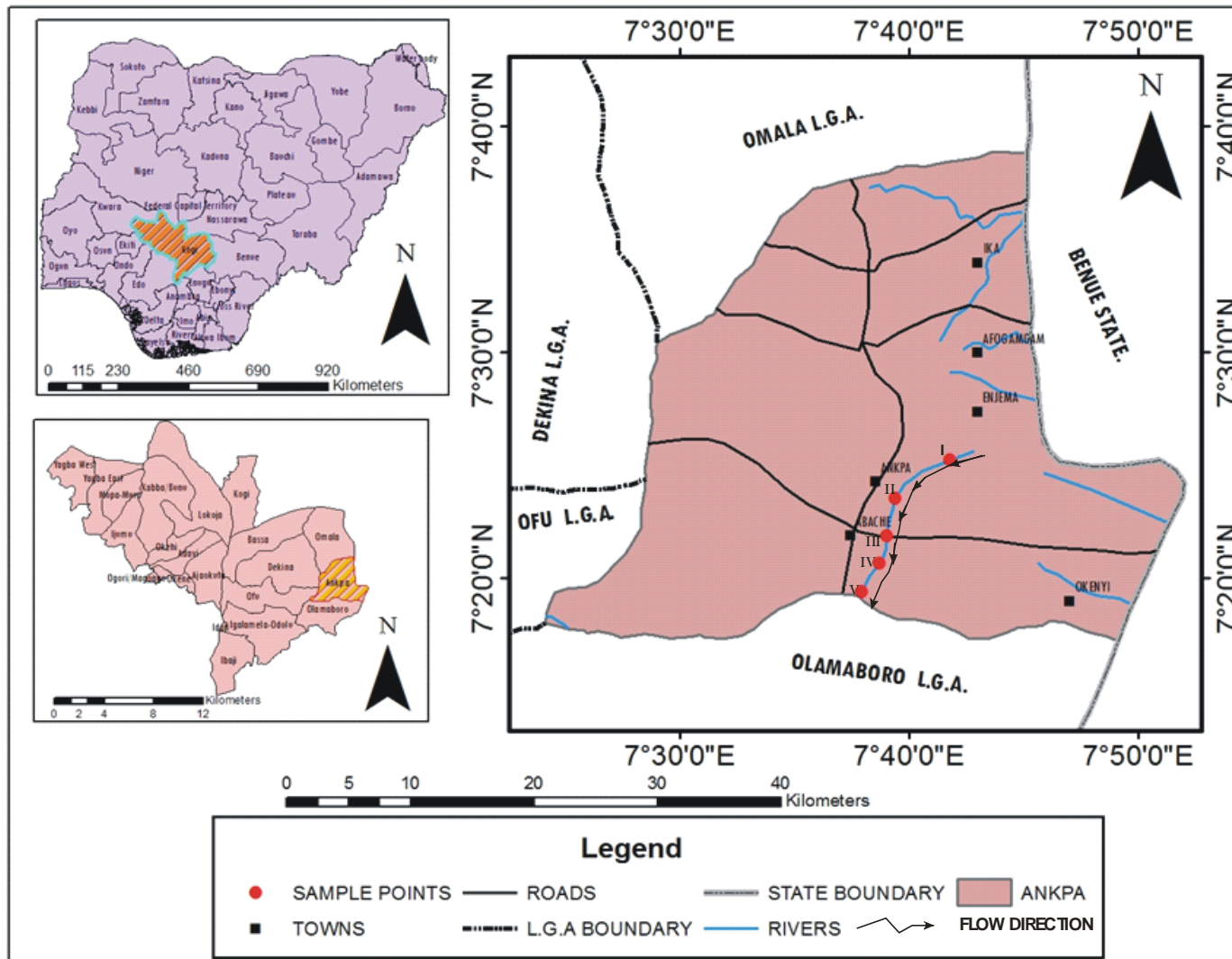


Figure 3.1: Study area showing Imaboro river and the sampling points
 Source: Modified from administrative map of Kogi State.

from mechanical and vehicular washers. It has an elevation of 298.40 m above the sea level and a coordinate of 07°24' 08.6"N 007°38' 19.6"E (GPS). Station IV is located at Owelle – Ankpa where the last major drainage channel that carries domestic and commercial effluents into the river is found. It has an elevation of 265.48 m above the sea level and a coordinate of 07°22' 20.7"N 007°37' 59.3"E (GPS). Station V is located at the bridge along Enugu road where the river finally leaves the town. It has an elevation of 311.81 m above the sea level and a coordinate of 07°21' 04.4"N 007°07' 41.9"E (fig. 3.1).

3.3 Sampling Procedure

Sampling was done from October 2012 to September 2013 (1 year). Duplicate water samples were collected from each site monthly for biological, physical and chemical analyses.

3.4 Physical and Chemical Parameters Determination

At each sampling station, water samples were taken, poured into appropriate sample containers, preserved according to APHA, (1995) and transported to the laboratory for analysis. Water temperature, pH and electrical conductivity were determined on the field. Dissolved oxygen (DO), biological oxygen demand (BOD), TDS, TSS and TS were determined at Chemistry Laboratory, Kogi State College of Education, Ankpa. Other analyses were done at Department of Biological Sciences Hydrobiology Laboratory, Ahmadu Bello University, Zaria.

3.4.1 Water temperature

Water temperature was measured using the portable Combo HANNA instrument water check (model HI 98129). The instrument was dipped in a water sample until a stable temperature value was displayed. Measurement was in degree Celsius (°C).

3.4.2 Water transparency

This was determined by the use of Secchi disc. The Secchi disc was lowered into the water at each station until it ceases to be visible. The depth of disappearance and appearance was measured to the nearest cm and the average taken. The depth at which it disappeared in the water (X1) and reappeared (X2) was noted. Measurement was in cm.

Estimation: The transparency of the water body was computed as follows:

Transparency (Secchi Disc Transparency) = $(X1 + X2) / 2$ (Ramachandra and Malvikaa, 2007).

Where, X1 = Depth at which Secchi disc disappears

X2 = Depth at which Secchi disc reappears

3.4.3 Water velocity

Velocity was determined using a measuring tape, a stop watch and a floating object (<http://www.geography-site.co.uk>). Five meters of a stretch of the river was measured and marked out at each sampling station. A float was made to travel the five meters and the time taken noted. This was done twice and the average time calculated in seconds. Velocity (m/s) was calculated by dividing the distance by the time.

3.4.4 Depth

A measuring rope with weight at one end was used to measure the water depth at each station. The rope was dipped into the water body and the length of the rope marked out. A measuring tape was used to determine the length of the rope which was the depth at that station. Measurement was in cm.

3.4.5 Water width

The width of the river was determined at each sampling station using a measuring tape. Measurement was determined to the nearest metre (m).

3.4.6 Water pH

The portable Combo HANNA instrument water check (model HI 98129) for pH, conductivity and TDS was used to determine the water pH. The instrument was dipped in a water sample until a stable pH value was displayed.

3.4.7 Electrical conductivity (EC)

The portable Combo HANNA instrument water check (model HI 98129) for pH, conductivity and TDS was used to determine the electrical conductivity of the water. The instrument was dipped in a water sample until a stable EC value was displayed.

3.4.8 Total dissolved solids (TDS)

This was determined by filtering 100ml of water sample through a filter paper. The filtrate was poured into a pre-weighed evaporating dish. The filtrate was evaporated to dryness in an oven at 103⁰C and cooled in a desiccator for at least 10 minutes. The dish containing filtrate residue was re-weighed and the amount of solids was calculated as Total Dissolved Solids on drying at 103⁰C (TS 103⁰C).

$$\text{TDS } 103^0\text{C} = \frac{W_2 - W_1}{\text{ml of sample}} \times 1000(\text{mg/l}) \text{ (APHA, 2002)}$$

Where,

W_1 = Initial weight of dish

W_2 = Weight of dish + residue after evaporation.

3.4.9 Total suspended solids (TSS)

This was determined by filtering 100ml of water sample through a pre-weighed filter paper. The residue retained on the filter is dried in an oven at 103 to 105°C until the weight of the filter no longer changes. The increase in weight of the filter represents the total suspended solids.

$$\text{TSS } 103^{\circ}\text{C} = \frac{W_2 - W_1}{\text{ml of sample}} \times 1000(\text{mg/l}) \text{ (APHA, 2002)}$$

Where,

W_1 =Initial weight of filter paper before filtration

W_2 =Final weight of filter paper and residue

3.4.10 Total solids (TS)

This was determined by pouring 100ml of water sample into a clean, dry, pre-weighed evaporating dish. The weight of dish containing the water sample was always taken. The water was evaporated to dryness in an oven at 103°C and cooled in a desiccator for at least 10 minutes. The dish containing water sample residue was re-weighed and the amount of solids was calculated as Total Solid on drying at 103°C (TS 103°C).

$$\text{TS } 103^{\circ}\text{C} = \frac{W_2 - W_1}{\text{ml of sample}} \times 1000(\text{mg/l}) \text{ (APHA, 2002)}$$

Where,

W_1 =Initial weight of dish without water

W_2 =Final weight of dish and content

3.4.11 Nitrate-nitrogen (NO₃-N)

The phenol-disuphonic acid method as described by APHA (1998) was used. In this method, 100ml of water sample was evaporated to dryness and 2ml of phenol-disuphonic acid was added to the residue and left for 10min. 15ml of distilled water was then added, followed by 5ml of strong ammonia solution. The resultant mixture

was stirred and allowed to cool. Setting the spectrophotometer at the wavelength of 410nm, absorbance was obtained against distilled water as blank. Nitrate-Nitrogen concentration was obtained from a calibration curve in mg/l (APHA, 1998).

3.4.12 Phosphate-phosphorus ($\text{PO}_4\text{-P}$)

Phosphate-phosphorus content of the water was determined by adding 1ml of ammonium molybdate and 5 drops of stannous chloride solution to 100ml of water sample and allowed to stand for 10min. Absorbance was taken at 690nm using spectrophotometer. Phosphate-Phosphorus concentration was obtained from a calibration curve in mg/l (APHA 1998).

3.4.13 Total hardness

The water hardness was determined by EDTA titrimetric method. The reagents needed were EDTA solution (0.01M), Buffer solution, Eriochrome Black-T indicator, Sodium hydroxide (1N) and Murexide indicator (ammonium purpurate).

1 ml each of buffer solution and inhibitor was added to 25 ml of the sample in a conical flask. One pinch of EBT indicator was then added to this solution. This was titrated against EDTA solution until the (wine red) pink colour changes to blue. The amount of titrant used was noted (APHA, 1998).

3.4.14 Total alkalinity

The alkalinity of the water was measured by sulphuric acid titrimetric method. The procedure involves the following:

25 ml of sample was taken in a conical flask, to which 2-3 drops of phenolphthalein indicator was added. If pink colour develops, this was titrated with 0.02 N H_2SO_4 till the colour disappears. The volume of H_2SO_4 needed was noted. To the same flask 2-3

drops of methyl orange indicator was added and titration is continued with 0.02 N H_2SO_4 till the yellow colour changes to pinkish orange. Again the volume of H_2SO_4 used was noted. In case the pink colour does not develop after addition of phenolphthalein, the titration was continued after adding methyl orange indicator.

Estimation:

P (phenolphthalein alkalinity), $\text{mg/L} = A \times 1000 / \text{ml of sample}$

T (total alkalinity), $\text{mg/l} = B \times 1000 / \text{ml of sample}$

In case H_2SO_4 is not 0.02 N, then the following formula is applied

Alkalinity, $\text{mg/l} = A / B \times N \times 50000 / \text{ml of sample}$

Where:

A = ml of H_2SO_4 required to change from pink to colourless with phenolphthalein indicator

B = ml of H_2SO_4 required to change from yellow to pinkish orange with methyl orange indicator

N = normality of H_2SO_4 used.

3.4.15 Dissolved oxygen

The modified Winkler's azide method (APHA, 1998) was used to determine dissolved oxygen. In this method, duplicate water samples collected in 250ml BOD stopper bottles was fixed in the field with 2ml standard manganous sulphate solution and 2ml alkaline-Iodide-Azide solution. The content was shaken for 10 seconds. 2ml of concentrated sulphuric acid (H_2SO_4) was added to the sample and the stopper replaced immediately to avoid air being trapped. The samples were then transported in a cooler to the laboratory. In the laboratory, 100ml of sample was transferred into 250ml conical flask and titrated against 0.0124M sodium thiosulphate solution until the colour changes to pale yellow. 2ml of starch solution (indicator) was then added and

further titrated to end point (indicated by appearance of colourless solution from the initial blue colour). The dissolved oxygen (mg/l) was obtained by 1:1 ratio, 0.0124N titrant to 1mg/L oxygen (APHA, 1998).

3.4.16 Biological oxygen demand (BOD)

After the determination of dissolved oxygen, the water sample was incubated in 250ml BOD bottles at 20⁰c for 5 days. On the 5th day, the dissolved oxygen of the incubated sample was determined.

$$\text{BOD}_5 \text{ (mg/L)} = \text{DO}_1 - \text{DO}_5 \text{ (mg/l)}$$

Where,

DO₁ =Dissolved oxygen concentration prior to incubation

DO₅ =Dissolved oxygen concentration after incubation (APHA, 1998).

3.5 Biological Parameters

The biological parameters sampled were phytoplankton, periphyton, zooplankton and benthos. Shannon Weiner Diversity Index and Palmers Pollution Index (1969) were used to determine the level of pollution.

3.5.1 Plankton sampling and analysis

Zooplankton and phytoplankton samples were collected with plankton net (net mesh size of 0.1 nm) of 25cm radius attached with a 50ml bottle at the base. The net was sunk and dragged just below the water surface to a distance of about 2m at each station. The content was poured into a small plastic bottle for preservation. Zooplankton was preserved in 4% formalin while phytoplankton was preserved in Lugol's iodine solution (WHO, 2000, APHA, 2002). Identification of the organisms was done with the aid of reference texts such as Barry and Catty (2000) and (Diatom Identification Chart) for the identification of diatoms; Edward and David (2010) and

Dunn (n.d) for the identification of algae and Harris *et al*, (2000) and (Zooplankton Methodology Manual) for the identification of zooplankton.

Counting was done by shaking the preserved sample and pipetting 1ml of it into a sedgewick rafter counting cell and then mounted on a microscope.

Individual alga was quantified and expressed per litre using the formulae:

$$(N= an/b) \text{ and } (D= N/V) \text{ (Adakole and Oladimeji, 1996)}$$

Where:

a = volume of sample

b = volume of sub sample

n = no. of species in sub sample

N = estimated no. of species per sample

D = abundance of species (individuals/litre)

V = volume (litres) of water originally filtered

3.5.2 Periphyton

The periphyton was collected by scraping stones, pebbles, wood, submerged plants and other materials found at the river substratum. Three samples were collected from each station (a sample each from the two sides and middle of the river). The sample was scraped from the substrate using a scalpel and a brush into a shallow dish and then preserved in a sample bottle using Lugol's solution (Karthick *et al.*, 2010).

3.5.3 Macrobenthic fauna

Sampling of benthos was done using Ekman Grab model 923 to collect the benthic fauna from the stations. The Grab measures 19cm by 14cm with an area of 0.0266m². At each station, 3 grabs were taken and the dredged materials washed through a standard sieve number 40 with 0.41mm mesh size. The residue was preserved in

plastic storage jars with 4% formalin prior to sorting and identification. Sorting was done by pouring the contents of each jar into a large, shallow plastic basin and enough water added to disperse the materials. The organisms were picked either with a pair of forceps or pipette. Dissecting and compound microscope was used to identify the specimens with the aid IOWATER Advanced Benthic Key (2005).

3.6 Statistical Analysis of Data

Data obtained was subjected to normality and homogeneity tests. Where data sets are not normally distributed, they were transformed ($\ln(x + 1)$) before further analyses. Factorial analysis of variance (ANOVA) was used to test for the effect of season, month and sampling stations on the physic-chemical parameters, phytoplankton and macro benthic invertebrate fauna composition. Tukey's HSD post hoc test was used to separate significantly different means. Principal component analysis (PCA) will be performed on the physico-chemical parameters to determine important determinant parameters.

Multivariate data analyses was performed on the plant and animal data set to explore the main gradients of floristic and fauna variation and to detect and visualize similarities in the samples. A preliminary detrended correspondence analysis (DCA) was applied to the phytoplankton and macro invertebrate community data set to determine the length of the gradient. Where DCA has three standard deviation units the use of unimodal ordination techniques (Ter Braak 1986) will be justified. Therefore, canonical correspondence analyses (CCA) with only one environmental variable at a time were performed to show the correlations between environmental variables and the biological parameters determined. Monte Carlo permutation tests (999 unrestricted permutations) was used to test for the significance of the axes and

hence determine if the selected environmental variables could explain nearly as much variation in the biological data set as all the environmental variables combined. Shannon-Weiner's diversity index was performed on the biological parameters to determine their density.

Analysis of variance was done using Statistica 8.0 for windows; DCA, CCA and Monte Carlo permutation tests was done using Canoco 4.5. All analyses were done at 95% confidence interval ($p < 0.05$).

CHAPTER FOUR

4.0

RESULTS

This chapter deals with presentation of results of the study. Tables and figures were used to aid the presentation.

4.1 Water Temperature

The mean monthly temperature of Imaboro river is as shown in Table 4.1. There was a rise in temperature from $27.16 \pm 0.16^{\circ}\text{C}$ in October to $27.24 \pm 0.36^{\circ}\text{C}$ in November. Temperature dropped to $23.24 \pm 0.39^{\circ}\text{C}$ in December from where there was a steady rise to $28.36 \pm 0.19^{\circ}\text{C}$ in March after which there was temperature fluctuations till September (table 4.1). The lowest temperature value of $23.24 \pm 0.39^{\circ}\text{C}$ was recorded in December and the highest in March ($28.36 \pm 0.19^{\circ}\text{C}$). Mean temperature value between stations showed station 1 with the lowest temperature value of $25.94 \pm 0.44^{\circ}\text{C}$ while the highest value of $26.95 \pm 0.38^{\circ}\text{C}$ was recorded at station 2 (Table 4.2). There was however, no wide variation in temperature between stations (Fig 4.1). The analysis of variance of mean temperature between stations revealed that station 1 is significantly different ($p < 0.05$) from all other stations; there was no significant difference between stations 2 and 3 just like stations 4 and 5 are statistically the same ($p \geq 0.05$) (Table 4.2). Independent t-test to determine the effects of seasons on the physicochemical parameters revealed that temperature did not show significant difference ($p \geq 0.05$) between wet and dry season (Table 4.3).

Table 4.1: Comparison of physico-chemical parameters of Imaboro river between months of the study period.

Parameters	Months											
	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Temp (°C)	27.16±0.16cd	27.24±0.36cd	23.24±0.39h	26.82±0.22d	27.96±0.25ab	28.36±0.19a	27.20±0.26cd	27.56±0.25bc	25.82±0.29ef	26.22±0.15e	25.40±0.26fg	25.26±0.21g
Transp (cm)	59.30±9.41a	59.20±9.35a	54.60±6.45a	56.10±3.00a	48.10±4.63a	47.00±4.84a	48.50±5.02a	52.72±2.28a	40.80±7.24a	39.80±9.16a	48.50±2.14a	57.80±7.21a
TSS (mg/l)	n.d	n.d	n.d	n.d	200.00±0.00b	300.00±0.00a	200.00±0.00b	300.00±0.00a	120.00±12.25c	260.00±24.49ab	100.00±68.24c	120.00±12.25c
TDS (mg/l)	n.d	n.d	n.d	n.d	220.00±20.00b	160.00±24.49bc	180.00±20.00bc	820.00±335.26a	220.00±73.48b	40.00±24.49d	100.00±0.00c	100.00±0.00c
TS (mg/l)	n.d	n.d	n.d	n.d	420.00±20.00b	460.00±24.49b	380.00±20.00bc	1120.00±335.26a	340.00±65.95bc	300.00±31.62cd	200.00±63.24d	220.00±12.25d
Depth (cm)	60.40±10.07a	60.50±10.13a	62.60±10.36a	68.70±14.32a	50.70±6.89a	58.80±16.03a	50.00±6.28a	56.92±6.18a	63.80±12.22a	52.70±2.06a	64.80±12.64a	65.10±12.54a
Width (m)		12.72±2.93a	12.72±2.93a	11.42±2.56ab	10.82±2.51ab	11.36±1.96ab	9.76±2.24b	9.84±2.21b	9.84±2.21b	9.74±2.24b	9.30±1.89b	9.30±1.89b
Velocity (m/s)	0.17±0.05e	0.17±0.05e	0.17±0.05e	0.28±0.11de	0.43±0.17bcd	0.62±0.19ab	0.38±0.09cd	0.50±0.03abc	0.27±0.11de	0.66±0.09a	0.40±0.13dc	0.54±0.03abc
pH	5.83±0.19cd	5.76±0.14d	5.71±0.11d	5.70±0.13d	5.75±0.11d	5.75±0.11d	5.80±0.12cd	5.83±0.12cd	5.98±0.18b	5.99±0.17b	5.91±0.17bc	6.19±0.17a
EC (µS/cm)	26.40±6.64abc	20.00±3.58c	17.80±3.54c	18.80±4.39c	24.40±3.60bc	23.40±4.40bc	24.20±4.60bc	23.00±5.26bc	26.40±6.42abc	31.80±5.96ab	21.60±5.38c	34.60±10.27a
DO (mg/l)	4.38±0.26ab	4.62±0.45a	4.24±0.43abc	4.12±0.20abcd	3.06±0.19e	2.96±0.17e	3.42±0.40bcde	3.78±0.11abcd	4.10±0.75abcd	3.15±0.14de	3.54±0.33bcde	3.24±0.14cde
BOD (mg/l)	1.06±0.21bcd	1.42±0.46bcd	1.68±0.38bcd	1.30±0.23bcd	0.80±0.13cd	0.84±0.10cd	0.96±0.16cd	0.82±0.12cd	2.70±0.77a	0.66±0.13d	1.76±0.22abc	2.00±0.41ab
Total Hardness CaCO ₃ (mg/l)	35.20±1.96abcd	25.60±2.40cde	22.80±2.42de	30.40±2.64bcde	48.00±8.10a	39.60±8.11abc	38.40±5.31abc	20.80±2.94e	41.60±5.46ab	18.40±2.40e	39.20±1.96abc	36.00±1.79abcd
Alkalinity CaCO ₃ (mg/l)	13.20±3.18a	8.20±0.97abc	9.60±1.36abc	9.00±1.76abc	4.75±0.95c	6.60±1.29bc	10.20±2.90abc	7.50±1.50abc	9.75±2.78abc	8.80±1.93abc	12.00±2.26ab	7.20±1.16bc
NO ₃ -N (mg/l)	20.00±3.69ab	11.50±0.67cde	13.20±1.52bcde	9.60±2.28de	9.50±1.79de	13.80±2.73bcde	16.80±1.23bcd	18.20±1.29abc	12.70±2.64bcde	7.20±0.73e	14.40±4.40bcde	24.80±1.39a
PO ₄ -P (mg/l)	1.83±0.09bcd	1.50±0.08de	2.34±0.04a	1.95±0.25bc	1.82±0.11bcd	1.96±0.02bc	2.10±0.04ab	1.47±0.17e	1.64±0.06cde	1.64±0.06cde	1.34±0.14e	1.00±0.07f

Means with the same letter along rows are not significant at p ≤ 0.05 level of significance

Note: DO= Dissolved Oxygen, BOD= Biological Oxygen Demand, TSS= Total Suspended Solids, TDS= Total Dissolved Solids, TS= Total Solids, NO₃-N= Nitrate-nitrogen, PO₄-P= Phosphate-phosphorus, EC= Electrical Conductivity n.d= Not Determined.

Table 4.2: Some physico-chemical parameters of a stretch of Imaboro river.

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5
Temperature (°C)	25.94±0.44c	26.97±0.43a	26.95±0.38a	26.30±0.43b	26.44±0.42b
Transparency (cm)	61.88±2.98a	59.79±5.48a	35.71±2.98b	48.25±2.11a	53.29±3.14a
TSS (mg/l)	125.00±37.18b	133.33±37.10a	133.33±37.10a	141.67±35.80a	133.33±33.33a
TDS(mg/l)	100.00±40.82b	191.67±112.45a	176.00±104.54a	200.00±112.14a	100.00±30.15b
TS (mg/l)	225.00±59.19b	325.00±135.33a	308.33±126.85a	341.67±134.53a	233.33±55.50b
Depth (cm)	61.88±2.98b	94.00±6.23a	40.54±1.97d	48.25±2.11cd	53.29±3.14c
Width(m)	10.54±0.98b	17.29±1.69a	8.29±1.17c	6.32±0.58d	6.22±0.77d
Velocity (m/s)	0.02±0.01b	0.02±0.01b	0.51±0.08a	0.40±0.04a	0.39±0.05a
pH	5.57±0.03c	5.59±0.03c	5.73±0.06b	6.22±0.06a	6.15±0.06a
EC (µS/cm)	12.50±0.80c	15.58±2.30c	22.25±2.00b	37.25±1.90a	34.25±3.21a
DO (mg/l)	4.06±0.31a	3.70±0.18a	3.07±1.8a	4.02±0.20a	3.78±0.29a
BOD (mg/l)	1.11±0.17a	1.60±0.23a	1.03±0.22a	1.61±0.35a	1.32±0.28a
Total Hardness					
CaCO ₃ (mg/l)	29.27±3.17a	33.50±4.89a	30.67±3.36a	34.17±3.42a	37.00±3.35a
Toall Alkalinity					
CaCO ₃ (mg/l)	6.78±1.24c	6.00±0.99c	9.58±0.95ab	11.67±1.57a	10.33±1.18a
NO ₃ -N (mg/l)	11.42±2.07a	14.29±2.42a	14.38±1.45a	16.00±1.56a	15.46±a
PO ₄ -P (mg/l)	1.64±0.13a	1.69±0.13a	1.78±0.11a	1.63±0.13a	1.75±0.13a

Note:

Means with the same letter are not significant at p < 0.05 level of significance

EC= Electrical Conductivity

DO= Dissolved Oxygen

BOD= Biological Oxygen Demand

TSS= Total Suspended Solids

TDS= Total Dissolved Solids

TS= Total Solids

NO₃-N= Nitrate-nitrogen

PO₄-P= Phosphate-phosphorus.

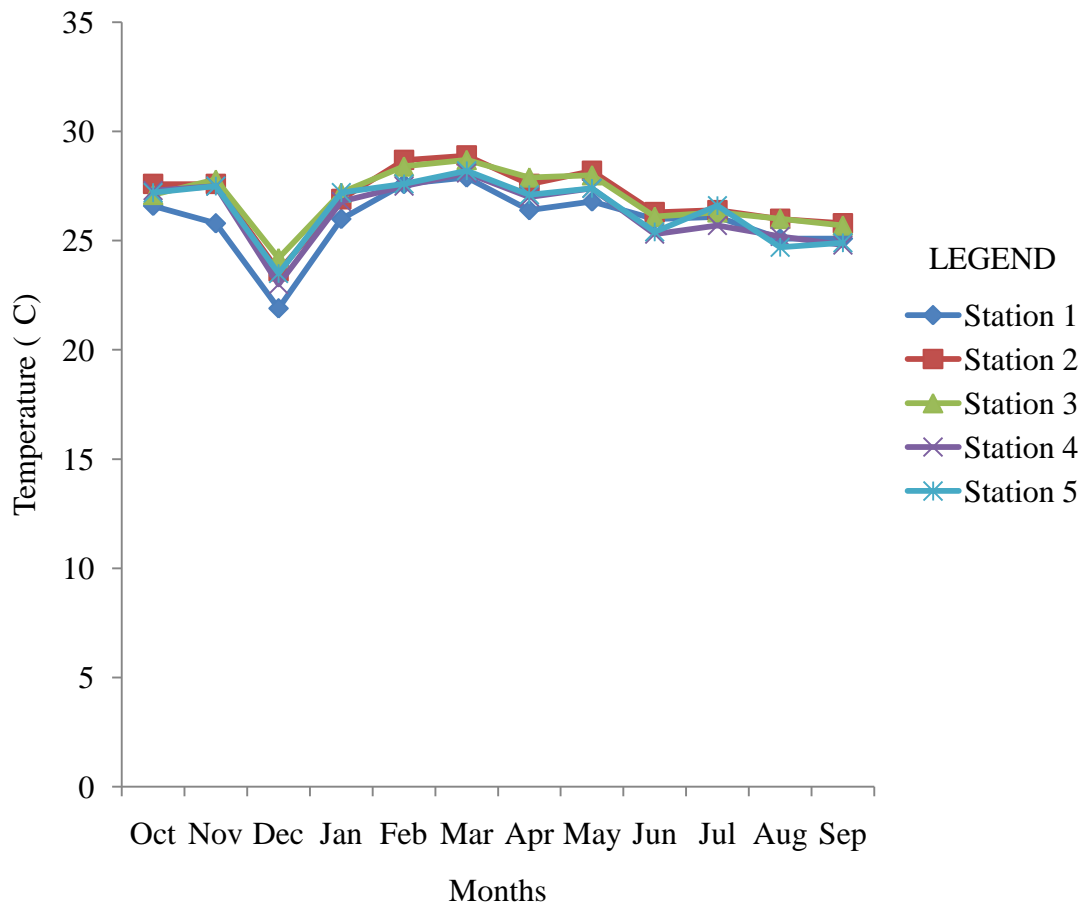


Figure 4.1: Mean monthly variations in temperature along stations on a stretch of Imaboro river.

Table 4.3: Seasonal variations in physico-chemical parameters of a stretch of Imaboro river.

Parameters	dry Season	wet Season	p value
Temperature (°C)	26.72±1.84	26.57±1.02	0.695
Transparency (cm)	53.00±4.70	49.77±7.03	0.577
TSS (mg/l)	200.00±0.00+	200.00±16.73	0.925
TDS(mg/l)	220.00±20.00+	231.00±78.98	0.673
TS (mg/l)	420.00±20.00+	431.00±95.69	0.546
Depth (cm)	60.26±6.15	59.12±5.60	0.758
Width(m)	11.81±7.734	9.63±2.36	0.00**
Velocity (m/s)	0.33±1.70	0.42±1.52	0.441
pH	5.74±2.59	5.93±1.24	0.01*
Conductivity (µS/cm)	20.88±2.94	20.86±4.58	0.032*
DO (mg/l)	3.80±0.67	3.66±0.42	0.69
BOD (mg/l)	1.21±3.40	1.42±6.89	0.572
Total Hardness CaCO ₃ (mg/l)	33.16±9.31	32.8±8.60	0.935
Total Alkalinity CaCO ₃ (mg/l)	7.63±1.76	9.81±2.05	0.11
NO ₃ -N (mg/l)	11.53±1.78	16.3±5.20	0.102
PO ₄ -P (mg/l)	1.91±0.43	1.57±0.33	0.112

*= Significant (p< 0.05)

+ = One month was used for dry season value

4.2 Water Transparency

The mean monthly transparency of Imaboro river is as shown in Table 4.1. The mean monthly transparency showed slight variations in all the months and stations. The highest transparency value of 59.30 ± 9.41 cm was recorded in October while the lowest value of 39.80 ± 9.16 cm was recorded in July. Comparison between stations showed that station two had the highest transparency value of 80.50 cm in October while station three showed the least transparency value of 15.00 cm in July (Fig 4.2). The analysis of variance (ANOVA) showed that transparency values were not statistically different throughout the months (Table 4.1). Independent t-test between seasons revealed that transparency showed no significant difference at $p < 0.05$ (table 4.3).

4.3 Total Suspended Solids

The mean monthly total suspended solids (TSS) value of Imaboro river is as shown in table 4.1. The mean monthly TSS showed great fluctuations between the highest value of 300.00 ± 0.00 mg/l and 100.00 ± 68.24 mg/l (Tale 4.1). The highest mean TSS value was recorded in May while the lowest value was recorded in August. The highest TSS value of 300.00 mg/l was recorded in all the stations as well as the lowest value (Fig 4.3). Lower values of TSS were recorded more in the dry months than in the rainy month (Table 4.3). The ANOVA between stations showed no significant difference ($p \geq 0.05$) in the TSS (Table 4.2).

4.4 Total Dissolved Solids

The mean monthly total dissolved solids (TDS) value of Imaboro river is as shown in Table 4.1. There were wide variations in the mean monthly TDS value of the study area. The lowest mean monthly value of 40.00 ± 24.49 mg/l was recorded in July

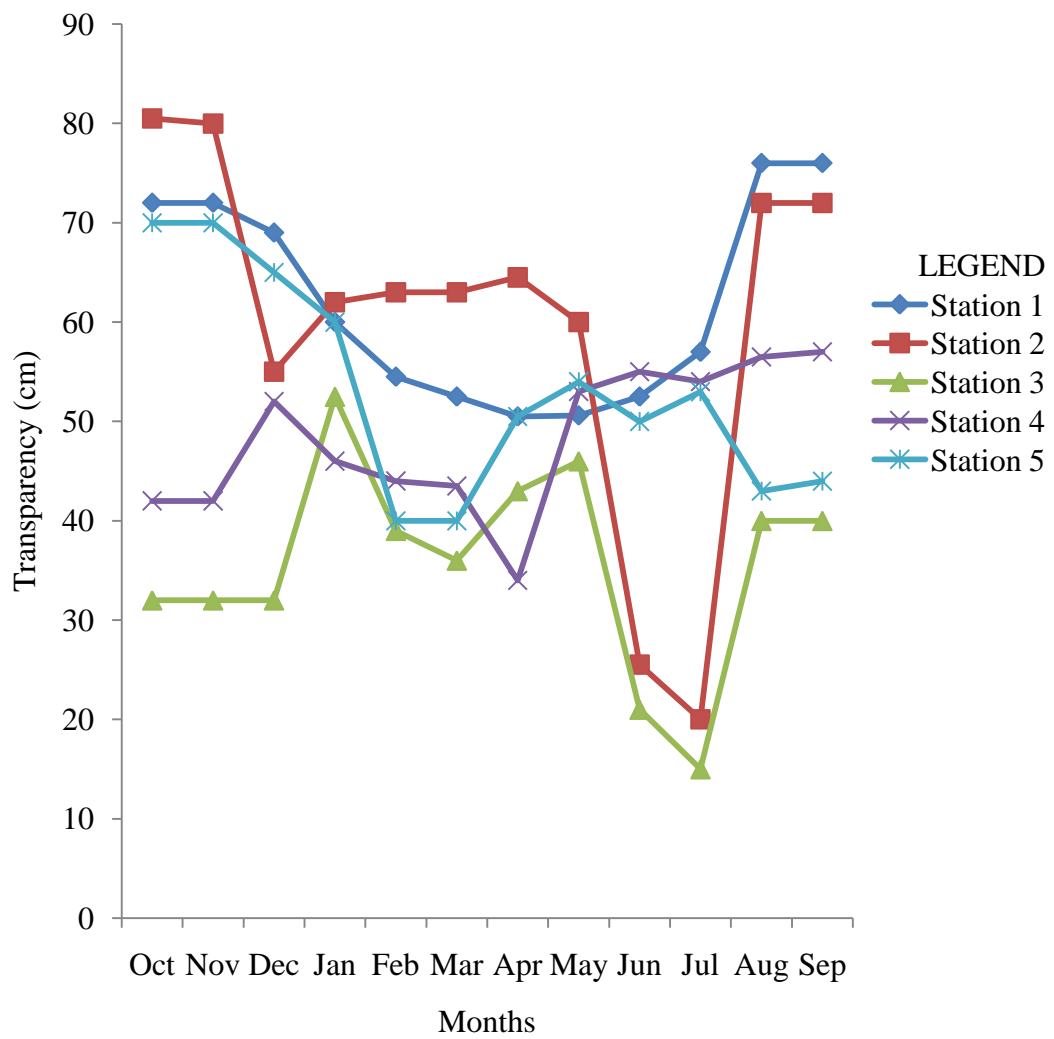


Figure 4.2: Mean monthly variations in transparency along stations on a stretch of Imaboro river

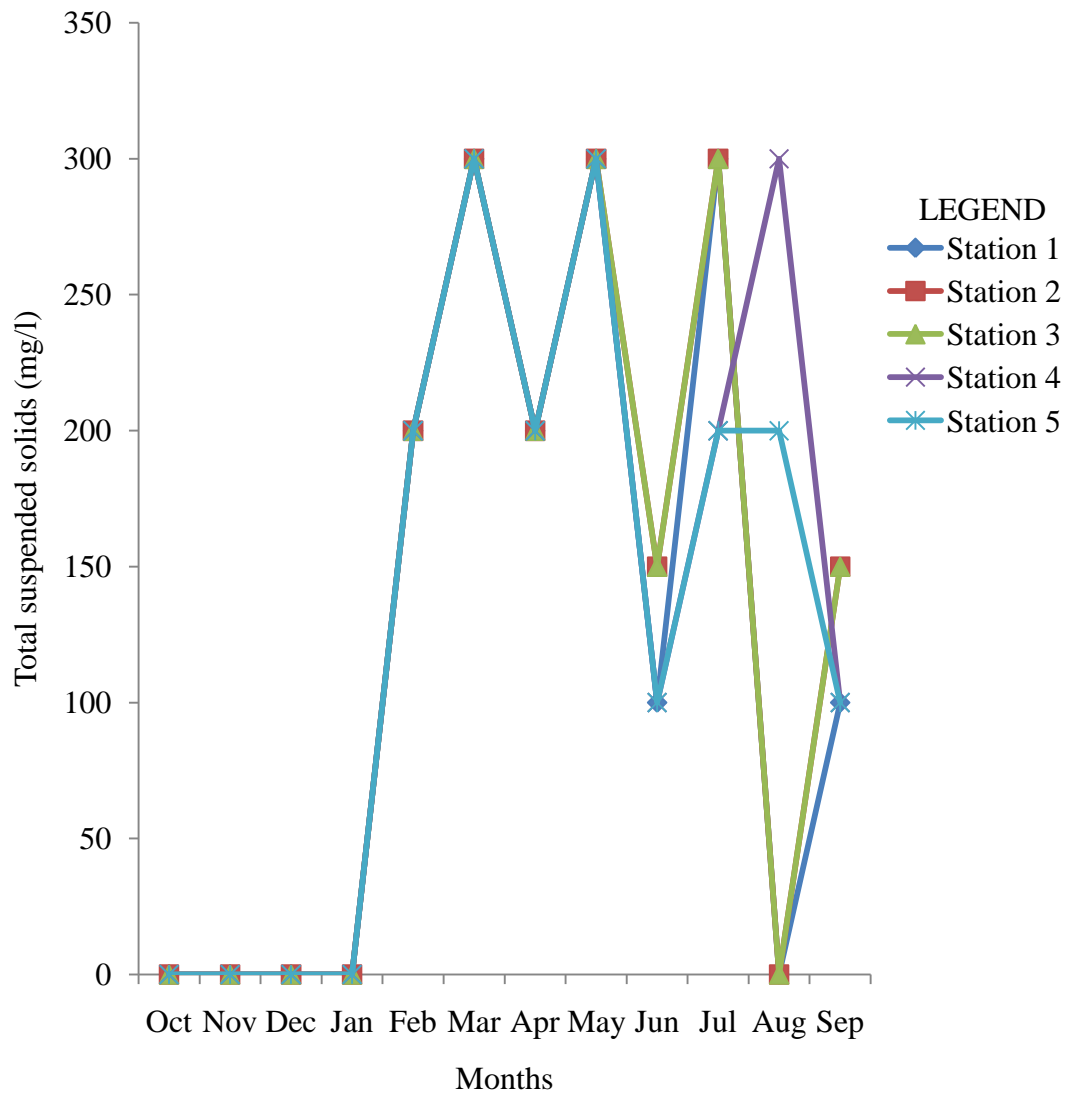


Figure 4.3: Mean monthly variations in total suspended solids along stations on a stretch of Imaboro river.

while the highest value of 820.00 ± 335.26 mg/l was observed in May. Comparison between stations revealed that stations two, three and four showed the highest TDS value of 1400.00 mg/l in May (Fig 4.4). The ANOVA of TDS between stations showed that there is no significant difference ($p \geq 0.05$) between station 1 and 5. Also, there is no significant difference ($p \geq 0.05$) between station 2, 3, and 4 (Table 4.2).

4.5 Total Solids

The mean monthly total solids (TS) value of Imaboro river is as shown in table 4.1. The mean TS value fluctuated between the lowest (200.00 ± 63.24 mg/l) in August and the highest (1120.00 ± 335.26 mg/l) in May (Table 4.1). Comparison between stations revealed that stations two and four showed the highest TDS value of 1700.00 mg/l each in May (Fig 4.5). The ANOVA of TS between stations showed that station 1 and 5 were not significantly different ($p \geq 0.05$) as also shown in stations 2, 3 and 4 (Table 4.2).

4.6 Water Depth

The mean monthly depth of Imaboro river is as shown in Table 4.1. The lowest mean monthly depth value of 50.00 ± 6.28 cm was recorded in April while the highest value of 68.70 ± 14.32 cm was recorded in January (Table 4.1). There were slight variations in the mean monthly depth values of station 1, 3, 4 and 5. But station 2 showed great fluctuation in its mean monthly depth values (Fig 4.6). Comparison between stations revealed that station 2 had the greatest mean depth value of 125.00 cm in January while station 3 had the lowest value of 32.00 cm in October, November and December (Fig 4.6). The ANOVA of mean monthly depth value showed no significant difference ($p \geq 0.05$) between all the months (Table 4.1), but the ANOVA

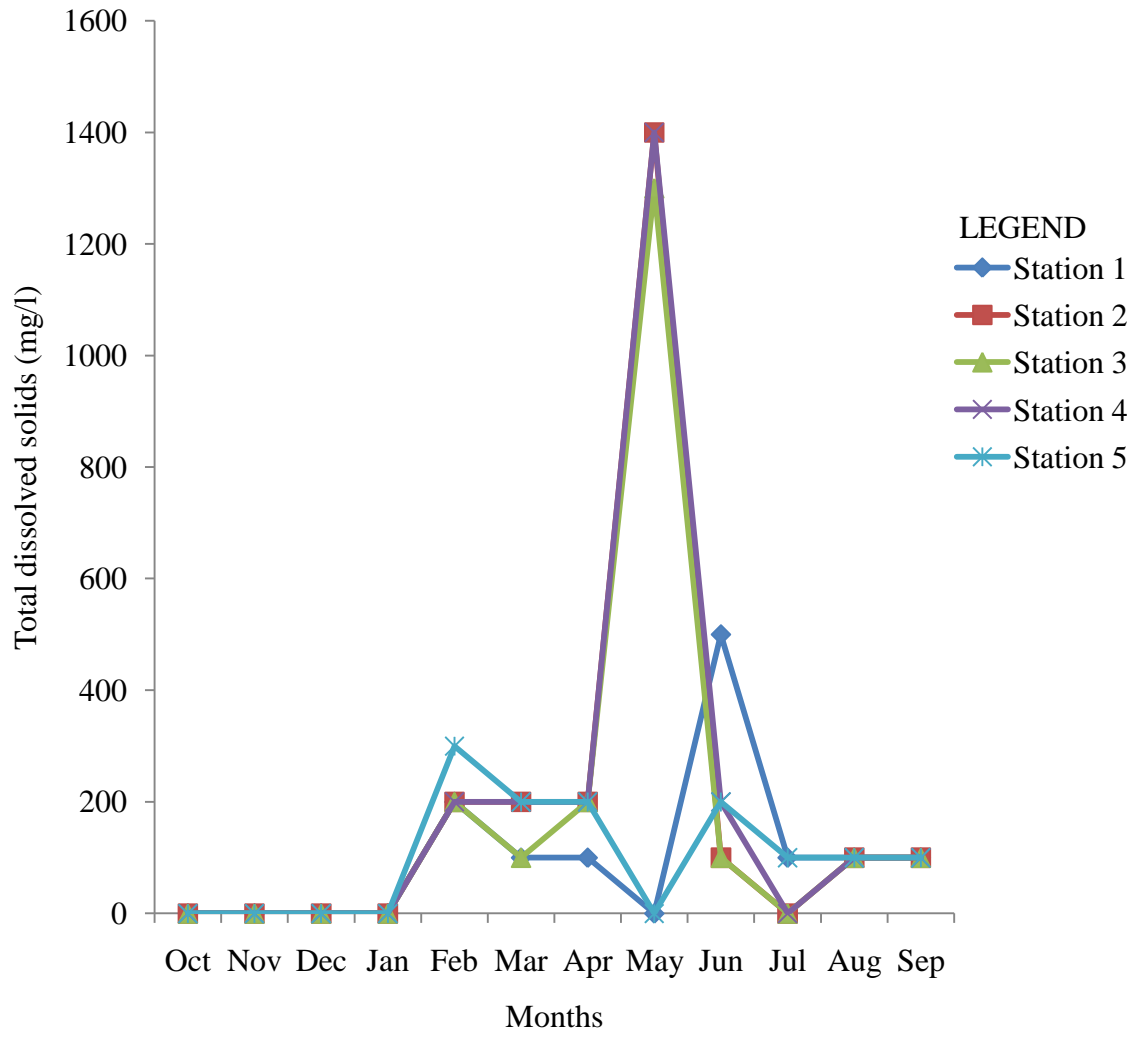


Figure 4.4: Mean monthly variations in total dissolved solids along stations on a stretch of Imaboro river.

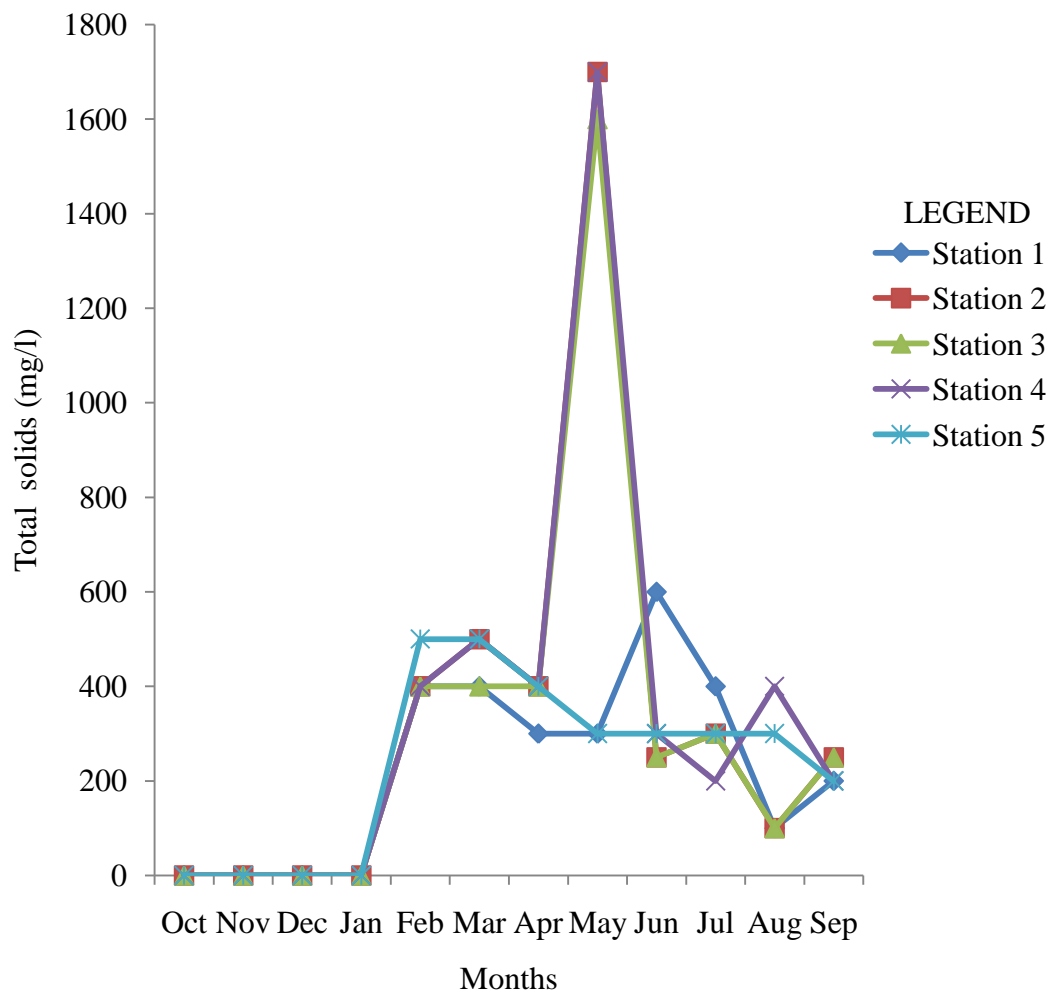


Figure 4.5: Mean monthly variations in total solids along stations on a stretch of Imaboro river.

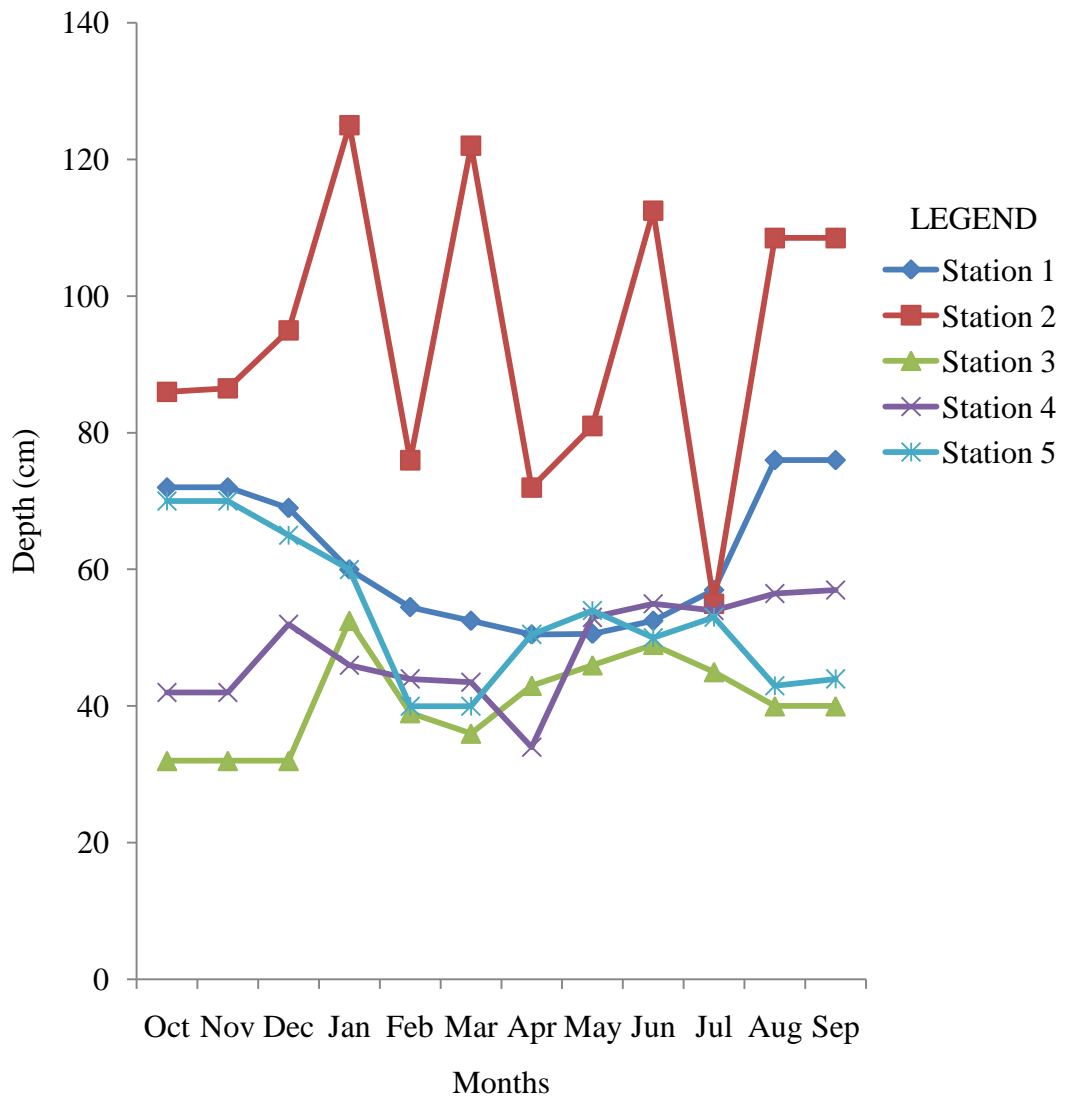


Figure 4.6: Mean monthly variations in depth along stations on a stretch of Imaboro river.

between stations showed significant difference ($p < 0.05$) between all the stations with the lowest mean value of 40.54 ± 1.97 cm at station 3 and highest mean depth value of 94.00 ± 6.23 cm at station 2. Comparison between seasons revealed that depth showed no significant difference ($p > 0.05$) (Table 4.3).

4.7 Water Width

The mean monthly width value of Imaboro river during the study period is as shown in Table 4.1. The lowest mean monthly width value of 9.30 ± 1.89 m was found in August and September while the highest value of 12.72 ± 2.93 m was recorded in November and December. ANOVA between months shows that there was no significant difference ($p > 0.05$) between the mean width values of November, December, January, February and March. The months of January – September also showed no significant difference ($p > 0.05$) in their mean width values (Table 4.1). Station 5 showed the least width value (6.22 ± 0.77 m) while station 2 had the highest width value of 17.29 ± 1.69 m (Fig. 4.7). The analysis of variance of the mean width values between stations showed that there was no significant difference between stations 4 and 5 but stations 1, 2, 3, and 4 differed significantly ($p < 0.05$) (Table 4.2). Independent t-test between seasons revealed that width showed a highly significant difference ($p < 0.05$) (Table 4.3).

4.8 Water Velocity

The mean monthly velocity value of Imaboro river is as shown in Table 4.1. The mean monthly velocity values showed no significant difference ($p > 0.05$) between October, November, December, January and June. But October, November, December and January showed significant difference ($p > 0.05$) from other months. March, May, July and September showed no significant difference. In the same way,

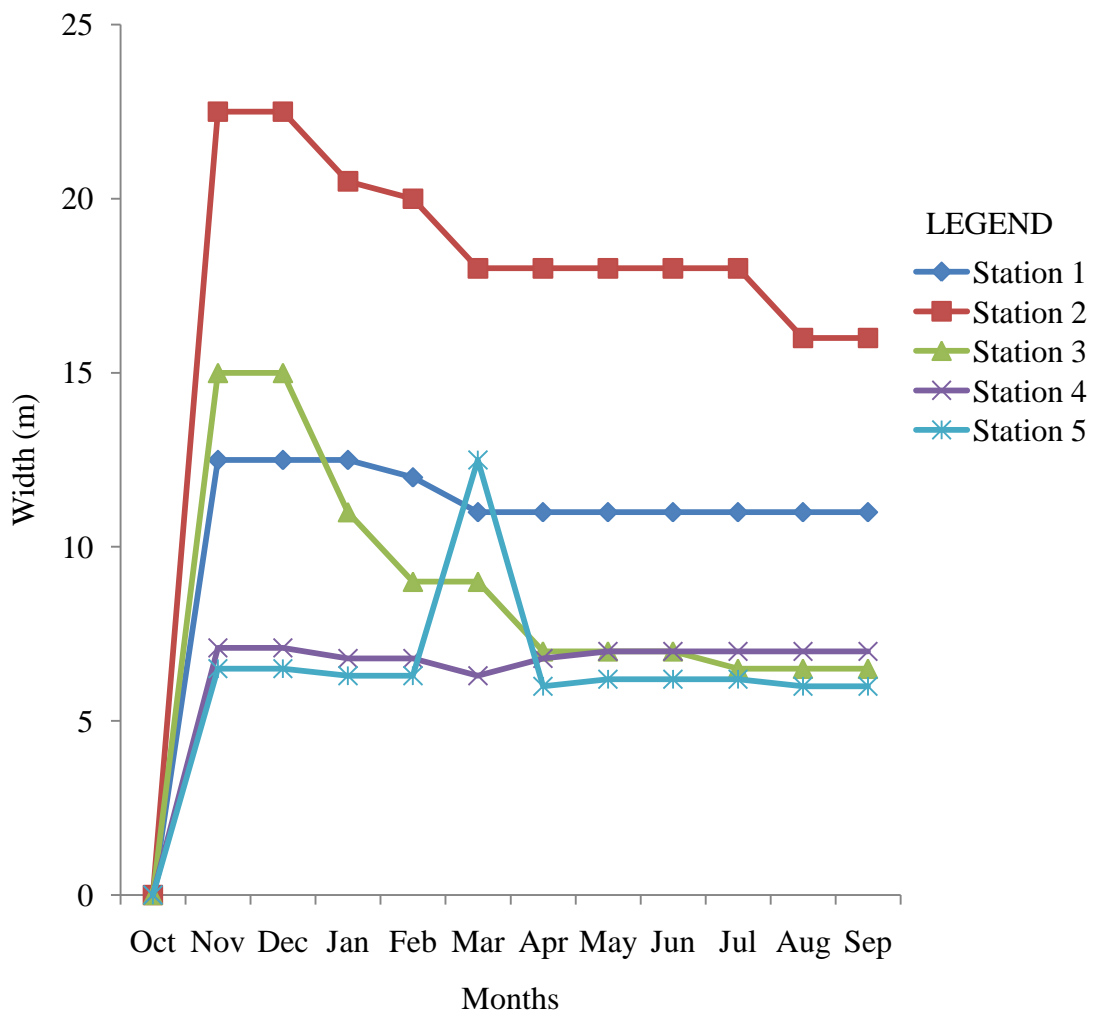


Figure 4.7: Mean monthly variations in width along stations on a stretch of Imaboro river.

January, February, April June and August showed no significant difference ($p>0.05$). The highest mean monthly velocity value of 0.66 ± 0.09 m/s was observed in July while the lowest value of 0.17 ± 0.05 m/s was recorded in October, November and December (Table 4.1). Comparison between stations revealed that the lowest velocity value was recorded at stations 1 and 2 while the highest value of 1.00 m/s was recorded at station 3 in March (Fig 4.8). Analysis of variance between stations showed that there was no significant difference between stations 1 and 2 and also between stations 2, 3 and 4. There was no significant difference in the velocity values between seasons (Table 4.3).

4.9 Water pH

There was a steady drop in the mean monthly pH value from 5.83 ± 0.19 in October to 5.6 ± 0.14 in November, down to 5.71 ± 0.11 in January before there was a steady rise till July (Table 4.1). Stations 1 and 2 showed lower pH value than other stations while stations 4 and 5 showed higher pH values than others (Fig 4.9). Table 4.2 showed that pH value varied between 5.57 and 6.22. There was significant difference ($p<0.05$) between the mean monthly pH values with the highest value of 6.19 ± 0.17 in September and lowest value of 5.70 ± 0.13 in January. Comparison between stations showed that there was no significant difference ($p>0.05$) between stations 1 and 2 and also between stations 4 and 5. Station 2 showed a significant difference ($p<0.05$) from the other stations (Table 4.2). Comparison between seasons showed a significant difference ($p<0.05$) with a higher value in the wet season than the dry season (Table 4.3).

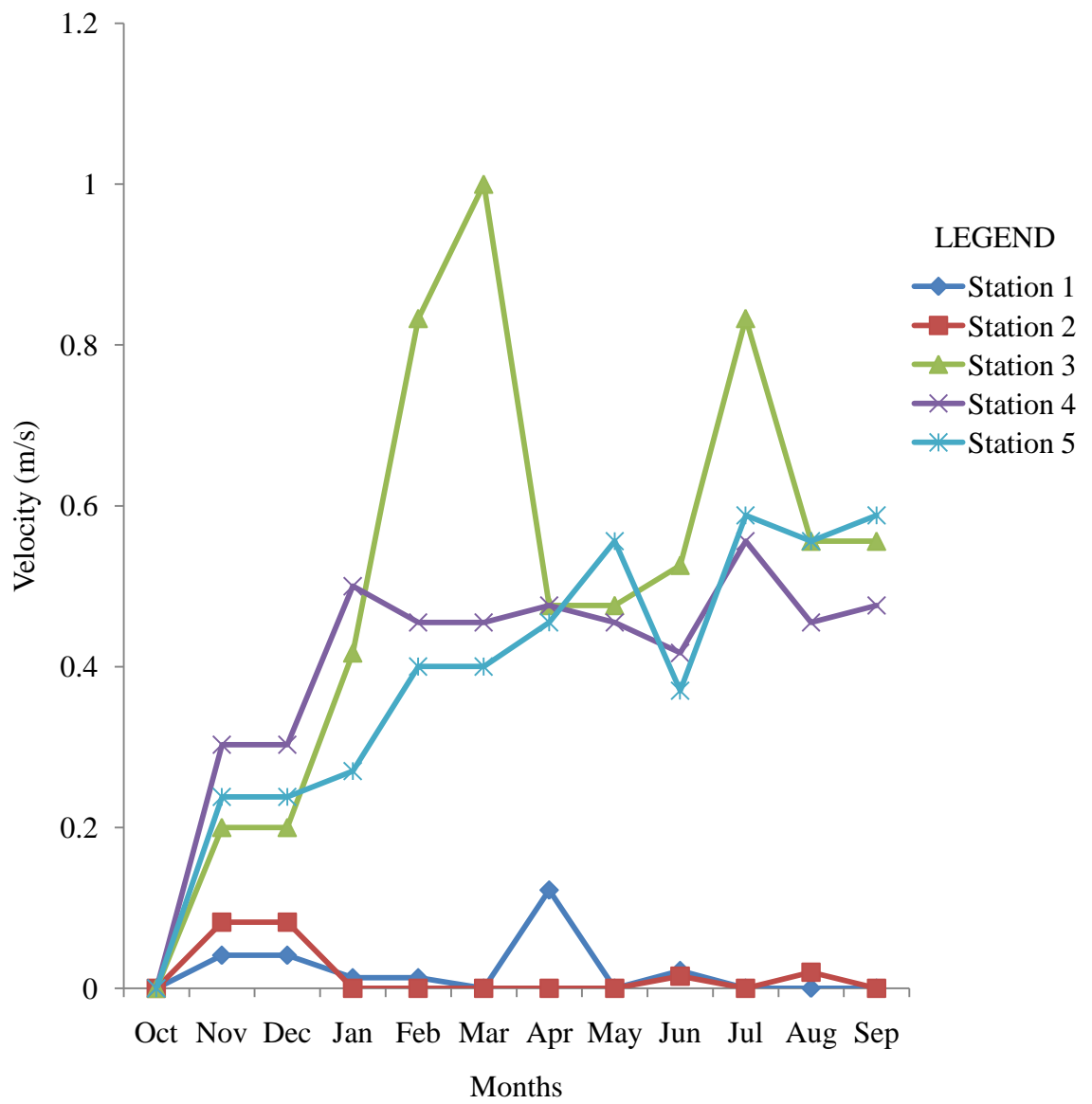


Figure 4.8: Mean monthly variations in velocity along stations on a stretch of Imaboro river.

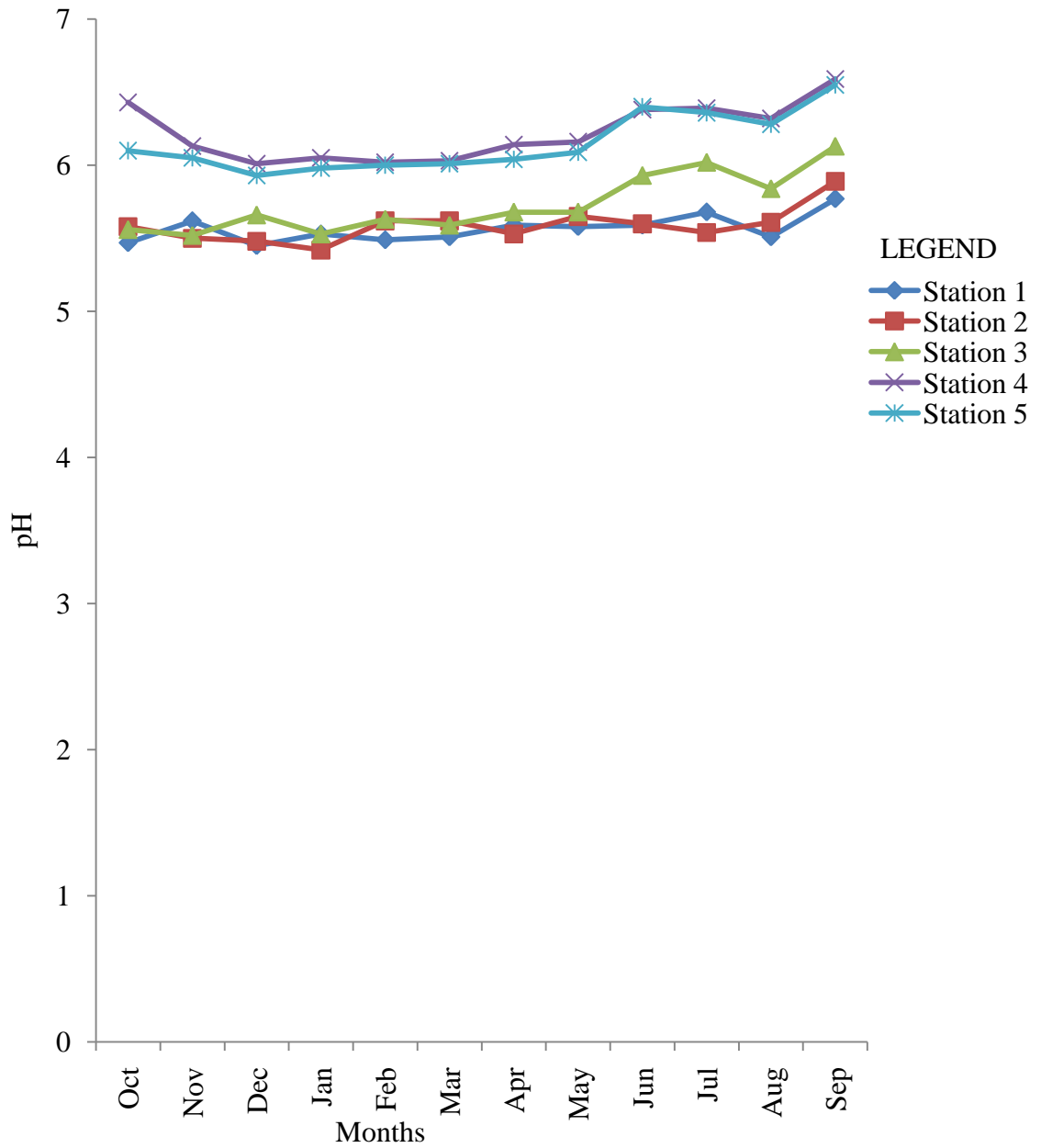


Figure 4.9: Mean monthly variations in pH along stations on a stretch of Imaboro river.

4.10 Electrical Conductivity

The mean monthly conductivity value of Imaboro river is as shown in Table 4.1. There was no significant difference between the month of June, July September and October but these were significantly different ($p>0.05$) from other months. There was also no significant difference ($p>0.05$) between April, May, June, July and October. The highest mean monthly value of 34.60 ± 10.27 $\mu\text{S}/\text{cm}$ was recorded in September while the lowest mean monthly value of 17.80 ± 3.54 $\mu\text{S}/\text{cm}$ was recorded in December (Table 4.1). Higher values were recorded in stations 4 and 5 than other stations (Fig 4.10). Station 5 showed the highest conductivity value in September. Analysis of variance of conductivity revealed that there was significant difference ($p<0.05$) between months (Table 4.1), stations (Table 4.2) and seasons (Table 4.3)

4.11 Dissolved Oxygen (DO)

The mean monthly DO values of Imaboro river is as shown in Figure 4.11. There was a steady fall in the DO value from 4.12 ± 0.20 mg/l in January to 2.96 ± 0.1 mg/l in March and a gradual rise from 2.96 ± 0.1 mg/l in March to 4.10 ± 0.75 mg/l in June. From June there was a fall to 3.15 ± 0.14 mg/l in July, a rise to 3.54 ± 0.33 mg/l in August and a fall again to 3.24 ± 0.14 mg/l in September. The highest mean DO value of 4.62 ± 0.45 mg/l was recorded in November while the lowest value of 2.90 ± 0.17 mg/l was recorded in March (Table 4.1). Fig 4.11 showed that station 1 had the highest DO value in November while station 3 had the lowest value in June. Analysis of variance of DO revealed that there was significant difference ($p<0.05$) between months, stations but analysis between seasons showed no significant difference ($p>0.05$) (Tables 4.1, 4.2 and 4.3).

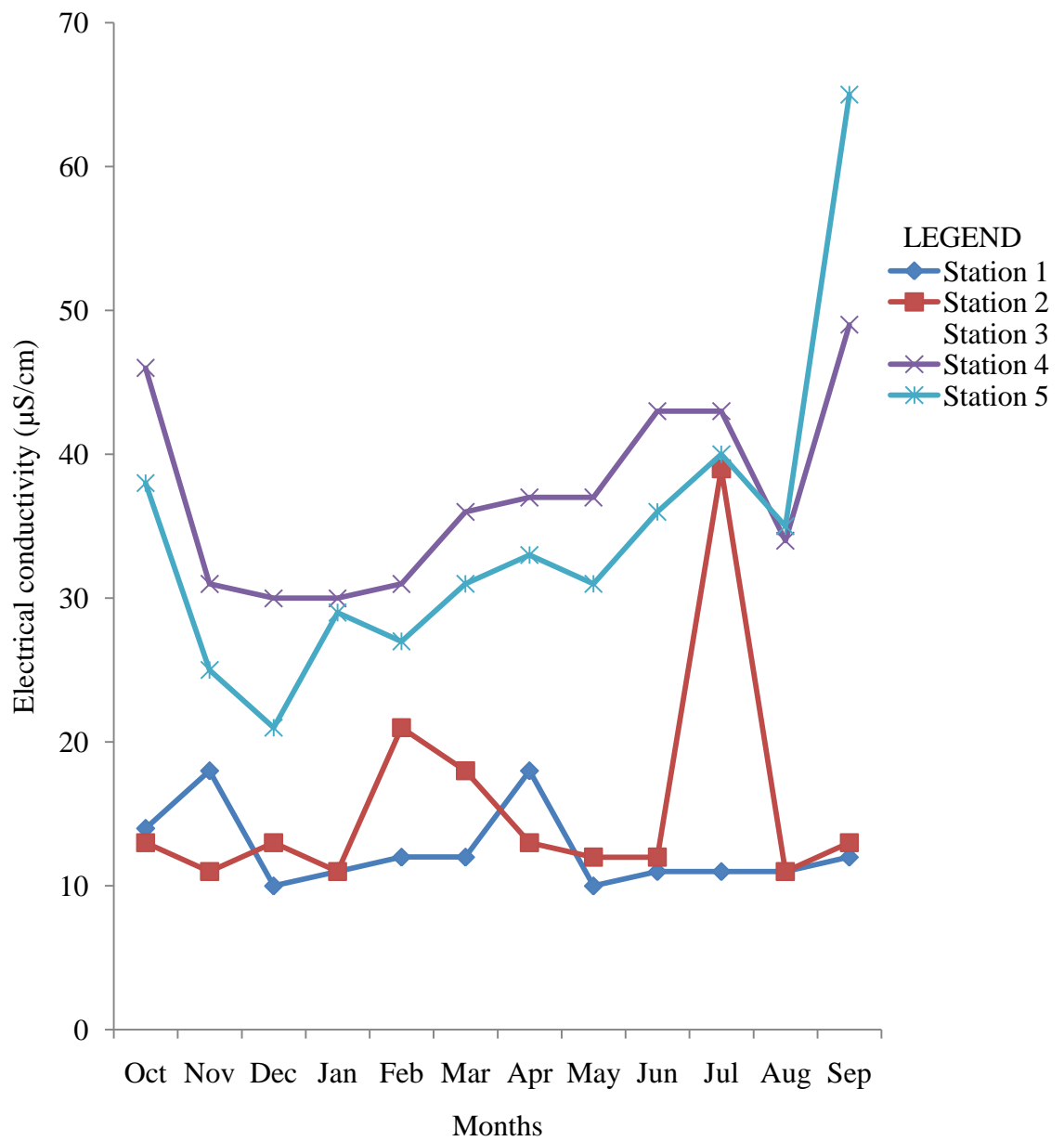


Figure 4.10: Mean monthly variations in electrical conductivity along stations on a stretch of Imaboro river

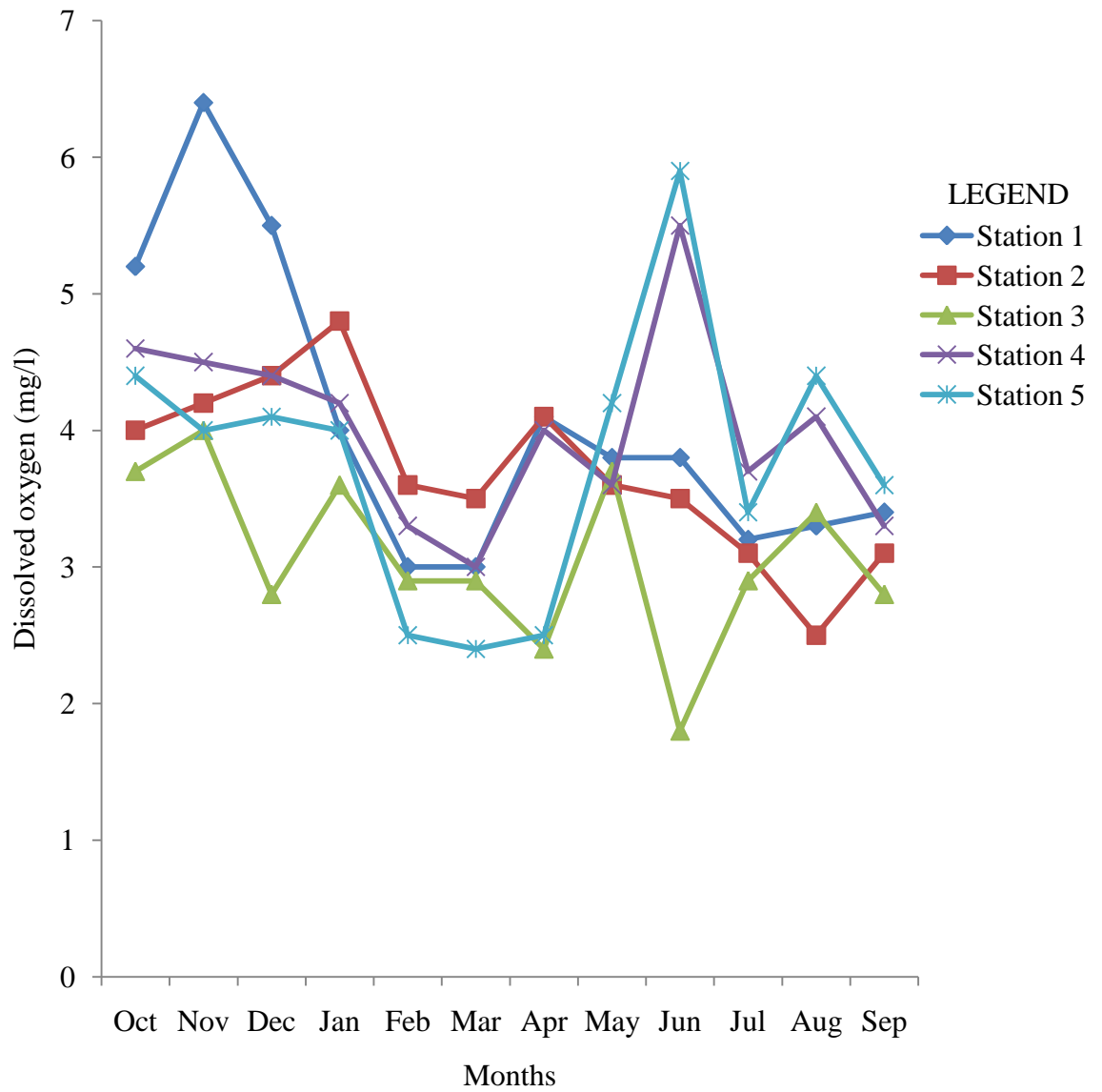


Figure 4.11: Mean monthly variations in dissolved oxygen along stations on a stretch of Imaboro river

4.12 Biological Oxygen Demand (BOD)

The mean monthly BOD value of Imaboro river is as shown in Table 4.1. There was marked fluctuation of BOD values throughout the months. The highest mean BOD value of 2.70 ± 0.77 mg/l was recorded in June and the lowest value of 0.66 ± 0.13 mg/l in July (Table 4.1). Fig 4.12 showed that station 4 had the highest BOD value (4.6mg/l) in June while station 3 had the lowest value (0.2mg/l) in November. The analysis of variance of BOD revealed that there was significant difference between months but no significant difference ($p > 0.05$) between the stations and seasons (Tables 4.1, 4.2 and 4.3).

4.13 Total Hardness

The mean monthly hardness value of Imaboro river is as shown in Table 4.1. The mean monthly hardness value showed marked fluctuations between 48.00 ± 8.10 mg/l (highest value) in February and 18.40 ± 2.40 mg/l (lowest value) in July (Table 4.1). Comparison between stations revealed that station 2 had the highest hardness value of 80.00 mg/l in February while stations 1, 3, 4 and 5 showed the lowest value of 16.00 mg/l at different months (Fig 4.13). The analysis of variance showed significant difference between months (Table 4.1) but no significant difference ($p < 0.05$) between the stations and the seasons (Table 4.2 and 4.3).

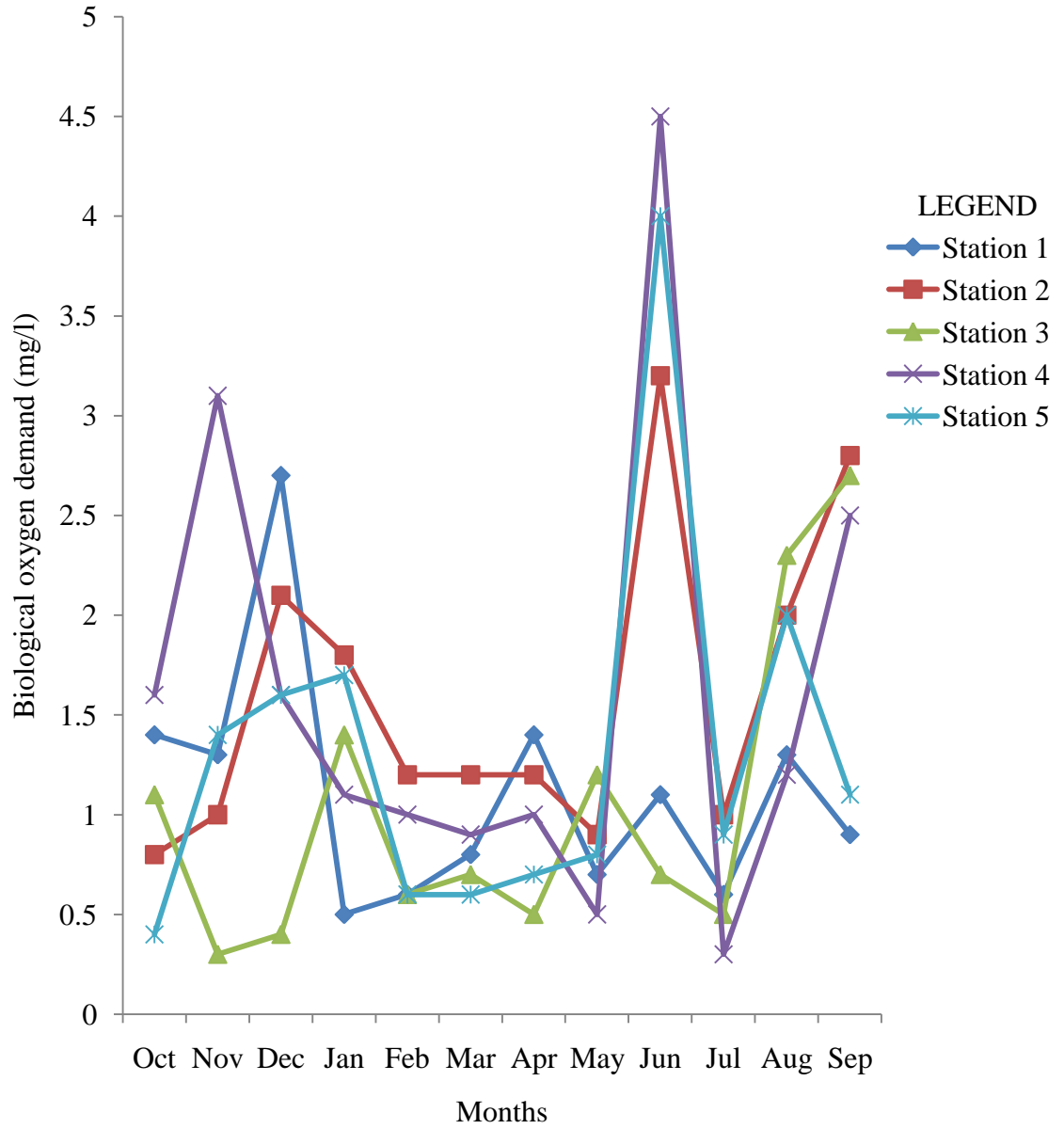


Figure 4.12: Mean monthly variations in biological oxygen demand along stations on a stretch of Imaboro river

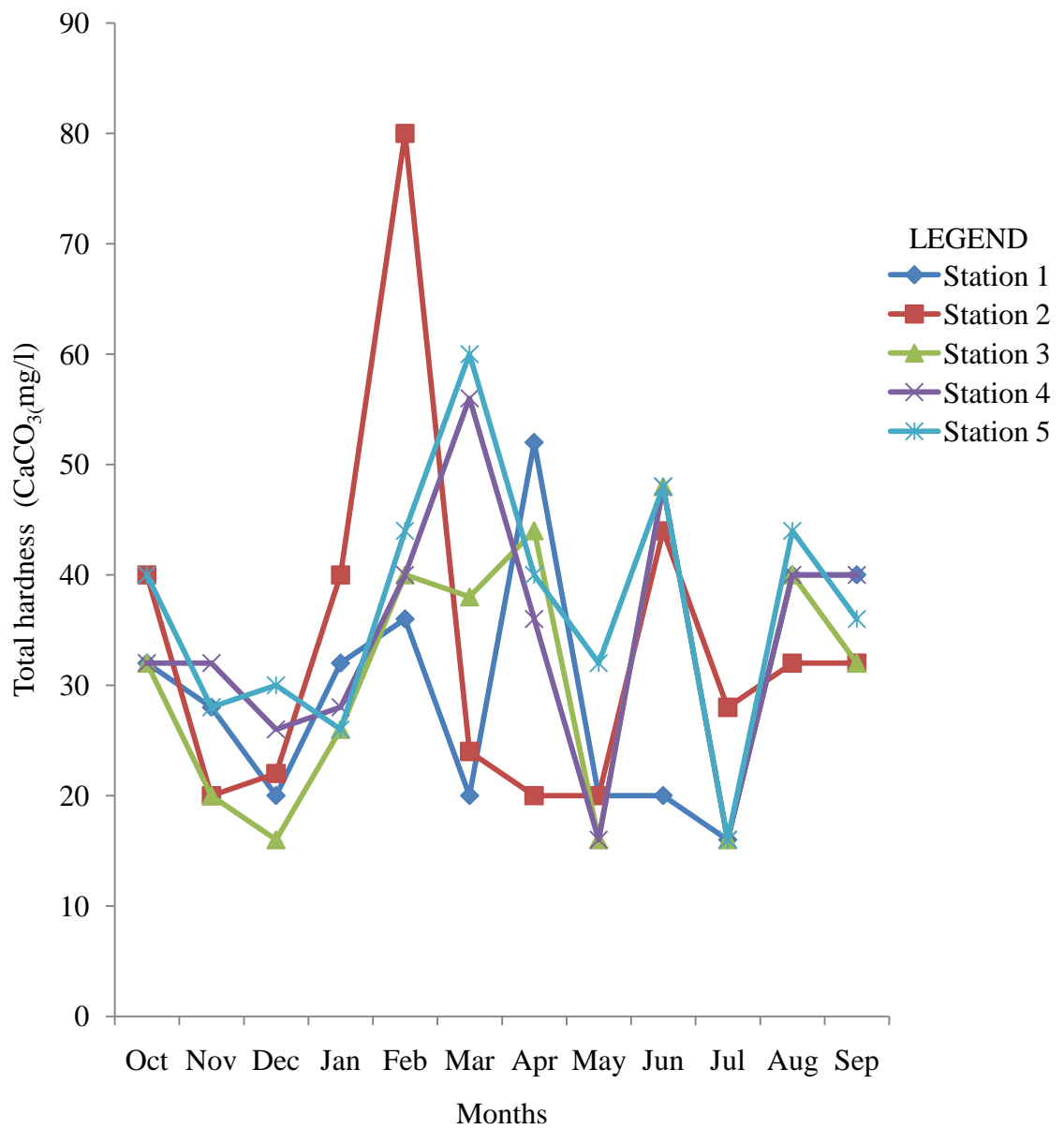


Figure 4.13: Mean monthly variations in total hardness along stations on a stretch of Imaboro river

4.14 Total Alkalinity

The mean monthly alkalinity value of Imaboro river is as shown in Table 4.1. There were marked fluctuations in the mean monthly alkalinity value during the study period (Table 4.1). The lowest alkalinity value of 4.75 ± 0.95 mg/l was recorded in February while the highest value of 13.20 ± 3.18 mg/l was recorded in October (Fig 4.14). Comparison between stations revealed that station 4 had the highest alkalinity value of 24.00 mg/l in October while station 2 had the lowest alkalinity value of 2.00 mg/L in February (Fig 4.14). The analysis of variance showed significant difference ($p < 0.05$) between months (Table 4.1). There was also significant difference ($p < 0.05$) between stations but no significant difference between seasons at the same level of significance (Table 4.3).

4.15 Nitrate-Nitrogen (NO₃-N)

The mean monthly Nitrate-Nitrogen (NO₃-N) value of Imaboro river is as shown in Table 4.1. NO₃-N showed a slight fall in mean monthly NO₃-N value from 9.60 ± 2.28 mg/l in January to 9.50 ± 1.79 mg/l in February from where there was a steady rise till May. From May the value dropped from 18.20 ± 1.2 mg/l to 7.20 ± 0.73 mg/l in July and rose again to 14.40 ± 4.40 mg/l in August and 24.80 ± 1.39 mg/l in September. There was a fall in NO₃-N in October and November and a slight rise in December (Table 4.1). Comparison between months revealed that station 2 had the highest NO₃-N value of 34.00 mg/l in October while station 1 had the lowest value of 4.00 mg/l in March (Fig. 4.15). The analysis of variance showed significant difference ($p < 0.05$) between months (Tables 4.1) but no significant difference ($p > 0.05$) between the stations and the seasons (Tables 4.2, and 4.3).

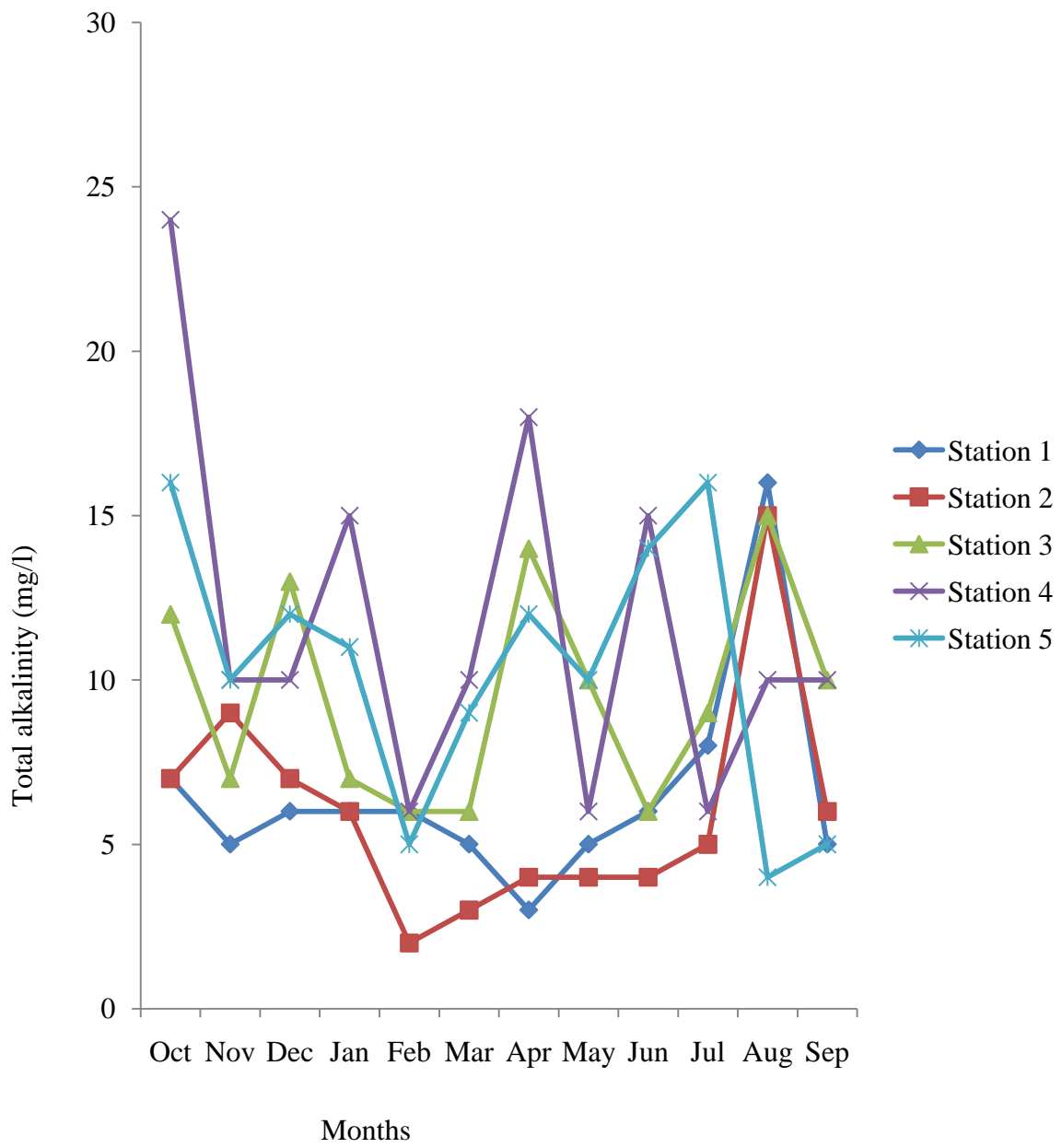


Figure 4.14: Mean monthly variations in total alkalinity along stations on a stretch of Imaboro river

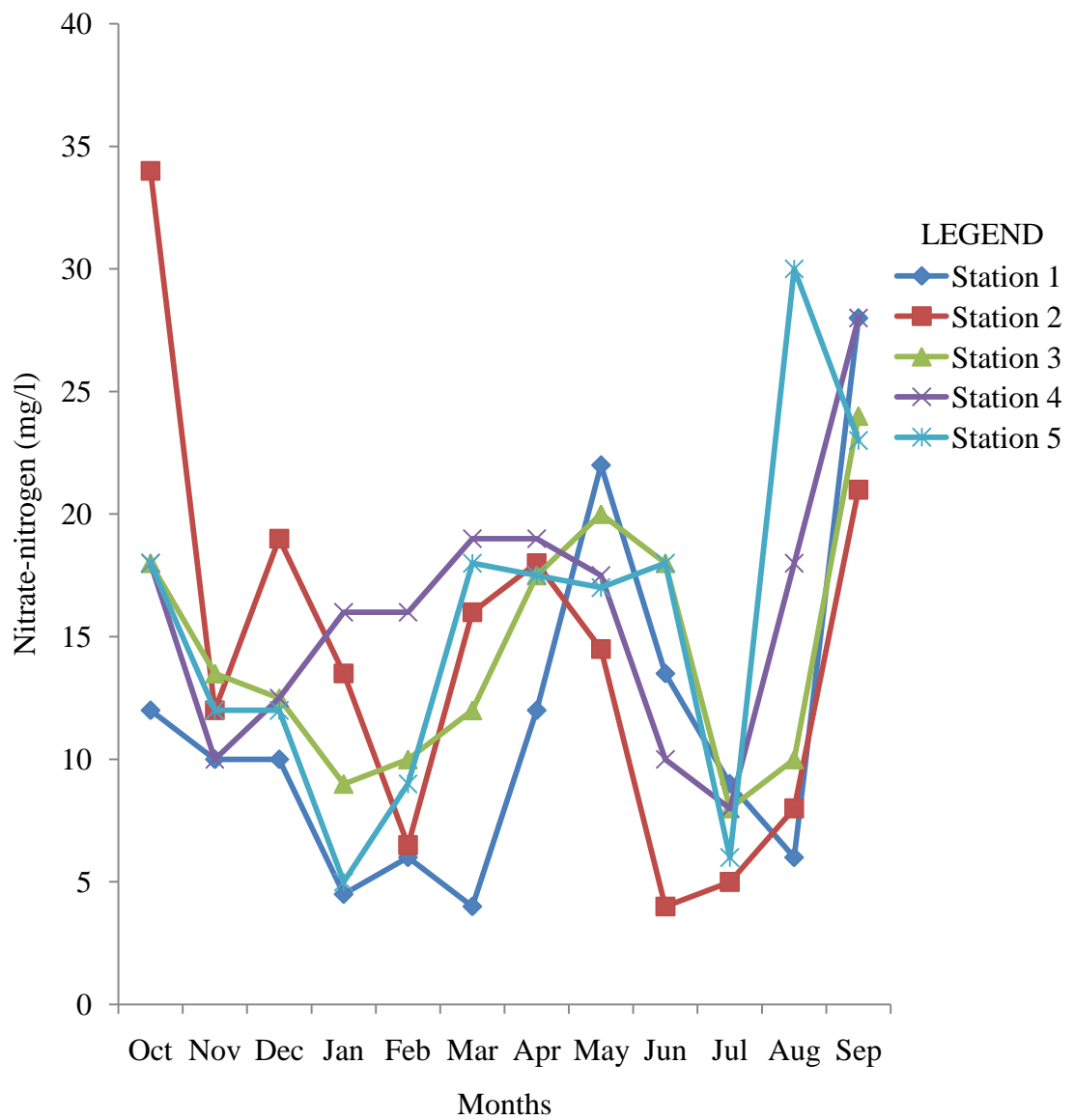


Figure 4.15: Mean monthly variations in $\text{NO}_3\text{-N}$ along stations on a stretch of Imaboro river

4.16 Phosphate-Phosphorus (PO₄-P)

The mean monthly Phosphate-Phosphorus (PO₄-P) value of Imaboro river is as shown in Figure 4.16. PO₄-P showed fluctuations in the monthly mean values. The lowest value of 1.00±0.07 mg/l was recorded in September while the highest value of 2.34±0.04 mg/l was recorded in December (Table 4.1). Comparison between stations revealed that stations 1, 2 and 3 showed the highest PO₄-P value of 2.40 mg/l. The analysis of variance showed significant difference between months (Tables 4.1) but no significant difference between the stations and the seasons at p<0.05 (Tables 4.2 and 4.3).

The principal component analysis (PCA) of all the physicochemical parameters showed that hardness, conductivity, PO₄-P, TSS TS, width, velocity and temperature showed positive correlation while alkalinity, BOD, DO transparency and TDS had positive correlations (Figure 4.17). The first axis accounted for 92.99% of the parameters (Figure 4.17). The eigenvalues of the first four axes were 0.928, 0.059, 0.009 and 0.002 (Appendix VIII).

4.17 Macrobenthic Fauna

Table 4.5 shows a checklist of macrobenthic fauna identified during the period of study. A total of 134 individuals of 13 families grouped into six orders were identified. Chironomidae larvae had the highest occurrence of 108 individuals (80.6%) and 1353 individuals/m² (Table 4.4). The relative abundance of other families ranges between 13 – 100 individuals/m². The highest number of occurrence was found at station 3 in the month of April while no occurrence was recorded at all stations in July, August and September (Fig. 4.18). The occurrence of macrobenthic fauna was higher in the dry season (1078 individuals/m²) than in the rainy season

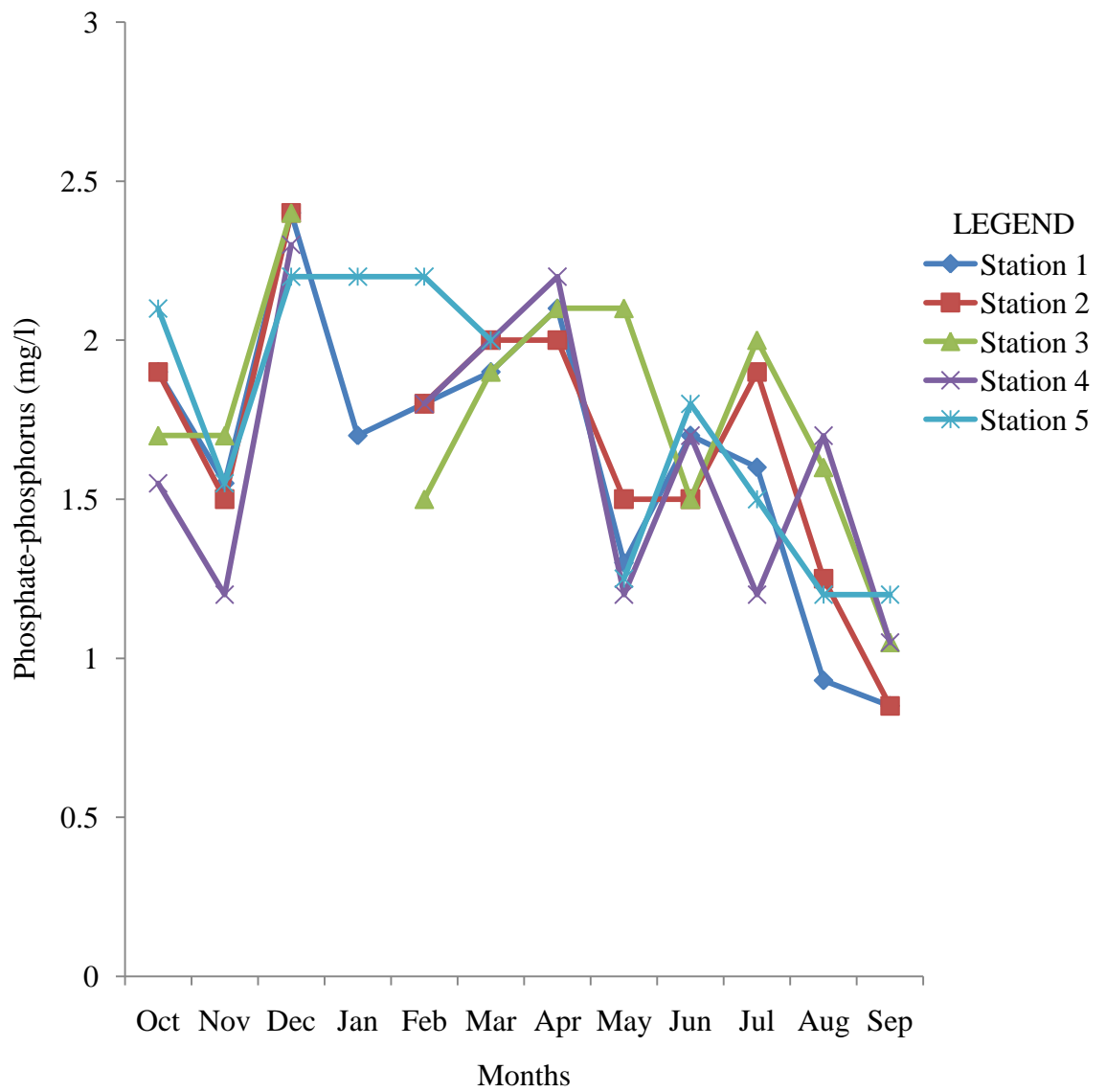


Figure 4.16: Mean monthly variations in PO₄-P along stations on a stretch of Imaboro river

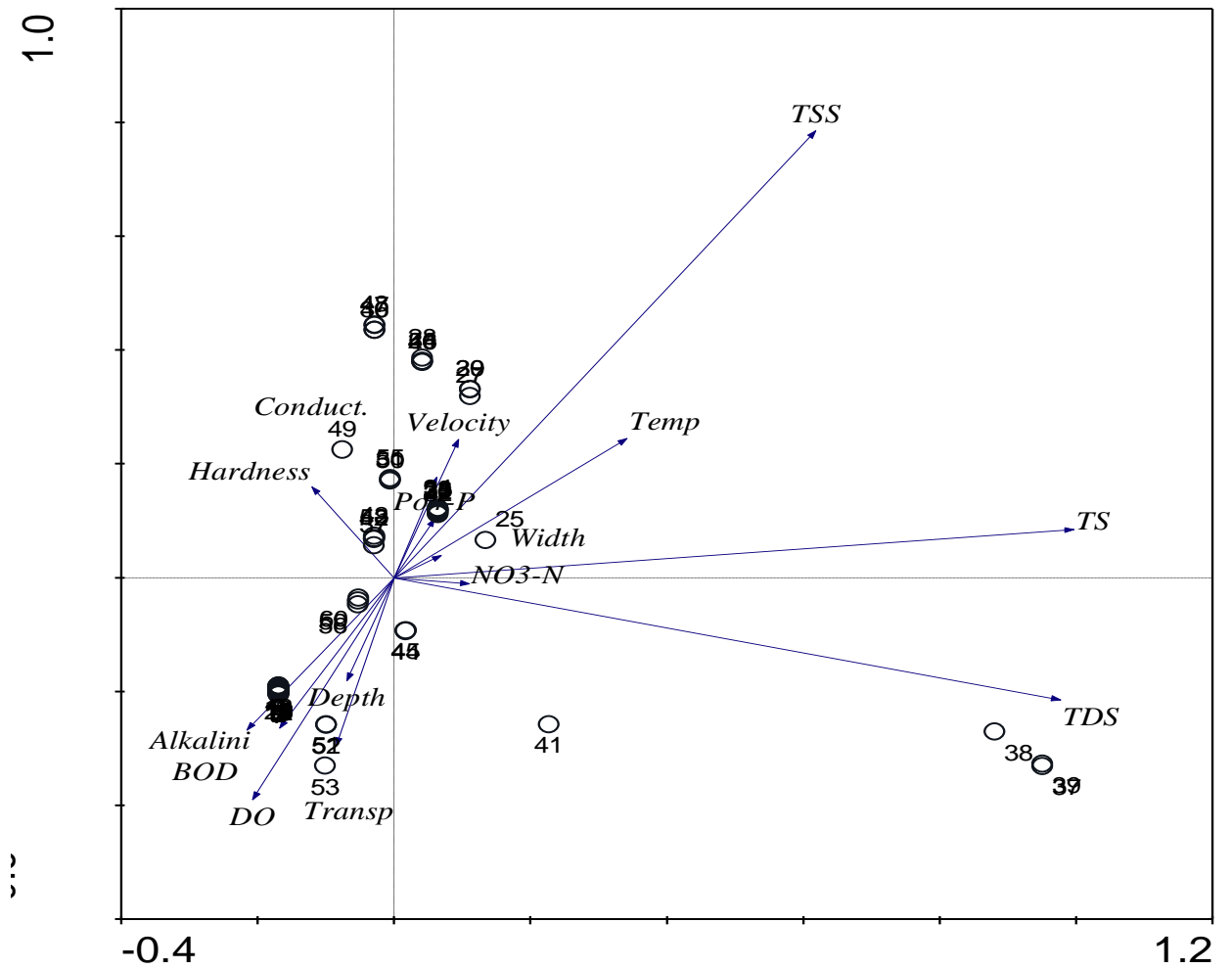


Figure 4.17: Principal Component Analysis (PCA) of Physico-chemical Parameters of Imaboro River, Kogi State.

Key:

- Alkalini = Alkalinity
- Conduct. = Electrical Conductivity
- DO = Dissolved Oxygen
- NO₃-N = Nitrate Nitrogen
- PO₄-P= Phosphate Phosphorus
- Temp = Temperature
- Transp = Transparency
- TDS = Total Dissolved Solids
- TS = Total Solids
- TSS = Total Suspended Solid

(602 individuals/m²) (Appendix IV). The analysis of variance of macrobenthic fauna means between months, stations and months/stations showed a highly significant value (Appendix VII). Shannon-Weiner's species diversity index showed that June sample at station 2 had the highest species diversity of H' 1.10 (Table 4.5).

4.18 Phytoplankton

The phytoplankton composition of the study area is made up of 50 species grouped into 13 families of Chlorophyta, 5 families of Cyanobacteria, 1 family each of Bacillariophyta, Rhodophyta and Pheophyta (Table 4.6). Comparison between stations and months showed that station 1 had the greatest occurrence (11 individual/l) in December followed by station 3 (10 individual/l) in the same month (Fig. 4.19). Independent t-test showed that season had significant effect ($p < 0.05$) on the abundance of phytoplankton. Their mean relative abundance was higher in the dry season than in the wet season. Comparison between months revealed that December had the highest percentage occurrence of phytoplankton. Comparison between stations revealed that station 3 had the highest percentage occurrence (Appendix VII). The division Chlorophyta had the highest number of species and highest percentage relative abundance (Table 4.6). Of the 27 families of the group chlorophyta, the family zygnemataceae showed the highest occurrence (278850) and individual per litre (Table 4.6). The analysis of variance showed that there is no significant difference in the mean value of phytoplankton between months, stations and month/station (Appendix VII). February sample of station 3 and March sample of station 5 had the highest Shannon-Weiner's species diversity of 1.75 each (Table 4.8).

Table 4.4: Macrobenthic community on a stretch of Imaboro river.

Order	Family	No. per Station					Total No. Identified	% Occurrence	Individual/m ²
		1	2	3	4	5			
Coleoptera	Dystiscidae	-	-	-	1	-	1	0.75	13
	Hydrophilidae	-	1	-	-	-	1	0.75	13
Diptera	Anthericidae	-	-	-	1	1	2	1.5	25
	Chironomidae	7	39	58	3	1	108	80.6	1350
	Empididae	-	1	-	-	-	1	0.75	13
	Simulidae	-	1	-	-	-	1	0.75	13
	Syrphidae	-	-	-	1	-	1	0.75	13
	Tupilidae	-	-	-	-	3	3	2.2	38
Hemiptera	Nepidae	-	-	-	2	2	4	3	50
Megaloptera	Sialidae	-	1	-	1	1	3	2.2	38
Odonata	Coenagrionidae	-	-	-	1	-	1	0.75	13
Lumbricina	Encliytraeidae	-	-	8	-	-	8	6	100

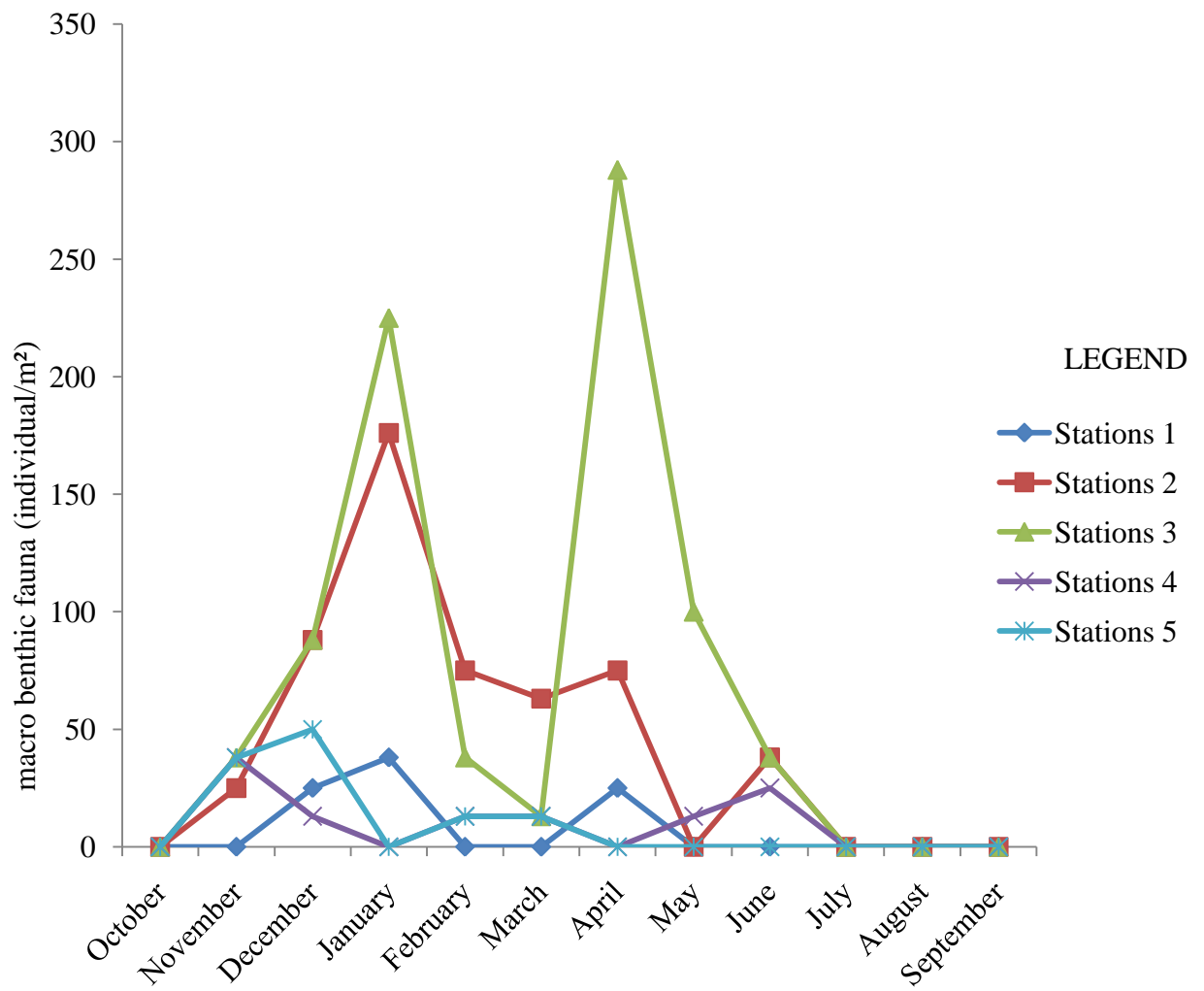


Figure 4.18: Mean monthly variations in macrobenthic fauna along stations on a stretch of Imaboro river

Table 4.5: Shannon-Weiner's diversity index for macrobenthic community on a stretch of Imaboro river.

Months	Stations				
	1	2	3	4	5
October	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.64	0.69	0.64
December	0.00	0.00	0.00	0.00	0.56
January	0.00	0.00	0.53	0.00	0.00
February	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.30	0.00	0.00
May	0.00	0.00	0.38	0.00	0.00
June	0.00	1.10	0.00	0.69	0.00
July	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00

Key:

0.00-0.4 = 1 Species

0.5-0.9 = 2 Species

1.0-1.2 = 3 Species

Source: Exponential table. W A E C (1995).

Table 4.6: Phytoplankton community on a stretch of Imaboro river.

Division	Family	No of species	Total Number Examined	%	Individual/l
Chlorophyta	Chaetophoraceae	3	600	0.16	0.15
	Cladophoraceae	1	8100	2.19	2.06
	desmidaceae	5	10950	2.95	2.79
	Hydrodictyaceae	3	1050	0.28	0.27
	Oedogoniaceae	1	3300	0.89	0.84
	Palmellaceae	1	450	0.12	0.11
	Scenedesmaceae	1	450	0.12	0.11
	Ulothrichaceae	1	4800	1.30	1.22
	Volvocaceae	3	2250	0.61	0.65
	Vaucheriaceae	1	1800	0.49	0.46
	Zygnemataceae	3	242250	65.36	61.72
	Oocystaceae	1	150	0.04	0.04
	Tetrasporaceae	1	600	0.16	0.15
			25	278850	75.23
Cyanobacteria	Chroococcaceae	9	62400	16.84	52.9
	Entophysalidaceae	2	1350	0.36	0.34
	Oscillatoriaceae	4	9900	2.67	2.52
	Rivulariaceae	1	450	0.12	0.11
	Synechococcaceae	1	1050	0.28	0.27
		17	83250	22.46	
Rhodophyta	Batrachospermaceae	2	300	0.08	0.08
Phaeophyta	Tribonemaceae	1	4050	1.09	1.03
Bacilliarophyta	Bacillariophyceae	3	3900	1.05	0.99
	Others	2	300	0.08	0.08
	Total	50	370650	100.00	

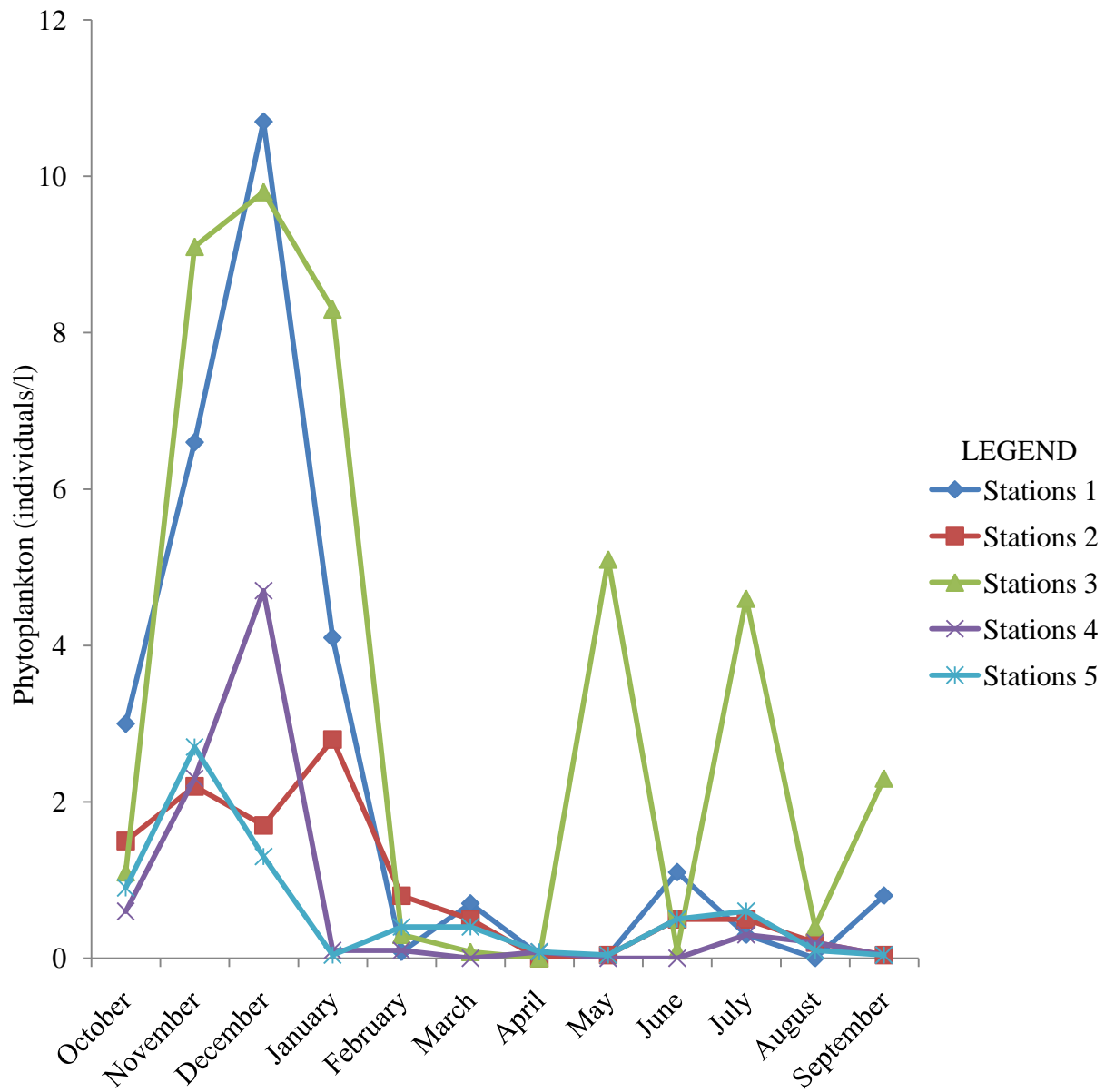


Figure 4.19: Mean monthly variations in phytoplankton along stations on a stretch of Imaboro river

Table 4.7: Shannon-Weiner's diversity index for phytoplankton community on a stretch of Imaboro river.

Month	Stations				
	1	2	3	4	5
October	1.64	1.28	1.45	1.49	1.18
November	0.00	0.69	1.29	1.66	1.18
December	0.53	2.04	0.48	1.14	1.22
January	1.17	1.82	1.11	0.64	0.00
February	0.69	0.39	1.75	0.64	1.22
March	1.02	0.00	0.69	0.00	1.75
April	0.00	0.00	0.00	0.69	0.69
May	0.00	0.00	0.00	0.00	0.00
June	0.91	0.00	1.10	0.00	1.58
July	1.26	0.29	0.86	0.66	0.00
August	0.00	1.05	1.17	0.87	0.64
September	0.82	0.00	0.64	0.00	0.00

Key:

0.00-0.4 = 1 Species

0.5-0.9 = 2 Species

1.0-1.2 = 3 Species

1.3-1.5 = 4 Species,

1.6-1.7 = 5 Species

Source: Exponential Table. W A E C (1995).

The result of the ordination analysis of the physicochemical and biological parameters is given in Figure 4.20. The first two axes of phytoplankton analysis accounted for 60.93% of the species. The eigenvalues of the first four axes were 0.463, 0.409, 0.331 and 0.228 (Appendix VIII). The species showed strong positive correlation with the environmental factors.

The Canonical Correspondence Analysis (CCA) of the physicochemical parameters shows their relationship with the phytoplankton (Fig 4.20). The analysis reveals that *Chlamydomonas polypyrenoideum*, *Desmidium grevilli*, *Volvox tertius* and *Zygnema pectinatum* are positively associated with alkalinity, nitrate – nitrogen (NO₃-N) and phosphate – phosphorus (PO₄-P) but negatively related to transparency and total dissolved solids (TDS). *Cladophora spp* and *Oedogonium spp* are positively correlated with conductance. On the other hand, *Phormidium ambiguum*, *muogeotia spp* and *Aphanocarpa grevillei* are negatively related to conductance, temperature and hardness. *Microcystis wesenbergii* and *Vaucheria spp* correlate positively with transparency and TDS but negatively with alkalinity, PO₄-P and NO₃-N. Positive correlation or association here means that as the concentration of the parameter increases, the number of individual species also increases while negative association means that as the concentration of the parameter increases, the number of individual species decreases.

4.19 Zooplankton

The zooplankton community of the study area is composed of 16 different species comprising of 5 classes groups. A total of 30150 individuals were identified during the study period. The group Cladocera had the highest percentage relative abundance of 74.63 and approximately 6 individuals/L (Table 4.8).

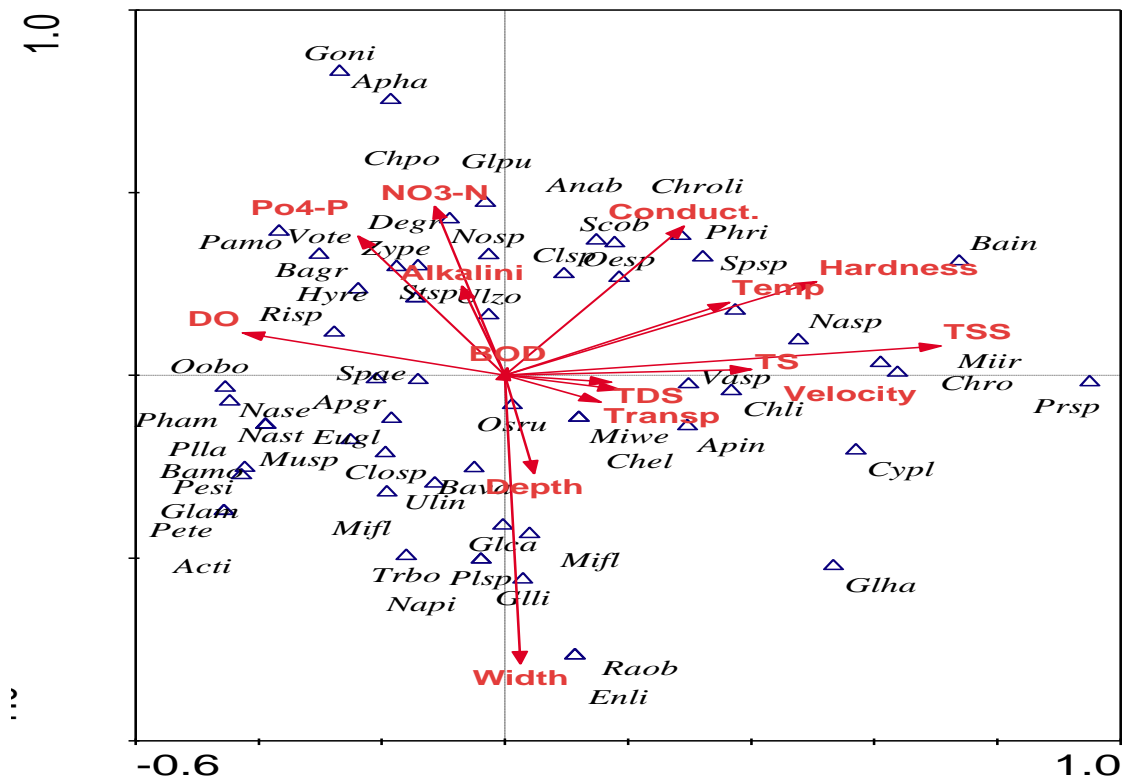


Figure 4.20: Canonical correspondent analysis (CCA) of phytoplankton community along a stretch of Imaboro river.

Acha=*Actinastrum hantzschii* Acsp=*Actinotaenium* Acsp=*Actinotaenium*
 Ansp=*Anabaena* Apsp=*Aphanizomenon* Apgr=*Aphanocapsa grevillei*
 Apin=*Aphanocapsa inarta* Bagr=*Bacularia gracilis* Bain=*Bacularia indurate*
 Bamo=*Batrachospermum morniliforme* Bava=*Batrachospermum vagum*
 Bava=*Batrachospermum vagum* Chel=*Chaetophora elegans* Chpo=*Chlamydomonas polypyrenoideum*
 Chli=*Chlorogloea lithogenes* Chsp=*Chroococcidium*
 Chrli=*Chroococcus limneticus* Clsp=*Cladophora spp* Closp=*Closterium spp*
 Cypl=*Cyanodictyon planctonicum* Degr=*Desmidium* Enli=*Entophysalis lithophula*
 Eusp=*Euglena* Glpu=*Gleocapsa punctata* Glam=*Gleocystis ampla*
 Glca=*Gloeodendron catanatum* Glha=*Gloeotheca haufleri* Glli=*Gloeotheca linearis*
 Gosp=*Gonium* Hyre=*Hydrodictyon reticulatum* Miir=*Microcrosis irregulae*
 Mifl=*microcystis flos-aquae* Miwe=*Microcystis wesenbergii* Micfl=*Microspora flucosa*
 Musp=*Muogeotia spp* Nast=*Nacicula stromii* Nase=*Navicula seminulum*
 Nasp=*Navicula spp* Nosp=*Nostoc* Nosp=*Nostoc* Oesp=*Oedogonium spp*
 Oobo=*oocystis borgei* Osru=*Oscillatoria rubescens* Pamo=*Pandorina morum*
 Pesi=*Pediastrum simplex* Pham=*Phormidium ambiguum* Phri=*Phormidium richardsii*
 Plla=*Planothidium lanceolatum* Plsp=*Pleurotaenium* Prsp=*Protoderma* Raob=*Raya obtuse*
 Risp=*Rivularia spp* Risp=*Rivularia spp* Scob=*Scenedesmus obtusus*
 Spae=*Spirogyra aequinoctialis* Spsp=*Spirulina* Stsp=*Stigeoclonium* Trbo=*Tribonema bombycinum*
 Ulzo=*Ulothrix zonata* Ulin=*Ulvella involvens* Vasp=*Vaucheria*
 Vote=*Volvox tertius* Zype=*Zygnem pectinatum*

Table 4.8: Zooplankton community on a stretch of Imaboro river.

Group	Species	No. in sub-sample	Estimated No. in Sample	%	Individual/l
Cladocera	<i>Bosminopsis dietersi</i>	63	3150	10.45	0.8
	<i>Daphnia pulex</i>	60	3000	9.95	0.76
	<i>Eurycercus spp</i>	3	150	0.50	0.04
	<i>Holopedium gibberum</i>	261	13050	43.28	3.32
	<i>Leptodora kindti</i>	3	150	0.50	0.04
	<i>polyphemus pediculus</i>	60	3000	9.95	0.76
	Subtotal	450	22500	74.63	5.72
Copepod	<i>Calanus hyperboreus</i>	27	1350	4.48	0.34
	<i>Diaphanosoma birgi</i>	18	900	2.99	0.23
	<i>Limnocalanus macrurus</i>	6	300	1.00	0.08
	<i>Osphranticum labionectum</i>	6	300	1.00	0.08
	Subtotal	57	2850	9.45	0.73
Rotifera	<i>Branchionus spp</i>	54	2700	8.96	0.69
	<i>Euchlanis spp</i>	21	1050	3.48	0.27
	Gastropidae	6	300	1.00	0.08
	Subtotal	81	4050	13.43	1.04
Hydracarina		3	150	0.50	0.04
Ostracoda		12	600	1.99	0.15
	Grand Total	603	30150		

They are more abundant in wet season than in dry season (Appendix VI). Comparison between months and stations showed that June and station 2 respectively had the highest occurrence (Fig. 4.21). The analysis of variance showed that there is no significant difference in the mean value of zooplankton between months, stations and month/station (Appendix VII). The sample in November at station 3 showed the highest Shannon-Weiner's diversity index of 1.75 (Table 4.9).

The CCA of the physicochemical parameters shows their relationship with the zooplankton in Fig. 4.22. The analysis reveals that gastropidae is positively associated with dissolved oxygen and negatively correlated with conductance and biological oxygen demand (BOD); *Diaphanosoma birgi* is positively correlated with total suspended solids (TSS) and negatively correlated with DO and temperature; *Euchlanis spp* correlates positively with alkalinity but negatively with PO₄-P (Fig. 4.22). The first two axes accounted for 59.34% of the species. The eigenvalues for the first four axes were 0.776, 0.723, 0.629 and 0.399 (Appendix VIII).

4.20 Non-diatom Periphytic Algae

A total number of 43 species comprising 12 families of Chlorophyta, 4 families of Cyanobacteria, 1 family of Rhodophyta, 2 of Phaeophyta and 1 of Pyrrophyta were identified (Table 4.10). The Division chlorophyta had the highest percentage abundance (77.56). Among this Division, the family zygnemataceae had the highest percentage relative abundance (44.80). Station 1 showed the highest number in October, November and January while station 5 had the highest number in December (Fig. 4.23). Comparison of percentage relative abundance between months shows the highest value (39.43) in December and lowest value (3.74) in October (Appendix VI).

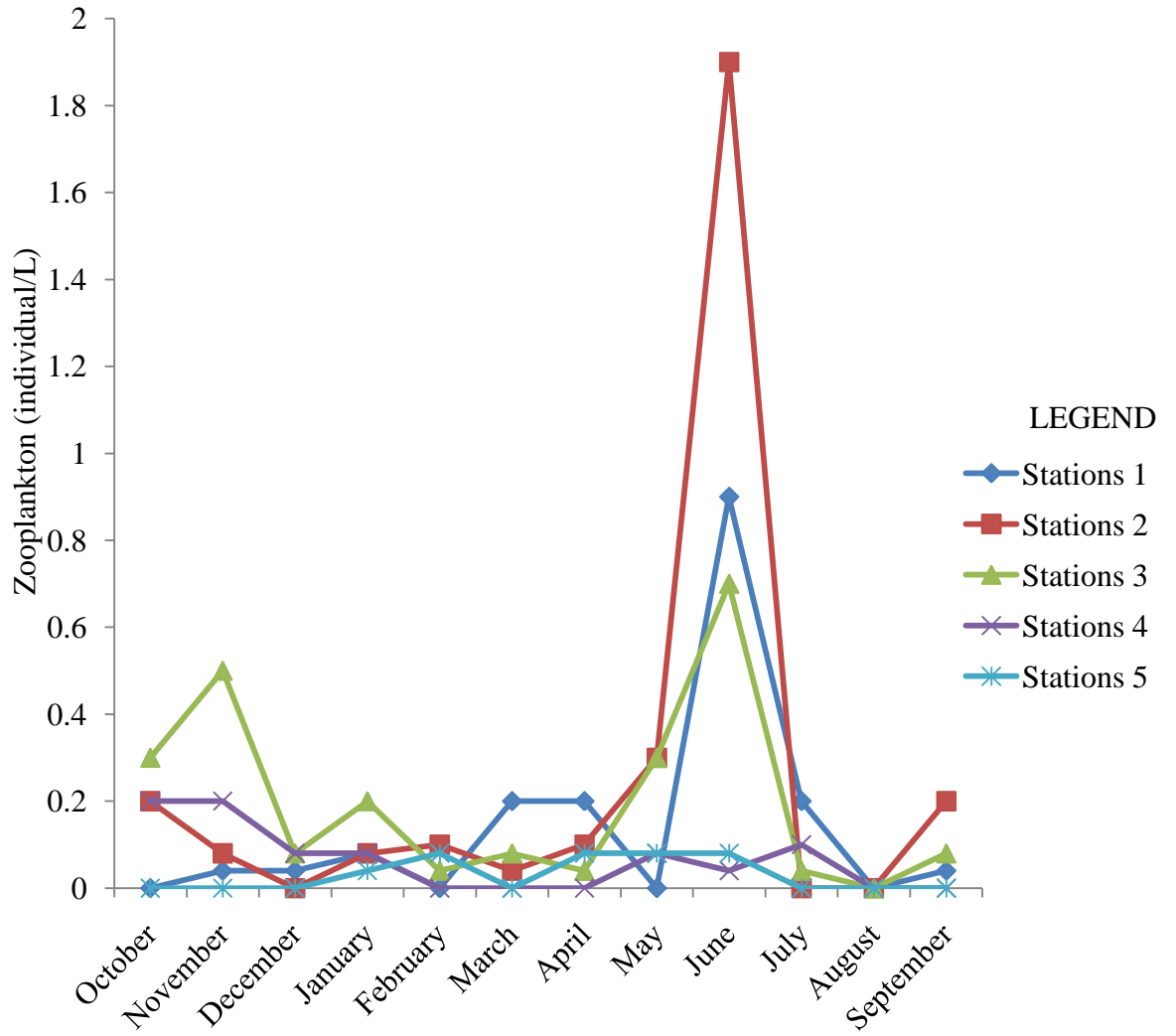


Figure 4.21: Mean monthly variations in zooplankton along stations on a stretch of Imaboro river.

Table 4.9: Shannon-Weiner's diversity index for zooplankton community on a stretch of Imaboro River.

Month	Stations				
	1	2	3	4	5
October	0.00	0.96	1.50	0.69	0.00
November	0.00	0.00	1.75	0.69	0.00
December	0.00	0.00	0.69	0.00	0.00
January	0.69	0.69	0.56	0.00	0.00
February	0.00	0.64	0.00	0.00	0.00
March	1.04	0.00	0.69	0.00	0.00
April	0.67	1.10	0.00	0.00	0.69
May	0.00	0.90	0.38	0.00	0.00
June	0.67	0.00	0.45	0.00	0.69
July	1.04	0.00	0.00	0.64	0.00
August	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00

Key:

0.00-0.4 = 1 Species

0.5-0.9 = 2 Species

1.0-1.2 = 3 Species

1.3-1.5 = 4 Species

1.6-1.7 = 5 Species

1.8 = 6 Species

Source: Exponential Table. W A E C (1995).

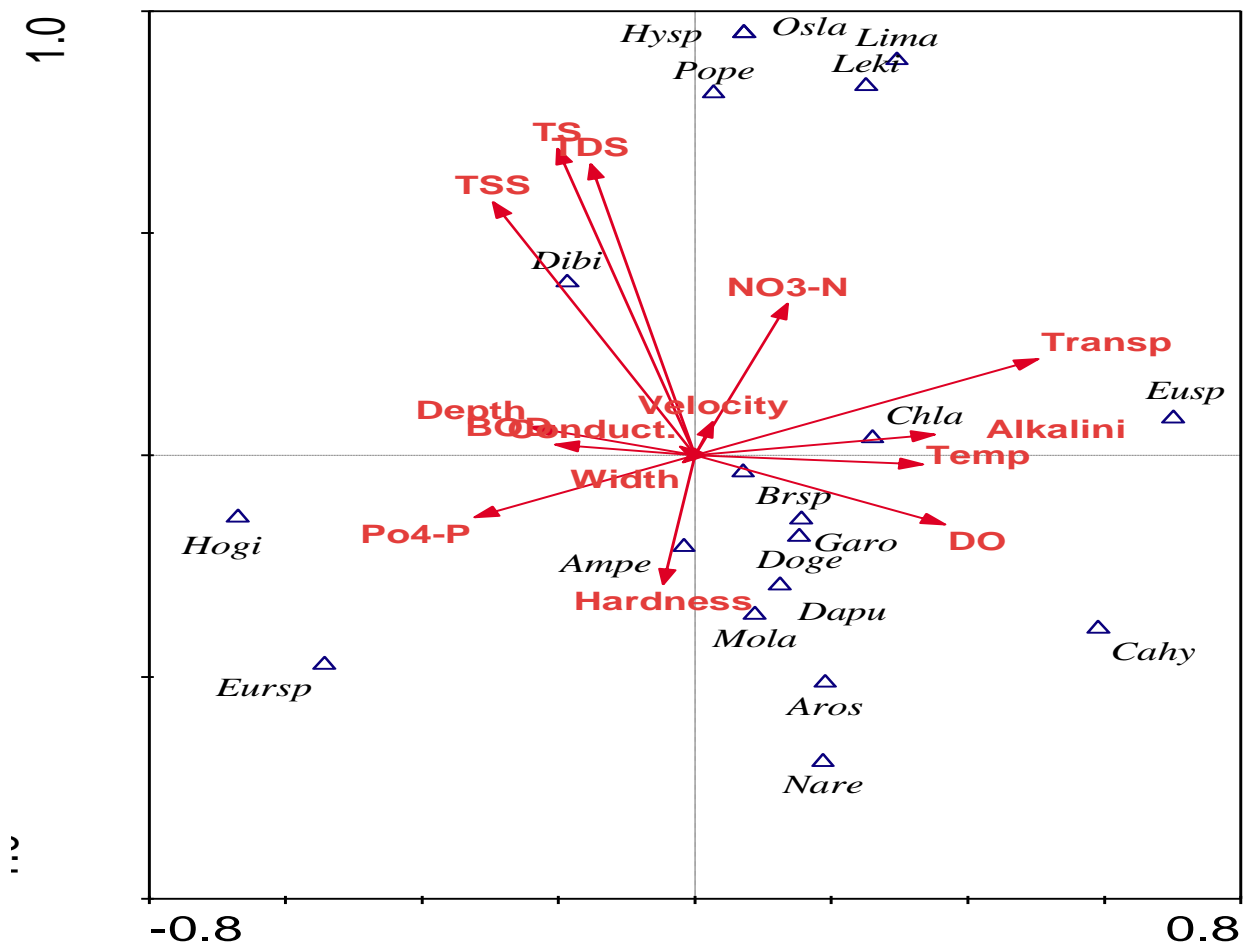


Figure 4.22: Canonical Correspondence Analysis (CCA) of Zooplankton of Imaboro River.

Key: Bodi=*Bosminopsis dietersi* Brsp=*Branchionus spp* Cahy=*Calanus hyperboreus* Dapu=*Daphnia pulex* Dibi=*Diaphanosoma birgi* Eusp=*Euchlanis spp* Eursp=*Eurycerus spp* Hogi=*Holopedium gibberum* Hysp=*Hydracarina* Leki=*Leptodora kindti* Lima=*Limnocalanus macrurus* Osla=*Osphranticum labionectum* Pope=*polyphemus pediculus* Chla=*Chironomidae larva* Mola=*Mosquito larva* Aros=*Arthropoda (Ostracoda)*

The analysis of variance showed that there is no significant difference in the mean value of phytoplankton between months, stations and month/station (Appendix VII). November sample of station 5 showed the highest Shannon-Weiner's diversity index (Table 4.11).

The relationship between the non – diatom periphyton and the physicochemical parameters is such that *Gloeocapsosis crepidium*, *Gloeotrichia achinulata* and *Rivularia species* are positively related to alkalinity, NO₃-N, and PO₄-P and are negatively related to DO, BOD and conductance; *Zygnema pectinatum*, *Ulothrix zonata* *Coelastrum microporum* have positive relationship to hardness, temperature and conductance (Fig 4.24). The first two ordination axes accounted for 59.38% of the species. The eigenvalues for the first four axes were 0.304, 0.218, 0.190 and 0.167 (Appendix VIII).

4.21 Periphytic Diatom

A total of 90 species of periphytic diatom were identified during the study period. *Eunotia species* showed the greatest occurrence (Table 4.12). Comparison of relative abundance between stations showed that station 1 had the highest value (Appendix VI). The same comparison between months showed that the greatest occurrence of number of individuals was in January (Fig. 4.25). The analysis of variance showed that there is no significant difference ($p > 0.05$) in the mean value of diatoms between months, stations and month/station (Appendix VII). The monthly sample with the highest species diversity was collected in December at station 1 (Table 4.13).

Table 4.10: Non- diatom periphytic algae community on a stretch of Imaboro river.

Division	Family	No of Species	Total Number Examined	%
Chlorophyta	Chaetophoraceae	3	42	1.20
	Cladophoraceae	2	296	8.48
	Desmidiaceae	3	69	1.98
	Coleochaetaceae	1	5	0.14
	Hydrodictyaceae	1	1	0.03
	Oedogoniaceae	1	602	17.25
	Oocystaceae	1	6	0.17
	Ulothrichaceae	2	56	1.61
	Volvocaceae	1	50	1.43
	Scenedesmaceae	2	5	0.14
	Vaucheriaceae	1	11	0.32
	Zygnemataceae	3	1563	44.80
Subtotal	12	21	2706	77.56
Cyanobacteria	Chroococcaceae	5	510	14.62
	Nostocaceae	3	5	0.14
	Oscillatoriaceae	2	88	2.52
	Rivulariaceae	5	15	0.43
Subtotal	4	15	618	17.71
Rhodophyta	Batrachospermaceae	3	34	0.97
		1		
Phaeophyta	Tribonemceae	2	63	1.81
	Phaostrophiaceae	1	2	0.06
Subtotal	2	3	65	1.86
Pyrrophyta	Dinophyceae	1	1	0.03
TOTAL		43	3489	

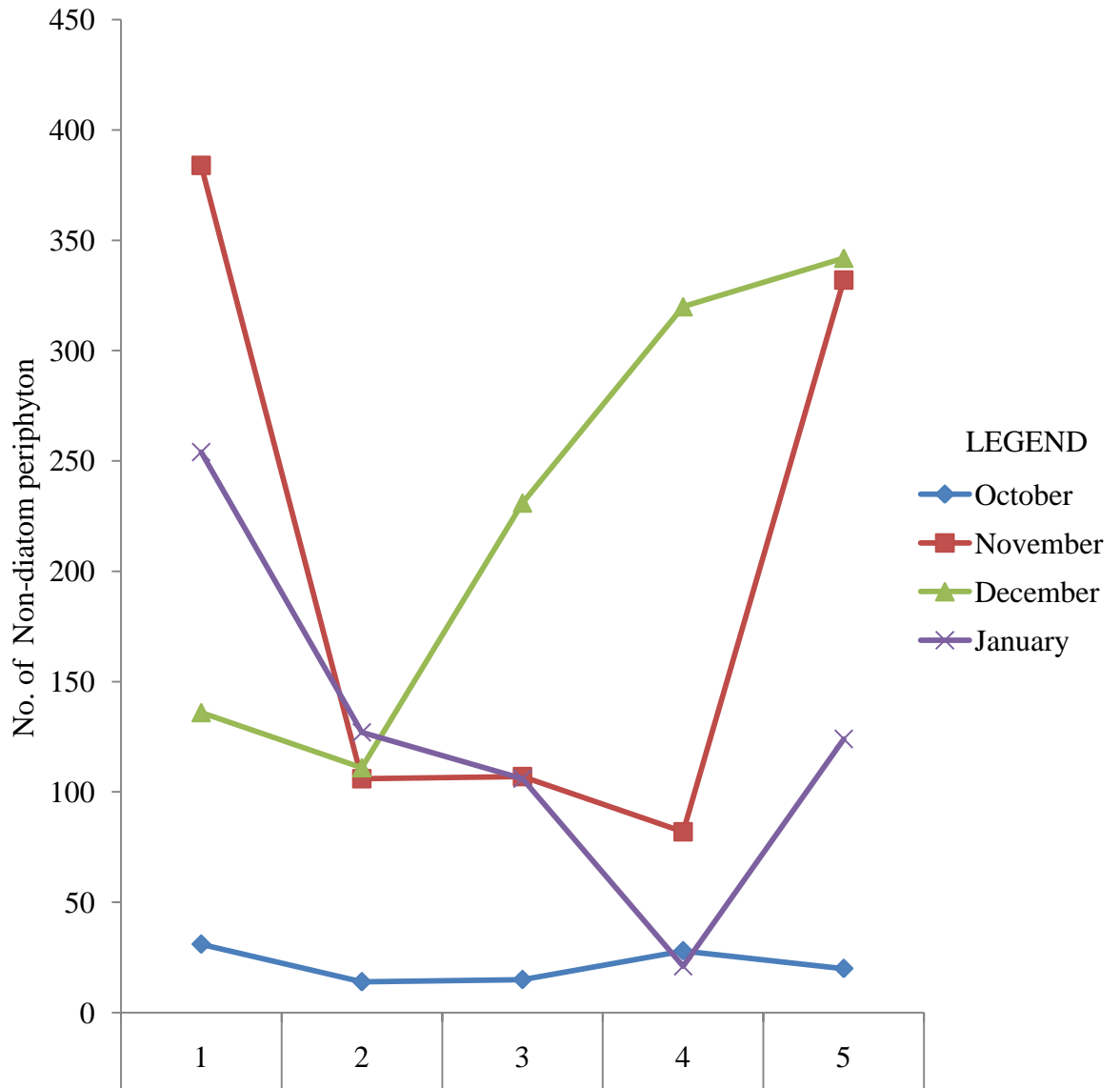


Figure 4.23: Mean monthly variations in non-diatom periphyton along stations on a stretch of Imaboro river

Table 4.11: Shannon-Weiner's diversity index for non-diatom periphyton community on a stretch of Imaboro river.

Months	Station 1	Station 2	Station 3	Station 4	Station 5
October	1.12	1.57	1.39	1.29	1.89
November	1.60	1.87	1.82	2.31	2.23
December	0.65	1.00	1.54	1.59	1.24
January	0.73	1.29	1.02	1.37	0.85

Note:

0.0-0.4 = 1 Species

0.5-0.9 = 2 Species

1.0-1.2 = 3 Species

1.3-1.5 = 4 Species

1.6-1.7 = 5 Species

1.8 = 6 Species

1.9-2.0 = 7 Species

2.1 = 8 Species

2.2 = 9 Species

2.3 = 10 Species

Source: Exponential Table. W A E C (1995).

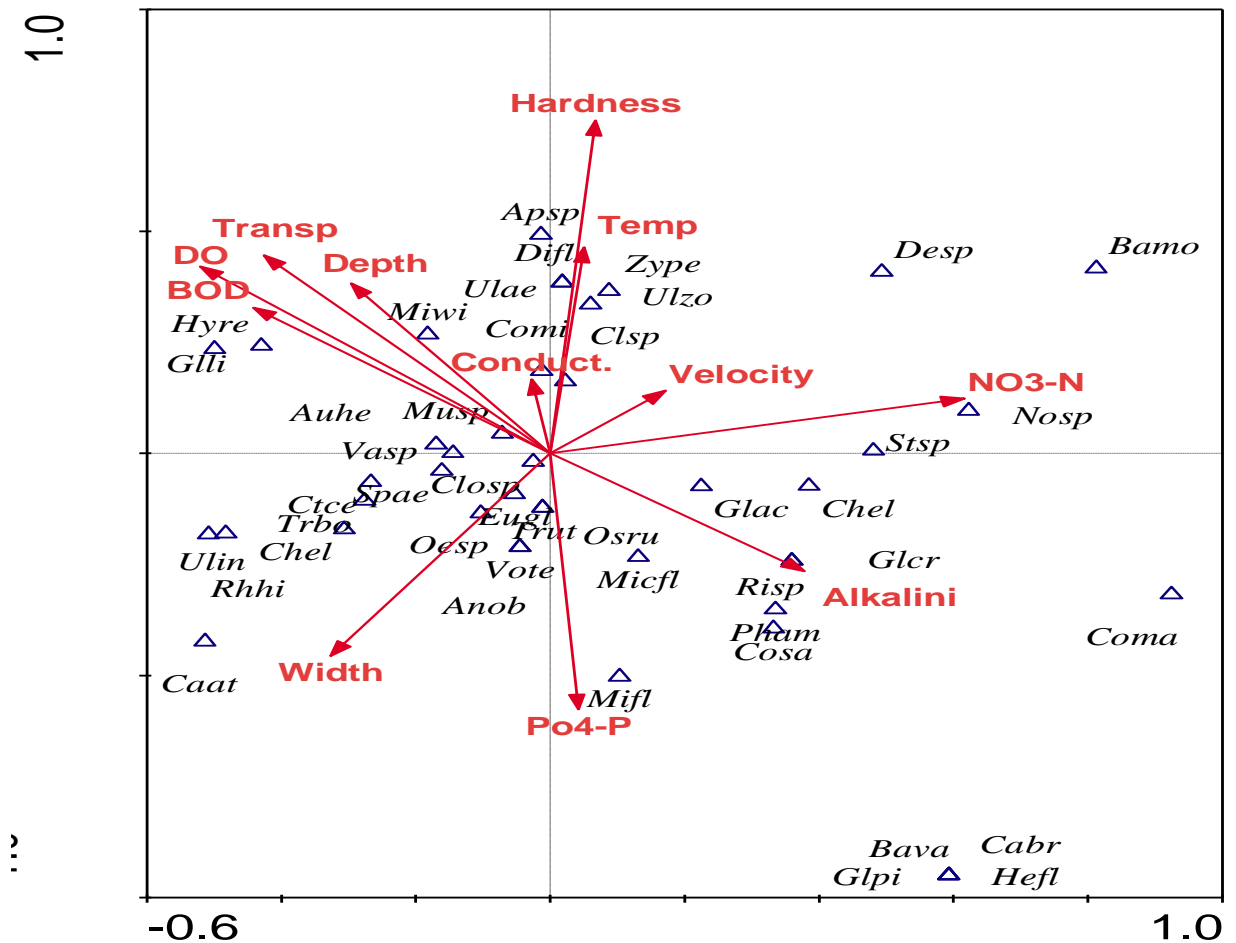


Figure 4.24: Canonical correspondence analysis (CCA) of non-diatom periphyton in a stretch of Imaboro river.

Key: Acha=*Actinastrum hantzschii* Anob=*Anabaena oblonga* Apsp=*Aphanizomenon*
 Auhe=*Audounella hermanis* Bamo=*Batrachospermum morniliforme*
 Bava=*Batrachospermum vagum* Caat=*Calothrix atrichia* Cabr=*Calothrix braunii*
 Chel=*Chlorella elipsoidea* Clsp=*Cladophora spp* Closp=*Closterium spp*
 Comi=*coelastrum microporum* Cosa=*Coleochaete salute* Coma=*Cosmarium*
margaritatum Ctce=*Ctenocladus cercinatus* Desp=*Desmidium* Disp=*Dinoflagellate*
 Eusp=*Euglena* Gler=*Gloeocapsosis crepidium* Glli=*Gloeotheca linearis*
 Glac=*Gloeotrichia achinaluta* Glpi=*Gloeotrichia pisum* Hefl=*Heribaudiella*
fluviatilis Hyre=*Hydrodictyon reticulatum* Mifl=*microcystis flos-aquae*
 Micfl=*Microspora flucosa* Miwi=*Microspora willeana* Musp=*Muogeotia spp*
 Nosp=*Nostoc* Oesp=*Oedogonium spp* Osru=*Oscillatoria rubescens*
 Pham=*Phormidium ambiguum* Rghi=*Rhizoclonium hieroglyphicum* Risp=*Rivularia*
spp Spae=*Spirogyra aequinoctialis* Stsp=*Stigeoclonium* Trbo=*Tribonema*
bombycinum Trut=*Tribonema utriculusum* Ulae=*Ulothrix aequalis* Ulzo=*Ulothrix*
zonata Ulin=*Ulvella involvens* Vasp=*Vaucheria* Vote=*Volvox tertius* Zype=*Zygnema*
pectinatum

Table 4.12: Periphytic diatoms along a stretch of Imaboro river.

Family	No. of Species	No. of Individuals Observed
Acanthaceae	5	138
Acanthidiaceae	7	940
Amphipleuraceae	2	774
Amphoraceae	3	295
Aulacoseiraceae	1	55
Bacillariaceae	4	129
Brachysiraceae	1	19
Cymbellaceae	9	1038
Eunotiaceae	8	9766
Flagilariaceae	16	5194
Gomphonemataceae	10	2262
Hygromidae	1	103
Melosiraceae	1	9
Naviculaceae	12	5398
Peroniaceae	1	363
Pinnulariaceae	1	28
Pleurosigmataceae	1	9
Rhoicospheniaceae	1	260
Rhopalodiaceae	1	28
Stephanodiscaceae	1	27
Total	86	26835

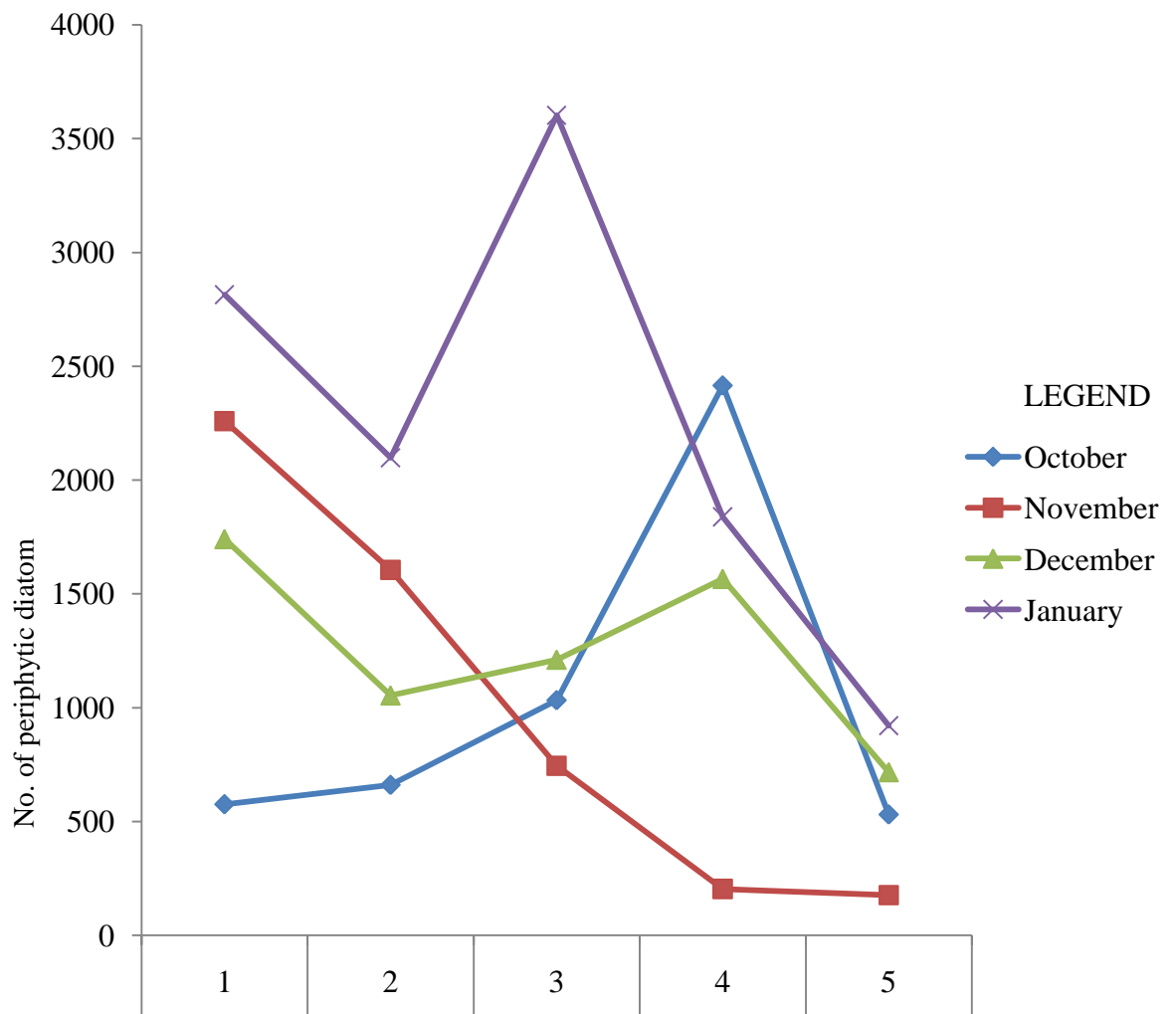


Figure 4.25: Mean monthly variations in periphytic diatoms along stations on a stretch of Imaboro river

Table 4.13: Shannon-Weiner's diversity index of periphytic diatom community along a stretch of Imaboro river.

Month	Stations				
	1	2	3	4	5
October	2.20	2.44	2.48	2.01	1.96
November	1.68	1.77	1.69	1.71	1.52
December	3.41	2.99	2.63	2.48	2.26
January	2.62	2.94	2.11	2.16	2.67

Note:

1.3-1.5 = 4 Species

1.6-1.7 = 5 Species

1.8 = 6 Species

1.9-2.0 = 7 Species

2.1 = 8 Species

2.2 = 9 Species

2.3 = 10 Species

2.4 = 11 Species

2.5 = 12 Species

2.6 = 13 Species

2.7 = 15 Species

2.8 = 16 Species

2.9 = 18 Species

3.0 = 20 Species

3.1 = 22 Species

3.2 = 25 Species

3.3 = 27 Species

3.4 = 30 Species

Source: Exponential Table. W A E C (1995).

CCA analysis showed that *Cratoneis arcus*, *Flagilaria hoelii* and *Stauroforma exiguiiformis* were positively related to DO and PO₄-Ps but were negatively related to temperature while *Cymbella turgidula*, *Gomphoneis erienne* var. *variabilis* and *Gomphonema truncatum* were related positively to temperature and negatively to DO, depth and PO₄-P. *Asterionella Formosa* and *Synedra ulna* showed positive relationship with alkalinity, NO₃-N and conductance (Fig 4.26). The first two axes accounted for 58.80% of the species. The eigen values for the first four axes were 0.253, 0.205, 0.182 and 0.13 (Appendix VIII).

Sample micrograph of the biological parameters encountered in the course of this study is as shown in plate 4.1.

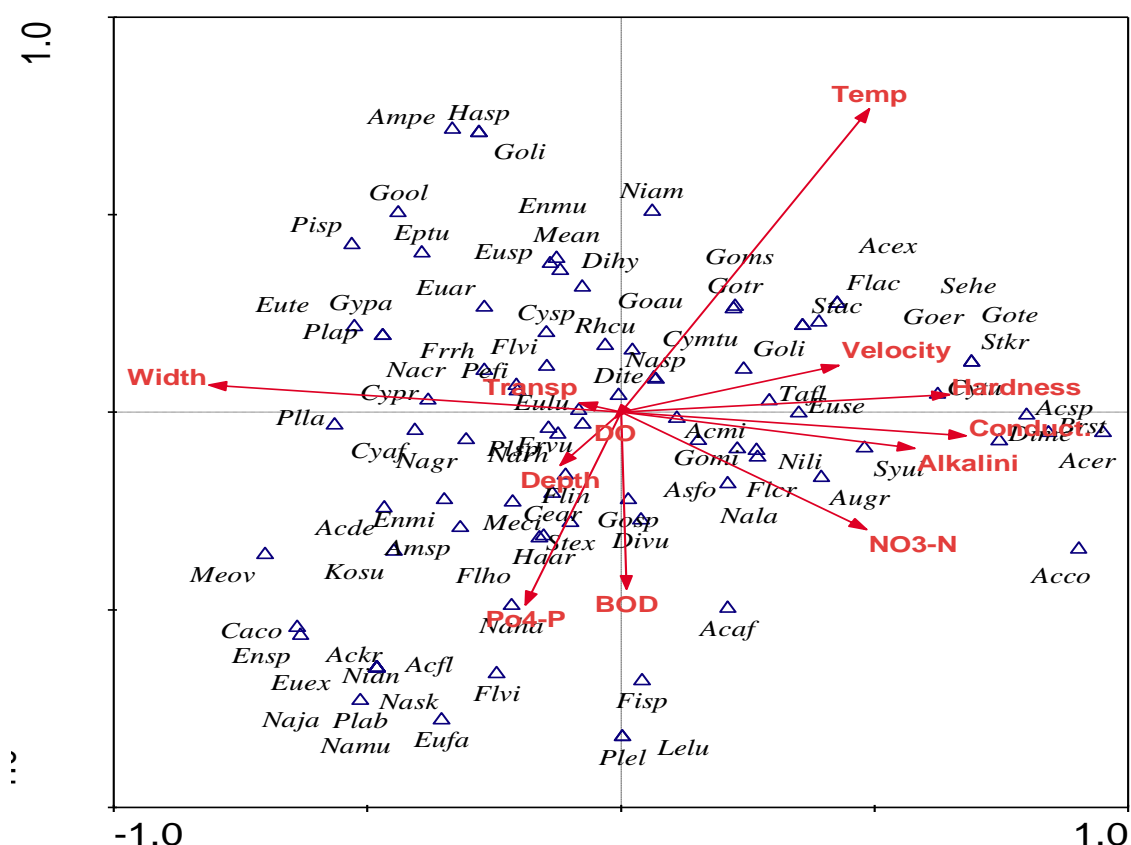
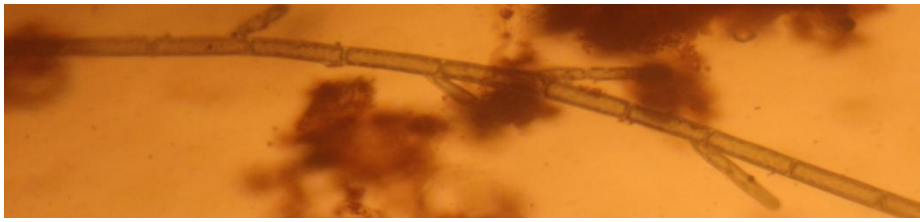


Figure 4.26: Cannonical correspondence analysis (CCA) of periphytic diatom community along a stretch of Imaboro river.

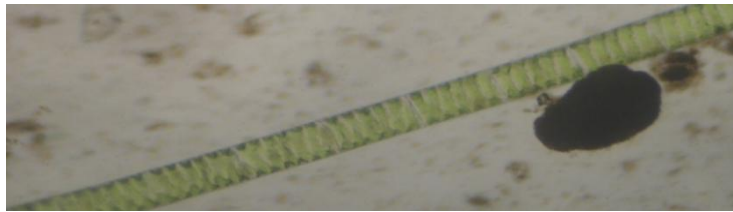
Key: Amob= *Amphora obscure* Acco=*Achanthes coaritata* Acer= *Achanthes erdmannensis* Acex= *Achanthidium exigum* Ackr= *Achanthes kryophila* Acaf= *Achanthidium affins* Acde= *Achanthidium deflexum* Acmi= *Achanthidium minutissimum* Acsp= *Actinella spp* Ampe= *Amphora pediculus* Brst=*Brachysira styriaca* Caco=*Carinula cocconeiformis* Cear=*Ceratoneis arcus* Cyaf=*Cymbella affinis* Cypr=*Cymbella proxima* Cytu=*Cymbella tumida* Cymtu=*Cymbella turgidula* Cysp=*Cytotella spp* Dihy=*Diatoma hyenalis* Dime=*Diatoma mesodon* Dite=*Diatoma tenue var. elongatum* Divu=*Diatoma vulgare* Enmi=*Encyonema minuta* Enmu=*Encyonema mualleri* Ensp=*Encyonema spp* Eptu=*Epithemia turgidula* Euar=*Eunotia arcus* Euex=*Eunotia exigua* Eufa=*Eunotia faba* Eulu=*Eunotia lunaris* Euse=*Eunotia serra* Eusp=*Eunotia spp* Eute=*Eunotia tenella* Fisp=*Fistulifera* Flvi=*Flagilaria virescens var. capitata* Flcr=*Flagilaria crotonensis* Flho=*Flagilaria hoelii* Flin=*Flagilaria intermedia* Flavi=*Flagilariforma virescens* Frrh=*Frustulia rhomboids* Frvu=*Frustulia vulgaris* Goer=*Gomphonema eriense var. variabilis* Gomi=*Gomphonema minuta var. iowei* Goau=*Gomphonema augur* Goli=*Gomphonema lingulataeformis* Gool=*Gomphonema olivacea* Gosp=*Gomphonema sphaerophorum* Goms=*Gomphonema spp* Gote=*Gomphonema tenellum* Gotr=*Gomphonema truncatum* Gomli=*Gomphosphenia lingulataeformis* Gypa=*Gyrosigma parkeri* Haar=*Hammnaea arcus* Hasp=*Hantzchia* Kosu=*Kobayasia subtilissima* Lelu=*Lemnicola lungarica* Meov=*Melosira ovate* Mean=*Meridion anceps* Meci=*Meridion circulare* Meci=*Meridion circulare* Nacr=*Navicula cryptocephala* Nagr=*Navicula gregaria* Naha=*Navicula hasta* Naja=*Navicula jarnefeldi* Nala=*Navicula lanceolata* Namu=*Navicula mutata* Narh=*Navicula rhyncocephala* Nask=*Navicula skifte* Nasp=*Navicula spp* Niam=*Nitzschia amphibian* Nian=*Nitzschia angustata* Nili=*Nitzschia linearis* Pefi=*Peronia fibula* Pisp=*Pinnularia* Plab=*Placoneis abisloensis* Plsp=*Placoneis spp* Plap=*Planothidium apiculatum* Plla=*Planothidium lanceolatum* Plel=*Pleurosigma elongatum* Rhcu=*Rhoicosphenia curvata* Sehe=*Semiorbis hemicyclus* Stex=*Stauriforma exiguiformis* Stkr=*Stauroneis kriegeri* Syul=*Synedra ulna* Tafl=*Tabellaria flucosa*



(a)



(b)



(c)



(d)



(e)

Plate 4.1: Sample Micrograph of Phytoplankton of Imaboro River, Kogi State.

(a) *Cladophora sp* (b) *Closterium sp* (c) *Spirogyra aequinoctialis* (d) *Ulothrix zonata* (e) *Gloeotrichia pisum*



(a)



(b)



(c)

Plate 4.2: Sample Micrograph of Zooplankton of a Stretch of Imaboro River- (a) Cladoceran (*Holopedium gibberum*) (b) Copepod (*Calanus hyperboreus*) (c) Hydracarina

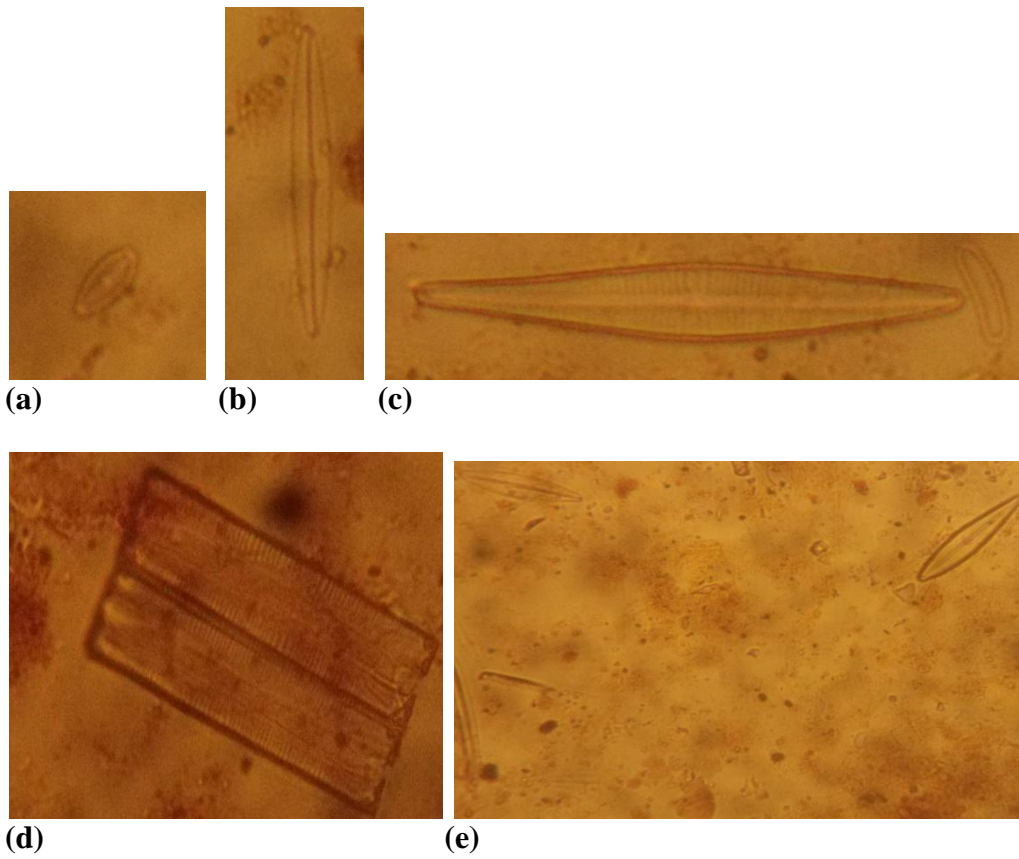


Plate 4.3: Sample Micrograph of Periphytic Diatom of a Stretch of Imaboro River-
 (a) *Cocconeis sp* (b) *Achanthidium deflexum* (c) *Gomphoneis minuta* (d)
Tabellaria flucosa (e) *Gomphonema sp*

CHAPTER FIVE

5.0

DISCUSSION

The results obtained in the course of this research work are revealed spatial and temporal variation in biota and physico-chemical parameters on a stretch of Imaboro river.

5.1 Physico-chemical Parameters

The mean temperature values of the water samples of Imaboro river during the study period were not statistically different $p > 0.05$ between seasons. This situation is indicative of limited changes associated with tropical areas as also noted by Chia and Bako, (2007). The spatial variations recorded could be the effects of vegetation on the water temperature. The lowest mean monthly temperature value recorded in December could be the effect of harmattan.

Lack of spatial and temporal variation in the transparency values could be the result of self-regulating mechanisms of the river to restore itself to the pristine condition. Lower transparency value in the wet season could be the result of surface runoff that makes the water turbid during the rainy season. Edward and Ugwumba (2010) also observed lower transparency value in the rainy season than in the dry season on Egbe reservoir.

TDS and TSS varied among sampling stations. The values for both TSS and TDS were below the permissible limit of 500mg/l and 1000mg/l respectively set by FEPA (as cited by Dimowo, 2013), throughout the whole stations. The higher TSS value in stations 2 and 3 could be the result of higher human activities such as washing and bathing that take place in the two stations than in the other stations. Higher total

dissolved solids in station 4 could be the result of runoff from mechanic workshop to the station. Lower TSS and TDS value in station 1 could be as a result of less runoff and anthropogenic activities.

Mean depth values were not significantly different between months and seasons but vary between stations. The lowest mean depth value recorded in July could be as a result of runoff bringing sand which settles at the river basin thereby reducing the depth.

Higher velocity values in the rainy months could be as a result of greater water volume from rainfall and run-off. The velocity of Imaboro river increased downstream. This could be as a result of increase in water volume downstream (as noted by water action volunteers (2006), and the fact that the whole section under study falls within the upper course section of the river.

Throughout the study period, the pH of the water of Imaboro River fell within 5.70 ± 0.13 - 6.19 ± 0.17 range. This is below the permissible limit of 6.5 – 8.5 set by USEPA and NAFDAC (as cited by Dimowo, 2013). This value is indicative of acidity which may be as a result of high organic content or mineral acids produced by hydrolyses of salts of metals such as aluminum and iron. The relatively stable pH value throughout the stations could be due to the effective buffering capacity of the water. Similar observation was made by Abolude (2007), on Ahmadu Bello University reservoir. pH values were however, higher in wet months than dry months.

Electrical Conductivity (EC) in natural waters is the normalized measure of the water's ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Most freshwater sources will range

between 0.1-10 μ s/cm (Bellingham, 2012). Field measurements of EC reflect the amount of total dissolved solids (TDS) in natural waters (Bellingham, 2012). The electrical conductivity of Imaboro river water was significantly different among the sampling stations, months and seasons. This situation is indicative of variable anthropogenic impacts spatially and temporally. Comparatively higher values were recorded in the wet season than the dry season. The same observation was made by Ugwu and Wakawa (2012), on River Usuma. Higher values of electrical conductivity in rainy season were possibly due to storm water runoff that brings in lots of water from the farms and shops with dissolved conducting minerals. Electrical conductivity values were below the Nigerian Standards for Drinking Water (NSDW in Dimowo, 2013) permissible values.

Dissolved oxygen (DO) is essential to all forms of aquatic life including the organisms that break down man-made pollutants. Oxygen tends to be less soluble as temperature increases (Ugwu and Wakawa, 2012). There is no defined trend in variation of maximum mean value of DO among the sites in all the seasons. This indicated that the turbulences and flow rate of river water at different sites, which may be beneficial for dissolved solid breakdown through self-pollution regulating mechanisms of fresh water system was not found here. The same observation was made by Hassan *et al.* (2009), on Euphrates river. It then means that each sampling site was instantaneously been polluted by anthropogenic activities around it as suggested by Li and Shen (2011). DO values were below WHO (2000) permissible limits and range between 2.90 ± 0.17 – 4.62 ± 0.45 mg/l. There is no significant difference in the DO value between seasons and stations. This low DO value is indicative of either anthropogenic pollution or natural organic material that heightens microbial activities that deplete oxygen.

The BOD value was low and uniform throughout the study period. The mean BOD value is lower than the recommended maximum allowable concentration (RMC) set by the European Union for good quality water for fisheries and other aquatic life which is 3.0–6.0 mg/l (Chapman, 1996). The low BOD value is an indication that the water of Imaboro River is suitable for fisheries and other aquatic life. Based on BOD classification of water bodies as modified by Adakole *et al.* (2008), Imaboro river's water can be designated as moderately polluted in both the dry and wet season.

The range of total hardness was between 18.40 ± 2.40 - 48.0 ± 8.10 mg/l lower than the permissible limit of 300 mg/l suggested by FEPA (as cited by Dimowo, 2013). Lack of significant difference in the total hardness values between stations and seasons could be the result of self-regulating mechanisms of the river.

Total alkalinity of the river water was found to be uniformly low; much lower than upper permissible limit of 100 mg/l (WHO, 2000). Higher total alkalinity value in station 4 than other stations could be as a result of hydrolysis of the underlying bed rock.

Nitrates-Nitrogen value was found to be higher than the permissible tolerance value of 10 mg/l in both dry and wet seasons suggested by WHO (2000). This may be due to inflow of sewage and runoff in the rainy season and fertilizer from farmlands. The $\text{NO}_3\text{-N}$ value was found to be significantly different between months and seasons. The higher nitrates value in the wet season could possibly be the result of inflow of sewage and runoff. Phosphate-Phosphorus range between 1.00 ± 0.07 - 2.34 ± 0.04 mg/l; a value lower than the tolerance limit of 5 mg/l. Phosphate-Phosphorus did not vary significantly between seasons and stations due to self-regulating mechanisms of the river (Dimowo, 2013).

5.2 Biological Parameters

The correlation that exists between the physicochemical quality of a water body and the population of macrobenthic invertebrates indicates that the physicochemical quality tends to have regulated the distribution of the organisms (Adakole *et al.*, 2008). The biotic component of an aquatic environment is affected in various ways by the physicochemical parameters (Adeogun *et al.*, 2004). Thus the macrobenthic invertebrates encountered and enumerated represent the summation of the prevailing water condition of Imaboro river water during the period of study. The one hundred and thirty four (134) species identified during the study period is grossly below the number reported by Adakole *et al.*, (2008), Adakole and Annune (2003) for tropical streams. The low number encountered during the study period could be attributed to frequent disturbance of the river by cattle and humans. The comparably lower number of macrobenthic fauna encountered in the rainy season and none at all in June, July August and December could be the result of sediments brought by flood which buried the organisms deeper beyond the reach of Eckman grab. The dominance of Chironomidae and Oligochaete worms was an indication of moderately polluted water (Debbie, 2012).

Phytoplankton community of Imaboro river was composed of five taxa comprising 57 species and 2474 individuals. The taxon Chlorophyta had the greatest number of species (27), 1862 individuals and 75.26% of the total population. The second most abundant taxon was cyanophyta with 7 species and 555 individuals (22.43%) of the total population. This is in agreement with the findings of Pramila *et al.* (2008). The high percentage composition of Chlorophyceae and cyanophyceae indicates higher productivity of Imaboro River water due to nutrient enrichment. The same

observation was made by Pramila *et al.* (2008), on Nagpur city Lakes. The family Zygnemataceae was the dominant family in the taxon Chlorophyta with a total of 1615 individuals (86.73%) of the total population of chlorophyta. Chia (2007), reported that the presence of some Chlorophyta taxa as the most predominant division of algae in diversity and population density is indicative of relatively clean water. The dominant family in the taxon cyanophyta was the family Chroococaceae with a population of 416 (74.95%) of the total cyanophyta population found during the period of study. The abundance of phytoplankton was higher in the dry season than in the rainy season. This trend could have been the grazing effects of the zooplankton which were found to be significantly higher in the rainy season than the dry season on the phytoplankton. *Closterium* showed negative correlation with electrical conductivity. Chia *et al.* (2011), also discovered same in man-made lakes in Zaria. *Scenedesmus* showed positive correlation with electrical conductivity but Chia *et al.* (2011), found that *scenedesmus* has positive correlation with alkalinity.

The zooplankton community of Imaboro river is dominated by Cladocera which formed 71.77% of the total population. Rotifera was next to Cladocera (12.92%), followed by Copepoda (9.09%). This zooplankton community is indicative of good water quality with the presence of some organic pollution as suggested by Pramila *et al.* (2008), that the presence of pollution indicator species such as *Branchionus* along with clean water indicator species like *Daphnia* indicates a good water quality of the water body with presence of some organic pollution. *Daphnia* (Cladocera) showed positive correlation to DO. *Holopedium* (cladocera) and *Polyphemus* (cladocera) were positively correlated to phosphate and nitrate respectively though Edward and Ugwumba (2010), found that Cladocera is positively correlated to nitrate and phosphate. This is because they are nutrient determined. *Calanus* (Copepoda) was

correlated positively to DO and negatively to BOD and electrical conductivity however, Edward and Ugwumba (2010) found that Copepoda correlated positively to conductivity. This variation could be as a result of wide disparity in the value of electrical conductivity in their study and the present study.

Five (5) non-diatom periphyton taxa composed of twenty one (21) families, forty four (44) species and two thousand, eight hundred and eighty six (2886) individuals were encountered and enumerated. Chlorophyta had the highest percentage (75.12) of the population followed by Cyanopyta. This trend was as a result of runoffs into the water body (Adakole *et al.*, 2004).

A fundamental part of lotic systems is the periphyton community assemblages whose diversity increases as anthropogenic influences on the system increases (Round, 1991). A major part of these periphyton assemblages is made up of diatoms which are various microscopic one-celled or colonial members of the algal division or phylum Bacillariophyta of the class Bacilliarophyceae, having cell walls of silica consisting of two interlocking symmetrical valves (Taurai, 2011). The relation between diatoms and environmental variables are robust and quantifiable making diatoms appropriate indicators of ecological conditions in lotic systems. They provide excellent indicators of water quality (Taurai, 2011). A change in nutrients or a number of other factors will allow some members of the diatom community to grow and reproduce more quickly while others are out competed, thus the community composition as a whole changes in response to change in the environmental conditions (Shruthi *et al.*, 2011). Up to 70% of what happens in the water quality can be reflected in diatom assemblages (Lani van, 2007).

Eunotiaceae was the dominant taxon of the periphytic diatom community of Imaboro river. The dominance of this taxon could be because of the slightly acidic nature of Imaboro River water. This agrees with Marina (1996), who found that several *Eunotia* species dominated the slightly acidic stations of rivers of the Kolyma Mountains. The presence of species that are intolerant to pollution such as *Cymbella tumida* and moderate tolerant species such as *Cymbella turgidula*, *Navicula cryptocephala*, *N. rhnchocephala* and *Synedra ulna* (Wu, 1986), is indicative of moderately polluted water. The high diversity index throughout the stations is indicative of high anthropogenic influence on the river as suggested by Round (1991).

Table 4.14: Range of physico-chemical parameters of Imaboro river and selected national and international guidelines for drinking water.

Parameters	Range		Maximum permissible limits in water						
	Minimum	Maximum	NAFDAC	SON	FEPA	NSDW	WHO	EU	USEPA
Temp (⁰ C)	23.24±0.39	28.36±0.19	-	-	-	-	-	-	-
Transp (cm)	39.80±9.16	59.30±9.41	-	-	-	-	-	-	-
TSS (mg/L)	100.00±68.24	300.00±0.00	-	-	-	-	-	-	-
TDS (mg/L)	40.00±24.49	820.00±335.26	500	500	500	500	1000	-	500
TS (mg/L)	200.00±63.24	1120.00±335.26	-	-	-	-	-	-	-
Depth (cm)	50.00±6.28	65.1012.54	-	-	-	-	-	-	-
Width (m)	9.30±1.89	12.72±2.93	-	-	-	-	-	-	-
Velocity (m/s)	0.17±0.05	0.66±0.09	-	-	-	-	-	-	-
pH	5.75±0.11	6.19±0.17	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.8	6.5-9.5	6.5-8.5
EC (µS/cm)	17.80±3.54	34.60±10.27	1000	1000	70	1000	-	-	-
DO (mg/L)	2.96±0.17	4.62±0.45	-	-	≥4	-	≥6	-	-
BOD (mg/L)	0.66±0.13	2.70±0.77	-	-	-	-	-	-	-
TotalHardness (mg/L)	18.40±2.40	48.00±8.10	100	100	-	150	100	-	-
Alkalinity (mg/L)	4.75±0.95	13.20±3.18	100	100	-	-	100	-	-
NO ₃ -N (mg/L)	7.200±73	24.80±1.39	-	-	-	-	-	-	-
PO ₄ -P (mg/L)	1.00±0.07	2.34±0.04	-	-	-	-	-	-	-

Source: Dimowo (2013).

Note: NAFDAC-National Administration for Food, Drugs and Control, SON-Standard Organization of Nigeria, FEPA-Federal Environmental Protection Agency, NSDW-Nigerian Standard for Drinking water, USEPA-United States Environmental Protection Agency, EU-European Union and WHO-World Health Organization

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The physico-chemical and Biological parameters of Imaboro river were studied monthly for a period of twelve (12) months- October, 2012 to September, 2013. The analysis showed that temperature ranges between 23.24 ± 0.39 and $28.36\pm 0.19^{\circ}\text{C}$, transparency between 39.80 ± 9.16 and 59.30 ± 9.41 cm, TSS between 100.00 ± 68.24 and 300.00 ± 0.00 mg/l, TDS between 40.00 ± 24.49 and 820.00 ± 335.26 mg/l, velocity between 0.17 ± 0.05 and 0.17 ± 0.05 m/s. pH ranges between 5.75 ± 0.11 and 6.19 ± 0.17 , EC between 17.80 ± 3.54 and 34.60 ± 10.27 $\mu\text{S/cm}$, DO between 2.96 ± 0.17 and 4.62 ± 0.45 mg/l, total hardness between 18.40 ± 2.40 and 48.00 ± 8.10 mg/l, alkalinity between 4.75 ± 0.95 and 13.20 ± 3.18 mg/l, $\text{NO}_3\text{-N}$ between 7.200 ± 73 and 24.80 ± 1.39 mg/l and $\text{PO}_4\text{-P}$ between 1.00 ± 0.07 and 2.34 ± 0.04 mg/l. The results of the analyses of physico-chemical parameters showed that most physico-chemical parameters did not vary statistically between stations. The results also showed that apart from pH conductivity and width, there was no significant difference ($p>0.05$) between seasons of the study period.

The analysis of biological parameters revealed that periphyton and phytoplankton had more diversified population than zooplankton and benthos. The result also showed that apart from benthos, the biological parameters did not vary significantly between months, stations and months/stations.

6.1 Conclusion

Most physico-chemical parameters of Imaboro river fall within permissible limits. However, the water showed evidence of pollution as suggested by low DO values reinforced by the dominance of Chironomidae larvae in the benthos and presence of pollution tolerant species among the diatoms. The water of the river was found to be slightly acidic. The physico-chemical parameters vary significantly between stations and months. The significant difference in most physico-chemical parameters between months and stations indicates variable anthropogenic impacts on the river.

The community structure of the biological parameters studied showed no significant difference ($p>0.05$) between stations and months. The biological parameters of Imaboro River were determined by the physico-chemical parameters.

6.2 Recommendations

In view of the findings of this work the following recommendations are put forward:

- (i) Imaboro river should be monitored regularly to identify and control any form of pollution on the river.
- (ii) More sampling points should be used to capture the effects of runoff from all the parts of the town on the river at the point of entry to the river.
- (iii) Molecular techniques should be used for accuracy in identification of organisms.
- (iv) Further research on Imaboro river should include the determination of heavy metal contents of the river.

REFERENCES

- Abolude, D.S., (2007). *Water quality and metal concentrations in sediments and fish from Ahmadu Bello University Reservoir, Zaria using Neutron Activation Analysis and Atomic Absorption Spectrophotometry*. An unpublished Ph. D. thesis submitted to Postgraduate School, Ahmadu Bello University, Zaria. P.136
- Adakole, J.A. and Oladimeji, A.O. (1996). The effects of pollution on phytoplankton in a stretch of River Kubanni, Zaria, Nigeria. *Proceedings of the 15th Annual Conference of Fisheries Society of Nigeria (FISON)*, 151-158.
- Adakole, J.A., Abolude, D.S. and Balarabe, M.L. (2008). Assessment of water quality of a man-made lake in Zaria, Nigeria. In Sengupta, M. and Dalwani, R. (Eds), *Proceedings of Taal 2007. The 12th World Lake Conference*, 342 – 346.
- Adakole, J.A. and Annune, P.A. (2003). Benthic macroinvertebrates as indicators of environmental quality of an urban stream, Zaria. *Nigerian Journal of Aquatic Sciences*, 18 (2):85-92.
- Adakole, J.A., Mbah, C.E. Odeje, S.C. and Balarabe, M.L. (2004). Primary productivity in relation to water quality in two man-made lakes in Zaria, Nigeria. *The Nigerian Society for Experimental Biology (NISEB) Journal*, 4 (1):37-42.
- Adeloye, A.J. (2004). *Rivers and human development*. Eolss publishers, Edinburg, UK www.eolss.net/EolssSampleChapter/c.
- Adeogun, O.A., Fafioye, O.O., Olaleye, B.A. and Ngobili, G.O. (2004).The relationship between some physicochemical parameters and plankton composition on fish production in ponds. *Proceedings of the 19th Fisheries Society of Nigeria (FISON)*, Lagos-Nigeria, 424-428.
- Akin-Oriola, G.A. (2003). On the phytoplankton of Awba reservoir, Ibadan, Nigeria. *Revista de Biologia Tropical*, 51:1
- Alberta Water Quality Awareness (AWQA), 2012, Dissolved Oxygen and Alberta Streams and Rivers, Alberta Surface Water Quality. scholar.google.com/scholar?q=Alberta+water+Quality+assesment&hl=en&as_sdt
- Allison, M.E., Sikoki, F.D., Hart, A.I., and Ansa, E.J. (2007). Some aspects of physic-chemical characteristics of the freshwater reaches of the lower Nun River, Niger Delta, Nigeria. *African Journal of Applied Zoology and Environmental Biology*, 9:51-58.
- APHA (1998) *Standard Method for the Examination of Water and Waste Water*.21st edition. American Public Health Authority, Water Environmental Federation, Washington D.C. 1287pp

- APHA (2002) *Standard Method for the Examination of Water and Waste Water*. 22nd edition. American Public Health Authority, Water Environmental Federation, Washinton D. C. 1280pp
- APHA (American Public Health Association) (1995). *Standard Method For The Examination Of Water And Waste Water*. 19th Edition. American Public Health Association Inc New York, pp1193.
- Barry, J.F.B. and Catty, K. (2000). *Stream Periphyton Monitoring Manual*. NIWA, Christchurch, New Zealand. 246pp
- Bellingham, K. (2012). *Physicochemical Parameters of Natural Waters: Stevens water monitoring systems*. <http://www.stevenswater.com/index.aspx>
- Best, G.A., Bogacka T. and Niemirycz, E. (1998). *International River Water Quality: Pollution and Restoration*. 1st Edn., Taylor and Francis, London UK., ISBN-10: 0419215409, p. 310.
- Biggs, B.J.F. and Kilroy, C. (2000). *Stream periphyton Monitoring Manual*. New Zealand Ministry for the Environment, NIWA: Christchurch, New Zealand. 246pp.
- Billigerr, B.J., Cocquyt, C and O'Relly, M. (2006). Benthic diatoms as indicators of eutrophication in tropical streams. *Hydrobiologia*, 573: 75-87.
- Boulton A. J. (2012). Temperature impacts on stream ecology, *Water Encyclopedia* <http://www.waterencyclopedia.com/Re-St/Stream-Ecology-Temperature-Impacts-on.html>
- Chapman D. (1996). *Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*. Chapman and Hall; London, UK <http://insects.about.com/bio/Debbie-Hadley-35908.htm>.
- Chia, A. M., Oniye, S. J., Ladan, Z., Lado, Z., Pila, A. E., Inekwe, V. U. and Mmerole, J. U. (2009). A survey for the presence of microcystins in aquaculture ponds in Zaria, Northern-Nigeria: Possible public health implication. *African Journal of Biotechnology*, 8 (22): 6282-6289
- Chia, A. M., Iortsun, D. N., Stephen, B. J., Ayobamire, A. E and Ladan , Z. (2011). Phytoplankton responses to changes n macrophyte density in a tropical artificial pond in Zaria, Nigeria. *African Journal of Aquatic Science*, 36 (1): 35-46
- Chigor, V. N., Umoh, V. J., Okuofu, C. A., Ameh, J. B., Igbinosa, E. O. and Okoh, A. I. (2012) Water quality assessment: surface water sources used for drinking and irrigation in Zaria, *Springer Science+Business Media B. V.2011* www.portico.org/.ebook

Debbie H. (2012). Water Quality Monitoring Using Aquatic Macroinvertebrates: What aquatic insects can tell you about the water quality of a stream. <http://insects.about.com/bio/Debbie-Hadly-35908.html>.

Diatom Identification Chart. diatom_ident_chart 1.pdf.

Dimowo B. O. (2013). Assessment of Some Physico-chemical Parameters of River Ogun (Abeokuta, Ogun State, Southwestern Nigeria) in Comparison With National and International Standards, *International Journal of Aquaculture*, 3 (15): 79-84 (doi: 10.5376/ija.2013. 03.0015)

Doung, T.T., Feurtet-Mazal, A., Coste, M., Dang, D.K. and Boudou, A. (2007). Dynamics of diatom colonization processes in some rivers influenced by urban pollution (Hanoi, Vietnam). *Ecological indicators*, 7:839-851.

Dunn, R. (n.d). Identification of Algae problems. www.ohiowater.org/...wwa/districts/southeast/2008/... pp84

Edward J.B. and Ugwumba A.A.A. (2010). Physico-chemical Parameters and Plankton Community of Egbe Reservoir, Ekiti, Nigeria. DOI: 10.3923/rjbsci.2010.356.367.

Edward, G. B. and David, C. S. (2010). *Freshwater algae*. John Wiley and sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO198SQ, UK. pp.285.

Environment and development. IUCN, Gland and Cambridge, UK (1989)

Environmental Information System [ENVIS] Technical Report: 25 (2007): *Ecological Assessment of Lentic Water Bodies of Bangalore*. <http://ces.iisc.ernet.in/biodiversity>. pp105

Federal Environmental Protection Agency (FEPA). In Dimowo B. O., (2013). Assessment of Some Physico-chemical Parameters of River Ogun (Abeokuta, Ogun State, Southwestern Nigeria) in Comparison With National and International Standards, *International Journal of Aquaculture*, 3 (15): 79-84 (doi: 10.5376/ija.2013. 03.0015)

Harris, R. P., Wiebe, P. H., Lenz, J., Skjoldal, H. R. and Huntly, M. (2000). *Zooplankton Methodology Manual*. Academic Press, Harcourt place, 32 Jamestown Road, London NW17BY, UK health/Globassessment/GlobalTOC.htm.

Hassan, F.M., M.M. Saleh and Salman, J.M. (2009). A Study of Physicochemical Parameters and Nine Heavy Metal in the Euphrates River, Iraq. *E-J. Chem.*, 7: 685-692. DOI: 10.1155/2010/906837.

- Hellawell, J.M. (1986) Biological indicators of freshwater pollution and environmental management. In : *Pollution Monitoring series*. Elsevier Applied Science Publishers, London, UK. p546.
- Howard, P. (2011). Water Quality. [Http//Ga.Waterusgs.Gov/Edu/Waterquality.Html](http://Ga.Waterusgs.Gov/Edu/Waterquality.Html).
- IUCN (1989). *From strategy to Action: The IUCN response to the report of the world commission on environment and development*. IUCN, Gland and Cambridge, UK
- Jacob, A. (2012). A guide to Diatoms as Indicators of Urban Stream Health. [../archive/ ../library/nrhp/diatoms_indicators/](http://archive.library/nrhp/diatoms_indicators/)
- Jain, A.K. (2009). *River Pollution*. 1st Edn., APH Publishing, New Delhi, ISBN: 8131304639, p. 330.
- Kannel, P. R., Lee, S., Lee Y. S., Kannel, S. R., and Khan S. P.(2007) Application of Water Quality Indices and Dissolved Oxygen as Indicators of River Water Classification and Urban Impact Assessment. *Environ. Monitor. Assessment*, 132: 1 – 3
- Karthick, B., Jonathan, C.Y., Mahesh, M.K., and Ramachandra, T.V. (2010). Protocols for collecting, preservation and enumeration of diatoms from aquatic habitats for water quality monitoring in India. *The inter-university programme (IUP) journal of soil and water sciences*, 3 (1): 25-60.
- Kelly Addy M. S., Linda Green M. S., Elizabeth Herron M. A. (2004). pH and Alkalinity, URI Watershed Watch program; Department of Natural Resources Science, College of the Environment and Life Sciences, University of Rhode Island; <http://www.uri.edu/ce/wq/ww/Publications/pH%26alkalinity.pdf>
- Kennish, M.J. (1992). *Ecology of Estuaries : anthropogenic effects*. CRC Press : Boca Raton.. 512pp. ISBN 9780849380419.
- Kolo, R. J. and Oladimeji, A. A. (2001). Water quality and some nutrient levels in shiroro lake, Niger State, *Nigeria. Journal of Aquatic Science*, 19 (2): 99.
- Landres, P. B., Verner J., and Thomas J.W. (1988). Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* 2: 316 – 328.
- Lani van V. (2007), diatom A new dimension to water monitoring. *Science in Africa*. <http://www.sciencein africa.co.za/2007/july/diatoms.htm>.
- Lavoie, I., Darchambeau, f., Cabana, G. and Dillon, P. J. (2008). Are diatoms good integrators of temporary viability in stream water quality? *Freshwater biology*, 53:827-841.
- Li, J., H. Li, B. Shen and Y. Li. (2011). Effect of non-point source pollution on water quality of the Weihe River. *Int. Journal of Sediment Resources*, 26: 50-61. DOI: 10.1016/S1001-6279(11)60075-9.

- Lobanga, K.P., Van Zyl, J.E. and Ilemobade, A.A. (2009) The extent of non-compliant plumbing components used in South Africa. *Water SA* 35 (2) 175-182.
- Lobo, E.A.; Callegaro, V. L., Hermany, G.; Bes, D., Wetzel, C.E. and Oliveira, M.A. (2004). Use of epilithic diatoms as bio-indicator from lotic systems in southern Brazil, with special emphasis on eutrophication. *Acta Limnologica Brasiliensia*, 16:25-40.
- Mahadev, J. and Hosamani, S.P. (2005). Algae for bio-monitoring of organic pollution in two lakes of Mysore city. *National Environmental Pollution Technology*. 4: 97 – 99
- Mann, D.G. (1999). The species concept in diatoms. *Phycology*, 38: 437-495.
- Marina P. (1996). Epilithic algal communities in rivers of the Kolyma Mountains, NE Siberia, Russia. *Nova Hedwigia* 63 3-4 309-334.
- Mitchell, M. K. and Stapp, W.B. (2000). *Field Manual for Water Quality Monitoring* 12th Edition.
- Njoku, D.C. and Keke, I.R. (2003). A Comparative Study On Water Quality Criteria Of Delimit River In Jos, Plateau State of Nigeria. *ASSET Series A* 3(4). 143 – 153.
- Pai, I.K. (2002). In Kumar, A. (Ed). *Ecology of polluted water*. Shodhganga.inffilbnet.ac.in.8080/jsp...
- Pramila, K., Sharda, D., Chaudhani, P.R., and Wate, S. R. (2007). A bio-monitoring of plankton to assess quality of water in the lakes of Nagpur city. In Sengupta, M and Dalwani, R (Eds). *Proceedings of Taal 2007: The 12th world lake conference*: 160 – 164
- Ramachandra T.V. Ahalya N., and Rajashekara Murthy C. (2005) *Aquatic Ecosystems: Conservation, Restoration and Management*, Capital Publishing Company, New Delhi., p 31.
- Ramachandra, T. V. and Malvikaa, S. (2007). Ecological Assessment of Lentic Water Bodies of Bangalore. *ENVIS Technical Report*: 25. <http://ces.iisc.ernet.in/biodiversity>.
- Resh, V. H. (2007). Multinational fresh water biological monitoring programs in the developing world: lessons learned from Africa and south-east Asian River Surveys. *Environmental Management*, 39: 737-748.
- Rocha, A.A. (1993). Algae as indicators of water pollution. In Cordeiro-marino, M., Azevedo, M.T. P., Sant'anna, C.L., Tomita, N.Y. and Pastino, E.M. (Editors). *Algae and Environment: a general approach*. Sao Paulo, *Sociedade Brasileira de Ficologia*, 34-55.

- Round, F.E. (1991). Diatoms in river water monitoring studies. *Journal of applied phycology*, 3: 129-145.
- Sheila, M. (2007). General Information on Solids. *BASINS*. City of Boulder/USGS Water Quality Monitoring. <http://bcn.boulder.cous/basin/index.html>.
- Shruthi M. S, Sushanth V. R. and Rajashekhar M. (2011). Diatoms as indicators of water quality deterioration in the estuaries of Dakshina Kannada and Udupi Districts of Karnataka. doi: 10.6088/ijes.00202020056.
- Singh, L.B. (2007). *River Pollution*. 1st Edn., APH Publishing, New Delhi, ISBN-10: 8131300854, pp: 192.
- Sonneman, J.A., Walsh, C.J., Breen, P.F. and Sharpe, A.K. (2001). Effects of urbanization on streams of the Melbourne region, Victoria, Australia. 11. Benthic diatom communities. doi: 10.1046/j.1365-2427.2001.00690.x
- Taurai, B. (2011).The Diatom Assemblages as Indicators of Field and Laboratory Ecological Conditions in Lotic Systems: Conservation and Water Quality Management in Sao Carlos-SP Catchment, Brazil. A Ph.D thesis submitted to the Federal University of SAO Carlos. pp 221
- Ter Braak C.J.F. (1986). Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 67: 1167–1179.
- Trainor, F. R. (1984). Indicator Algal Assay Laboratory and fields approaches. In: Shubert E.D., “*Algae as Ecological Indicators*. Academic press London. p 3 – 14.
- Ugwu, A.I. and Wakawa R.J. (2012). A Study of seasonal physicochemical parameters in River Usman. *American Journal of Environmental Science*, 8 (5), 569-576.
- UNEP (United Nations Environment Programme) (2002). Convention on biological Diversity. United Nations. <http://www.biodiv.org/convention/articles.asp>.
- UNESCO-World Water Assessment Program Report (2009). Climate Change and Water: Water in a Changing World. www.unesco.org/water/wwap
- United Nations. <http://www.biodiv.org/convention/articles.asp>
- USEPA. (2002). *Methods for Evaluating Wetland condition*. Office of water, U.S. Environmental Protection Agency, Washington, DC. Water.epa.gov/type/wetlands/methods_index.cfm
- Venkataraman, L.V. Krishi M.K.and Suvarnalatha G., (1994). Algae as tool for biomonitoring and abatement of pesticide pollution in aquatic system. *Phykos*, 33 (1 & 2) : 171-193.

- WAEC (The West African Examination Council), (1995). *Mathematical and statistical tables and formulae*. P 18
- Water Action Volunteers. (2006). *Stream flow: flow speaks volume*. Volunteer monitoring factsheet series. <http://water.epa.gov/type/rsl/monitoring/vms5l.cfm>.
- World Health Organization, WHO (1971). International Standards for Drinking Water. 3rd Edn. WHO (Geneva, 1963 – 2006 Pp).
- World Health Organization, WHO (2000). Water Planning Branch (919): 733 – 5083. [Www.Epci.Gov/Watersciences/Criteria](http://www.Epci.Gov/Watersciences/Criteria).
- World Health Organization, WHO (2000). Global Water Supply and Sanitation Assessment Report. World Health Organization, Geneva. URL: http://www.who.int/docstore/water_sanitation_
- Wu, J. T. (1986). Relation of change in river diatom assemblages to water pollution. *Bot. Bull Academia Sinica* 27: 237-246.
- Yogendra, K. and Puttaiah, E. T. (2008). Determinant of Water Quality Index and Substanability of an Urban Water Body In Shimiga Town, Karnataka. In Sengupta, M. and Dalwani, R. (Eds). *Proceedings of Taal 2007: The 12th World Lake Conference* 342-346

APPEDICES

Appendix I: Mean monthly phytoplankton population of a stretch of Imaboro river per station

Month	Stations					Total (%)
	1	2	3	4	5	
October	78	39	29	15	24	185 (7.47)
November	174	57	237	61	70	599 (24.17)
December	281	45	254	123	31	734 (29.62)
January	108	74	218	3	1	404 (16.30)
February	2	20	7	3	10	42 (1.69)
March	19	12	2	0	10	43 (1.74)
April	1	0	0	2	2	5 (0.20)
May	1	1	133	0	1	136 (5.49)
June	29	12	3	0	12	56 (2.26)
July	8	12	121	8	15	164 (6.62)
August	0	5	10	6	3	24 (0.97)
September	22	1	61	1	1	86 (3.47)
Total (%)	723 (29.18)	278 (11.22)	1075 (43.38)	222 (8.96)	180 (7.26)	2478

Appendix II: Mean monthly Zooplankton population of a stretch of Imaboro river per station

Month	Stations					Total (%)
	1	2	3	4	5	
October	0	6	9	4	0	19 (9.09)
November	1	2	12	4	0	19 (9.09)
December	1	0	2	2	0	5 (2.39)
January	2	2	4	2	1	11 (5.26)
February	0	3	1	0	2	6 (2.87)
March	4	1	2	0	0	7 (3.35)
April	5	3	1	0	2	11 (5.26)
May	0	8	8	2	2	20 (9.57)
June	24	51	18	1	2	96 (45.93)
July	4	0	1	3	0	8 (3.83)
August	0	0	0	0	0	0 (0.00)
September	1	4	2	0	0	7 (3.35)
Total (%)	42 (20.10)	80 (38.28)	60 (28.71)	18 (8.61)	9 (4.31)	209

Appendix III: Benthos community of a stretch of Imaboro river during the study period.

Families	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Total
Chironomidae larvae	0	3	16	31	9	8	28	8	5	0	0	0	108
simulidae larvae	0	1	0	0	0	0	0	0	0	0	0	0	1
oligocheate worm	0	1	0	4	0	0	2	1	0	0	0	0	8
syrphidae larvae	0	1	0	0	0	0	0	0	0	0	0	0	1
Nepidae (waterscorpion nymph)	0	3	0	0	0	0	0	0	0	0	0	0	3
Nepidae(waterscorpion adult)	0	1	0	0	0	0	0	0	0	0	0	0	1
Coleoptera (Dystiscidae)	0	1	0	0	0	0	0	0	0	0	0	0	1
Anthericidae larvae(cranefly)	0	0	2	0	0	0	0	0	0	0	0	0	2
Tupilidae larvae (cranefly)	0	0	3	0	0	0	0	0	0	0	0	0	3
Sialidae larvae (Alderfly)	0	0	0	0	2	0	0	0	1	0	0	0	3
Coleoptera (Hydrophilidae)	0	0	0	0	0	0	1	0	0	0	0	0	1
Empididae larvae	0	0	0	0	0	0	0	0	1	0	0	0	1
Damselfly larvae	0	0	0	0	0	0	0	0	1	0	0	0	1

Appendix IV: Comparison of phytoplankton, zooplankton and benthos between seasons

Season	Month	Phytoplankton	Zooplankton	Benthos
Dry	November	599	19	11
	December	734	5	21
	January	404	11	35
	February	42	6	11
	March	43	7	8
		1822	48	86
Wet	April	5	11	31
	May	136	20	9
	June	56	96	8
	July	164	8	0
	August	24	0	0
	September	86	7	0
	October	185	19	0
		657	161	48
Total		2478	209	134

Appendix V: Non-diatom Periphytic Community of a stretch Imaboro river

Month	Stations					Total (%)
	1	2	3	4	5	
October	31	14	15	28	20	108 (3.74)
November	384	106	107	82	332	1011 (34.97)
December	136	111	231	320	342	1140 (39.43)
January	254	127	106	21	124	632 (21.86)
Total (%)	805 (27.85)	358 (12.38)	459 (15.88)	451 (15.60)	818 (28.29)	2891

Appendix VI: Monthly Periphytic Diatom Community of a Stretch of Imaboro river per station

Month	Stations					Total (%)
	1	2	3	4	5	
October	576	661	1033	2416	531	5217 (18.79)
November	2259	1606	745	204	177	4991 (17.97)
December	1741	1054	1211	1566	717	6289 (22.65)
January	2814	2098	3602	1838	921	11273 (40.59)
Total (%)	7390 (26.61)	5419 (19.51)	6591 (23.73)	6024 (21.69)	2346 (8.45)	27770

Appendix VII: Periphytic Diatom Families of a Stretch of Imaboro river.

Families	Species	No of individuals observed	%
Acanthaceae	<i>Acanthes coaritata</i>	9	
	<i>Acanthes erdmannensis</i>	56	
	<i>Acanthes flagilarioides</i>	9	
	<i>Acanthes kryophila</i>	9	
	<i>Kobayasia subtilissima</i>	55	
		138	0.497
Acanthidiaceae	<i>Acanthidium affins</i>	18	
	<i>Acanthidium deflexum</i>	55	
	<i>Acanthidium exigum</i>	19	
	<i>Acanthidium minutissimum</i>	792	
	<i>Lemnicola lungarica</i>	19	
	<i>Planothidium apiculatum</i>	9	
	<i>Planothidium lanceolatum</i>	28	
		940	3.385
Amphipleuraceae	<i>Frustulia rhomboides</i>	690	
	<i>Frustulia vulgaris</i>	84	
		774	2.798
Amphoraceae	<i>Amphora obscura</i>	83	
	<i>Amphora pediculus</i>	55	
	<i>Amphora spp</i>	157	
		295	1.062
Aulacoseiraceae	<i>Aulacoseira granulata</i>	55	
Bacillariaceae	<i>Hantzchia</i>	9	
	<i>Nitzschia amphibia</i>	36	
	<i>Nitzschia angustata</i>	56	
	<i>Nitzschia linearis</i>	28	
		129	0.465
Brachysiraceae	<i>Brachysira styriaca</i>	19	0.068

Appendix VIII: Periphytic Diatom Families of a Stretch of Imaboro river Continued.

Families	species	No of individuals observed	%
Cymbellaceae	<i>Cymbella affinis</i>	149	
	<i>Cymbella proxima</i>	18	
	<i>Cymbella tumida</i>	84	
	<i>Cymbella turgidula</i>	308	
	<i>Encyonema minuta</i>	198	
	<i>Encyonema mualleri</i>	131	
	<i>Encyonema spp</i>	47	
	<i>Placoneis abisloensis</i>	18	
	<i>Placoneis spp</i>	85	
		1038	3.738
Eunotiaceae	<i>Eunotia arcus</i>	494	
	<i>Eunotia exigua</i>	19	
	<i>Eunotia faba</i>	65	
	<i>Eunotia lunaris</i>	2867	
	<i>Eunotia serra</i>	232	
	<i>Eunotia spp</i>	5790	
	<i>Eunotia tenella</i>	290	
	<i>Semiorbis hemicyclus</i>	9	
		9766	35.167
Flagilariaceae	<i>Asterionella formosa</i>	399	
	<i>Ceratoneis arcus</i>	415	
	<i>Diatoma hyenalis</i>	47	
	<i>Diatoma mesodon</i>	66	
	<i>Diatoma tenue var. elongatum</i>	363	
	<i>Diatoma vulgare</i>	204	
	<i>Flagilaria virescens var. capitata</i>	47	
	<i>Flagilaria crotonensis</i>	1352	
	<i>Flagilaria crotonensis var. orogona</i>	9	
	<i>Flagilaria hoelii</i>	364	
	<i>Flagilaria intermedia</i>	409	
	<i>Flagilariforma virescens</i>	140	
	<i>Stauroforma exiguiformis</i>	280	
	<i>Stauroneis acuta</i>	9	
	<i>Stauroneis kriegeri</i>	9	
	<i>Synedra ulna</i>	1081	
		5194	18.703

Appendix IX: Periphytic Diatom Families of a Stretch of Imaboro river continued

Families	species	No of individuals observed	%
Gomphonemataceae	<i>Gomphoneis eriense</i> var		
	<i>variabilis</i>	1202	
	<i>Gomphoneis minuta</i> var. <i>iowei</i>	75	
	<i>Gomphonema augur</i>	28	
	<i>Gomphonema lingulataeformis</i>	19	
	<i>Gomphonema olivacea</i>	56	
	<i>Gomphonema sphaerophorum</i>	698	
	<i>Gomphonema spp</i>	112	
	<i>Gomphonema tenellum</i>	9	
	<i>Gomphonema truncatum</i>	45	
	<i>Gomphosphenia lingulataeformis</i>	18	
		2262	8.145
Hygromidae	<i>Actinella</i> spp	103	
Melosiraceae	<i>Melosira ovata</i>	9	
Naviculaceae	<i>Fistulifera</i>	9	
	<i>Gyrosigma parkeri</i>	9	
	<i>Hamnaea arcus</i>	37	
	<i>Navicula cryptocephala</i>	18	
	<i>Navicula gregaria</i>	178	
	<i>Navicula hasta</i>	288	
	<i>Navicula jarnefeldi</i>	9	
	<i>Navicula lanceolata</i>	2230	
	<i>Navicula mutata</i>	37	
	<i>Navicula rhyncocephala</i>	410	
	<i>Navicula skiftei</i>	28	
	<i>Navicula spp</i>	2145	
		5398	19.438
Peroniaceae	<i>Peronia fibula</i>	363	
Pinnulariaceae	<i>Pinnularia</i>	28	
Pleurosigmataceae	<i>Pleurosigma elongatum</i>	9	
Rhoicospheniaceae	<i>Rhoicosphenia curvata</i>	260	
Rhopalodiaceae	<i>Epithemia turgida</i>	28	
Stephanodiscaceae	<i>Cytotella</i> spp	27	
OTHERS	<i>Carinula cocconeiformis</i>	28	
	<i>Hamnaea arcus</i>	37	
	<i>Meridion anceps</i>	218	
	<i>Meridion circulare</i>	372	
		27770	
	TOTAL		

Appendix X: ANOVA of Biological Parameters per Month, Station and Station/month

Source	Variable	Mean	df	Mean square	F	Sig.
Month	Periphyton	72.748	2	5292.255	32.668	.123
	Diatoms	1187.341	2	1409780.405	.392	.749
	Phytoplankton	92.021	10	8467.855	11.135	.229
	Zooplankton	11.519	10	132.677	7.371	.280
	Benthos	5.170	10	26.729	2.285E28	.000
Stations	Periphyton	100.208	4	10041.549	61.985	.095
	Diatoms	2119.081	4	4490503.502	.136	.946
	Phytoplankton	119.010	4	14163.403	18.624	.172
	Zooplankton	8.003	4	64.044	3.558	.376
	Benthos	6.718	4	45.137	3.858E28	.000
Month/Station	Periphyton	107.424	7	11540.012	71235	.091
	Diatoms	463.635	7	205784.443	.057	.996
	Phytoplankton	43.569	39	1898.217	2.496	.470
	Zooplankton	6.130	39	37.576	2.088	.507
	Benthos	3.225	39	10.401	8.890E27	.000

Alpha = .05.

Appendix XI: Summary of PCA of Physico-chemical Parameters and CCA of Biological Parameters of Imaboro river

Parameters		Axes				Total
		1	2	3	4	
physicochemical parameters	Eigenvalues (%inertia)	0.928(92.99)	0.059(5.91)	0.009(0.90)	0.002(0.20)	0.998
Phytoplankton	Eigenvalues (%inertia)	0.463(32.35)	0.409(28.58)	0.331(23.13)	0.228(15.93)	1.431
	Species-environment correlation	0.871	0.886	0.875	0.819	
Zooplankton	Eigenvalues (%inertia)	0.776(30.71)	0.723(28.61)	0.629(24.89)	0.399(15.79)	2.527
	Species-environment correlation	0.918	0.893	0.861	0.737	
Periphytic diatoms	Eigenvalues (%inertia)	0.253(32.48)	0.205(26.32)	0.182(23.36)	0.139(17.84)	0.779
	Species-environment correlation	0.975	0.987	0.982	0.967	
Non-diatom periphyton	Eigenvalues (%inertia)	0.304(34.58)	0.218(24.80)	0.190(21.62)	0.167(19.00)	0.879
	Species-environment correlation	0.876	0.977	0.904	0.893	

Appendix XII: Phytoplankton Families and Species of a Stretch of Imaboro river

Division	Family	species	NO.identified	
chlorophyta	Chaetophoraceae	<i>Chaetophora elegans</i>	1	
		<i>Protoderma spp</i>	1	
		<i>Stigeoclonium spp</i>	2	
	Cladophoraceae	<i>Cladophora spp</i>	54	
		desmidaceae	<i>Closterium spp</i>	10
		<i>Desmidium grevilli</i>	56	
		<i>Pleurotaenium spp</i>	4	
		<i>Roya obtusus</i>	1	
		<i>Actinotaenium spp</i>	2	
	Hydrodictyaceae	<i>Hydrodictyon reticulatum</i>	1	
		<i>Pediastrum simplex</i>	2	
		<i>P. Tetras</i>	4	
	Oedogoniaceae	<i>Oedogonium spp</i>	22	
	Palmellaceae	<i>Gloeocystis ampla</i>	3	
	Scenedesmaceae	<i>Actinastrum hantzchii</i>	1	
		<i>Scenedesmus obtusus</i>	2	
	Ulothrichaceae	<i>Ulothrix zonata</i>	32	
	Volvocaceae	<i>Pandorina morum</i>	5	
		<i>Gonium</i>	4	
		<i>Volvox tertius</i>	8	
Vaucheriaceae	<i>Vaucheria spp</i>	12		
Zygnemataceae	<i>Muogeotia spp</i>	244		
	<i>Spirogyra aequinoctialis</i>	1327		
	<i>Zygnema pectinatum</i>	39		
Oocystaceae	<i>Oocystis borgei</i>	1		
Tetrasporaceae	<i>Gloeodendron catanatum</i>	4		
Ulvellaceae	<i>Ulvella involvens</i>	3		
Cyanophyta	Chroococcaceae	<i>Aphanocapsa grevilli</i>	14	
		<i>A. inarta</i>	28	
		<i>Gleocapsa punctata</i>	8	
		<i>Gloeotheca haufleri</i>	3	
		<i>G. linearis</i>	5	
		<i>Microcrosis irregulae</i>	102	
		<i>Microcystis flos-aquae</i>	17	
		<i>M. wesenbergii</i>	2	
		<i>Microspora flucossa</i>	237	
		Entophysalidaceae	<i>Chlorogloea lithogens</i>	7
			<i>Entophysalis lithophura</i>	2
		Hydrococcaceae	<i>Chroococcidium spp</i>	4

		<i>Chroococcus limneticus</i>	6
	Nostocaceae	<i>Anabaena spp</i>	6
		<i>Aphanizomenon</i>	37
		<i>Nostoc</i>	1
	oscillatoriaceae	<i>Oscillatoria rubescens</i>	4
		<i>Phormidium ambiguum</i>	51
		<i>P. richardsii</i>	1
		<i>Spirulina</i>	10
	Rivulariaceae	<i>Rivularia spp</i>	3
	Synechococcaceae	<i>Cyanodictyon planctonicum</i>	7
Rhodophyta	Batrachospermaceae	<i>Batrachospermum morniliforme</i>	1
		<i>B. vagum</i>	11
Phaeophyta	tribonemaceae	<i>Tribonema bombycinum</i>	27
Bacilliarophyta	Bacillariophyceae	<i>Navicula stromii</i>	5
		<i>N. seminulum</i>	6
		<i>N. spp</i>	15
	Others	<i>Bacularea gracilis</i>	1
		<i>B. indurata</i>	1

Appendix XIII: Non-diatom Periphyton Families and Species of a Stretch of Imaboro river

Division	Families	species	NO.identified	
chlorophyta	Chaetophoraceae	<i>Chaetophora elegans</i>	20	
		<i>Ctenocladus cercinatus</i>	4	
		<i>Stigeoclonium spp</i>	18	
	Cladophoraceae	<i>Cladophora spp</i>	292	
		<i>Rhizoclonium hieroglyphicum</i>	4	
	Desmidaceae	<i>Closterium spp</i>	62	
		<i>Cosmarium margaritatum</i>	2	
		<i>Desmidium grevilli</i>	5	
	Coleochaetaceae	<i>Coleochaeta saluta</i>	5	
	Hydrodictyceae	<i>Hydrodictyon reticulatum</i>	1	
	Oedogoniaceae	<i>Oedogonium spp</i>	60	
	Oocystaceae	<i>Chlorella elipsoidae</i>	6	
	Ulothrichaceae	<i>Ulothrix zonata</i>	40	
		<i>U. aequalis</i>	16	
	Volvocaceae	<i>Volvox tertius</i>	50	
	Scenedesmaceae	<i>Coelastrum microsporum</i>	2	
		<i>Actinastrum hantzchii</i>	3	
	Ulvellaceae	<i>Ulvella involvens</i>	4	
	Vaucheriaceae	<i>Vaucheria spp</i>	11	
	Zygnemataceae	<i>Muogeotia spp</i>	410	
		<i>Spirogyra aequinoctialis</i>	1093	
		<i>Zygnema pectinatum</i>	62	
	cyanophyta	Chroococcaceae	<i>Gloeocapsosis crepidium</i>	2
			<i>Gloeothece linearis</i>	32
			<i>Microcystis flos-aquae</i>	319
			<i>Microspora flucossa</i>	319
			<i>M. willeana</i>	149
Nostocaceae		<i>Nostoc</i>	2	
		<i>Anabaena oblonga</i>	2	
		<i>Aphanizimenon</i>	1	
Oscillatoriaceae		<i>Oscillatoria rubescens</i>	5	
		<i>Phormidium ambiguum</i>	83	
Rivulariaceae		<i>Calothrix atrichia</i>	1	
		<i>C. braunii</i>	3	
		<i>Gloeotrichia achinulata</i>	2	
		<i>G. pisum</i>	3	
		<i>Rivularia spp</i>	6	
Rhodophyta		Batrachospermaceae	<i>Batrachospermum morniliforme</i>	22

		<i>B. vagum</i>	2
		<i>Audonella hermanis</i>	10
Phaeophyta	Tribonemceae	<i>Tribonema bombycinum</i>	62
		<i>T. utriculassum</i>	1
	Phaostropiaceae	<i>Heribaudiella fluviatilis</i>	1
Pyrrophyta	Dinophyceae	<i>Dinoflagellate</i>	1

Appendix XIV: Number of Benthos Family at Each Station of a Stretch of Imaboro

river

Families	Stations					Total
	1	2	3	4	5	
Chironomidae larvae	7	39	58	3	1	108
simulidae larvae	0	1	0	0	0	1
oligocheate worm	0	0	8	0	0	8
syrphidae larvae	0	0	0	1	0	1
Nepidae (waterscorpion nymph)	0	0	0	1	2	3
Nepidae(waterscorpion adult)	0	0	0	0	1	1
Coleoptera (Dystiscidae)	0	0	0	1	0	1
Anthericidae larvae(cranefly)	0	0	0	1	1	2
Tupilidae larvae (cranefly)	0	0	0	0	3	3
Sialidae larvae (Alderfly)	0	1	0	1	1	3
Coleoptera (Hydrophilidae)	0	1	0	0	0	1
Empididae larvae	0	1	0	0	0	1
Damselfly larvae	0	0	0	1	0	1

Appendix XV: Number of Zooplankton species at Each Station of a Stretch of
Imaboro river

Species	Stations					Total
	1	2	3	4	5	
<i>Bosminopsis dietersi</i> (clado)	11	2	5	0	3	21
<i>Branchionus spp</i> (rotifa)	5	3	4	5	1	18
<i>Calanus hyperboreus</i> (cope)	0	5	2	2	0	9
<i>Daphnia pulex</i> (clado)	3	6	5	4	2	20
<i>Diaphanosoma birgi</i> (cope)	0	0	4	2	0	6
<i>Euchlanis spp</i> (rotifa)	1	0	3	2	1	7
<i>Eurycercus spp</i> (clado)	0	0	0	1	0	1
Gastropidae (rotifa)	0	1	1	0	0	2
<i>Holopedium gibberum</i> (clado)	18	51	16	2	0	87
<i>Hydracarina</i> (water mite)	0	1	0	0	0	1
<i>Leptodora kindti</i> (clado)	1	0	0	0	0	1
<i>Limnocalanus macrurus</i> (cope)	2	0	0	0	0	2
<i>Osphranticum labionectum</i> (cope)	0	2	0	0	0	2
<i>polyphemus pediculus</i> (clado)	0	9	9	0	2	20
Chironomidae larva	1	0	1	0	0	2
Mosquito larva	0	6	0	0	0	6
Arthropoda(Ostracoda)	0	0	4	0	0	4

Appendix XVI: Number of Phytoplankton species at Each Station of a Stretch of
Imaboro river

Species	Stations					Total
	1	2	3	4	5	
<i>Actinastrum hantzschii</i>	0	1	0	0	0	1
<i>Actinotaenium</i>	0	2	0	0	0	2
<i>Anabaena</i>	1	0	5	0	0	6
<i>Aphanizomenon</i>	16	10	3	3	5	37
<i>Aphanocapsa grevillei</i>	1	2	3	2	6	14
<i>Aphanocapsa inarta</i>	3	6	12	6	1	28
<i>Bacularia gracilis</i>	0	0	0	0	1	1
<i>Bacularia indurata</i>	0	0	0	0	1	1
<i>Batrachospermum morniliforme</i>	1	0	0	0	0	1
<i>Batrachospermum vagum</i>	1	0	0	0	0	1
<i>Chaetophora elegans</i>	0	0	1	0	0	1
<i>Chlamydomonas polypyrenoideum</i>	2	0	0	10	0	12
<i>Chlorogloea lithogenes</i>	3	0	4	0	0	7
<i>Chroococcidium</i>	0	1	1	1	1	4
<i>Chroococcus limneticus</i>	0	0	1	2	3	6
<i>Cladophora spp</i>	11	1	24	4	14	54
<i>Closterium spp</i>	0	4	4	0	2	10
<i>Cyanodictyon planctonicum</i>	3	1	2	0	1	7
<i>Desmidium grevilli</i>	1	3	4	48	0	56
<i>Entophysalis lithophula</i>	0	2	0	0	0	2
<i>Euglena</i>	0	0	4	0	1	5
<i>Gleocapsa punctata</i>	0	0	0	8	0	8
<i>Gleocystis ampla</i>	1	2	0	0	0	3
<i>Gloeodendron catanatum</i>	0	3	1	0	0	4
<i>Gloeotheca haufleri</i>	0	2	1	0	0	3
<i>Gloeotheca linearis</i>	1	3	1	0	0	5
<i>Gonium</i>	1	2	1	0	0	4
<i>Hydrodictyon reticulatum</i>	0	0	0	0	1	1
<i>Microcrosis irregulae</i>	28	43	14	1	6	92
<i>Microcystis flos-aquae</i>	2	9	1	2	3	17
<i>Microcystis wesenbergii</i>	0	0	2	0	0	2
<i>Microspora fluccosa</i>	44	61	116	1	15	237
<i>Muogeotia spp</i>	68	29	59	73	19	248
<i>Nacicula stromii</i>	5	0	0	0	0	5
<i>Navicula seminulum</i>	6	0	0	0	0	6
<i>Navicula spp</i>	1	2	2	1	9	15
<i>Nostoc</i>	0	0	0	1	0	1

<i>Oedogonium spp</i>	0	3	0	5	14	22
<i>oocystis borgei</i>	0	0	1	0	0	1
<i>Oscillatoria rubescens</i>	0	0	3	1	0	4
<i>Pandorina morum</i>	1	3	1	0	0	5
<i>Pediastrum simplex</i>	1	1	0	0	0	2
<i>Pediastrum tetras</i>	0	4	0	0	0	4
<i>Phormidium ambiguum</i>	0	0	50	1	0	51
<i>Phormidium richardsii</i>	0	0	0	1	0	1
<i>Planothidium lanceolatum</i>	2	0	0	0	0	2
<i>Pleurotaenium</i>	0	0	4	0	0	4
<i>Protoderma</i>	1	0	0	0	0	1
<i>Raya obtusa</i>	0	1	0	0	0	1
<i>Rivularia spp</i>	0	0	2	1	9	12
<i>Scenedesmus obtusus</i>	1	0	1	0	0	2
<i>Spirogyra aequinoctialis</i>	486	18	680	44	43	1271
<i>Spirulina</i>	0	1	8	1	0	10
<i>Stigeoclonium</i>	0	0	0	0	2	2
<i>Tribonema bombycinum</i>	0	0	27	0	0	27
<i>Ulothrix zonata</i>	0	0	2	5	25	32
<i>Ulvella involvens</i>	0	0	2	0	1	3
<i>Vaucheria</i>	4	1	3	0	4	12
<i>Volvox tertius</i>	4	1	2	1	0	8
<i>Zygnema pectinatum</i>	27	0	12	0	0	39

Appendix XVII: Number of Non-diatom Periphyton Species at Each Station of a
Stretch of Imaboro river

Species	Stations					Total
	1	2	3	4	5	
<i>Actinastrum hantzschii</i>	0	0	0	0	3	3
<i>Anabaena oblonga</i>	0	0	0	0	2	2
<i>Aphanizomenon</i>	0	1	0	0	0	1
<i>Audounella hermanis</i>	0	0	3	7	0	10
<i>Batrachospermum morniliforme</i>	1	8	11	1	1	22
<i>Batrachospermum vagum</i>	0	0	2	0	0	2
<i>Calothrix atrichia</i>	0	1	0	0	0	1
<i>Calothrix braunii</i>	0	0	3	0	0	3
<i>Chaetophora elegans</i>	4	2	13	0	1	20
<i>Chlorella elipsoidea</i>	0	3	1	2	0	6
<i>Cladophora spp</i>	7	10	76	151	48	292
<i>Closterium spp</i>	18	9	2	31	2	62
<i>coelastrum microporum</i>	1	1	0	0	0	2
<i>Coleochaete saluta</i>	0	1	4	0	0	5
<i>Cosmarium margaritatum</i>	0	0	2	0	0	2
<i>Ctenocladus cercinatus</i>	2	0	0	0	2	4
<i>Desmidium</i>	2	1	1	1	0	5
<i>Dinoflagellate</i>	0	0	0	0	1	1
<i>Euglena</i>	0	1	2	0	0	3
<i>Gloeocapsosis crepidium</i>	0	0	2	0	0	2
<i>Gloeothece linearis</i>	32	0	0	0	0	32
<i>Gloeotrichia achinaluta</i>	0	0	1	0	1	2
<i>Gloeotrichia pisum</i>	0	0	3	0	0	3
<i>Heribaudiella fluviatilis</i>	0	0	2	0	0	2
<i>Hydrodictyon reticulatum</i>	0	0	0	1	0	1
<i>microcystis flos-aquae</i>	1	1	6	0	0	8
<i>Microspora flucosa</i>	17	64	129	38	69	317
<i>Microspora willeana</i>	63	20	2	8	56	149
<i>Muogeotia spp</i>	190	11	47	61	101	410
<i>Nostoc</i>	1	0	1	0	0	2
<i>Oedogonium spp</i>	1	10	30	15	4	60
<i>Oscillatoria rubescens</i>	5	0	0	0	0	5
<i>Phormidium ambiguum</i>	0	0	50	0	33	83
<i>Rhizoclonium hieroglyphicum</i>	0	3	0	1	0	4
<i>Rivularia spp</i>	0	0	6	0	0	6
<i>Spirogyra aequinoctialis</i>	437	159	41	97	378	1112
<i>Stigeoclonium</i>	1	3	11	1	2	18

<i>Tribonema bombycinum</i>	6	24	5	26	1	62
<i>Tribonema utriculasum</i>	1	0	0	0	0	1
<i>Ulothrix aequalis</i>	0	0	0	0	16	16
<i>Ulothrix zonata</i>	0	14	3	10	13	40
<i>Ulvella involvens</i>	1	3	0	0	0	4
<i>Vaucheria</i>	2	2	0	1	6	11
<i>Volvox tertius</i>	0	0	0	0	50	50
<i>Zygnema pectinatum</i>	12	4	0	0	46	62

Appendix XVIII: Number of Periphytic Diatom Species at Each Station of a Stretch of Imaboro river

Species	Stations					Total
	1	2	3	4	5	
<i>A mphora obscura</i>	9	56	9	9	0	83
<i>Achanthes coaritata</i>	0	9	0	0	0	9
<i>Achanthes erdmannensis</i>	0	0	0	56	0	56
<i>Achanthes flagilarioides</i>	9	0	0	0	0	9
<i>Achanthes kryophila</i>	9	0	0	0	0	9
<i>Achanthidium affins</i>	9	9	0	0	0	18
<i>Achanthidium deflexum</i>	27	9	28	0	0	64
<i>Achanthidium exigum</i>	0	0	0	0	19	19
<i>Achanthidium minutissimum</i>	84	346	112	241	9	792
<i>Actinella spp</i>	9	0	19	75	0	103
<i>Amphora pediculus</i>	0	37	9	0	9	55
<i>Amphora spp</i>	65	56	27	9	0	157
<i>Asterionella formosa</i>	18	186	149	37	9	399
<i>Aulacoseira granulata</i>	9	9	19	0	9	46
<i>Brachysira styriaca</i>	0	0	0	0	19	19
<i>Carinula cocconeiformis</i>	0	9	19	0	0	28
<i>Ceratoneis arcus</i>	182	205	0	19	9	415
<i>Cymbella affinis</i>	28	28	93	0	0	149
<i>Cymbella proxima</i>	18	0	0	0	0	18
<i>Cymbella tumida</i>	28	56	0	0	0	84
<i>Cymbella turgidula</i>	19	224	47	0	18	308
<i>Cytotella spp</i>	9	9	9	0	0	27
<i>Diatoma hyenalis</i>	19	0	19	0	9	47
<i>Diatoma mesodon</i>	19	19	19	0	9	66
<i>Diatoma tenue var. elongatum</i>	19	83	65	121	75	363
<i>Diatoma vulgare</i>	9	46	0	56	93	204
<i>Encyonema minuta</i>	38	56	75	28	0	197
<i>Encyonema mualleri</i>	28	38	37	19	9	131
<i>Encyonema spp</i>	0	19	28	0	0	47
<i>Epithemia turgida</i>	28	0	0	0	0	28
<i>Eunotia arcus</i>	411	65	9	0	9	494
<i>Eunotia exigua</i>	19	0	0	0	0	19
<i>Eunotia faba</i>	9	37	0	19	0	65
<i>Eunotia lunaris</i>	1009	572	877	140	299	2897
<i>Eunotia serra</i>	46	46	121	19	0	232
<i>Eunotia spp</i>	1570	1102	2370	551	196	5789
<i>Eunotia tenella</i>	57	28	224	0	0	309
<i>Fistulifera</i>	0	0	0	0	9	9

<i>Flagilaria virescens</i> var. <i>capitata</i>	28	0	0	0	19	47
<i>Flagilaria crotonensis</i>	243	168	318	410	214	1353
<i>Flagilaria crotonensis</i> var. <i>orogona</i>	0	0	0	0	9	9
<i>Flagilaria hoelii</i>	75	131	112	46	0	364
<i>Flagilaria intermedia</i>	121	46	56	74	112	409
<i>Flagilariforma virescens</i>	47	84	9	0	0	140
<i>Frustulia rhomboides</i>	587	19	84	0	0	690
<i>Frustulia vulgaris</i>	56	0	0	19	9	84
<i>Gomphoneis eriense</i> var variabilis	37	65	382	541	117	1142
<i>Gomphoneis minuta</i> var. <i>iowei</i>	9	38	28	0	0	75
<i>Gomphonema augur</i>	0	19	9	0	0	28
<i>Gomphonema lingulataeformis</i>	19	0	0	0	0	19
<i>Gomphonema olivacea</i>	47	9	0	0	0	56
<i>Gomphonema sphaerophorum</i>	140	84	158	120	196	698
<i>Gomphonema spp</i>	37	19	28	0	28	112
<i>Gomphonema tenellum</i>	9	0	0	0	0	9
<i>Gomphonema truncatum</i>	9	9	9	9	9	45
<i>Gomphosphenia lingulataeformis</i>	0	9	0	0	9	18
<i>Gyrosigma parkeri</i>	9	0	0	0	0	9
<i>Hamnaea arcus</i>	28	0	0	0	9	37
<i>Hantzchia</i>	9	0	0	0	0	9
<i>Kobayasia subtilissima</i>	46	9	0	0	0	55
<i>Lemnicola lungarica</i>	0	0	0	19	0	19
<i>Melosira ovata</i>	0	0	9	0	0	9
<i>Meridion anceps</i>	75	19	96	19	9	218
<i>Meridion circulare</i>	93	158	0	75	37	363
<i>Navicula cryptocephala</i>	9	9	0	0	0	18
<i>Navicula gregaria</i>	103	47	0	19	9	178
<i>Navicula hasta</i>	93	28	46	121	0	288
<i>Navicula jarnefeldi</i>	9	0	0	0	0	9
<i>Navicula lanceolata</i>	92	186	195	1596	160	2229
<i>Navicula mutata</i>	37	0	0	0	0	37
<i>Navicula rhyncocephala</i>	271	27	9	47	56	410
<i>Navicula skifteii</i>	28	0	0	0	0	28
<i>Navicula spp</i>	663	475	187	783	37	2145
<i>Nitzschia amphibia</i>	0	0	18	9	9	36
<i>Nitzschia angustata</i>	56	0	0	0	0	56
<i>Nitzschia linearis</i>	0	0	0	0	28	28
<i>Peronia fibula</i>	45	9	196	18	19	287
<i>Pinnularia</i>	19	9	0	0	0	28

<i>Placoneis abisloensis</i>	9	9	0	0	0	18
<i>Placoneis spp</i>	0	38	9	19	19	85
<i>Planothidium apiculatum</i>	9	0	0	0	0	9
<i>Planothidium lanceolatum</i>	19	0	9	0	0	28
<i>Pleurosigma elongatum</i>	0	0	0	9	0	9
<i>Rhoicosphenia curvata</i>	74	56	65	37	28	260
<i>Semiorbis hemicyclus</i>	0	0	0	9	0	9
<i>Stauroforma exiguiformis</i>	19	233	9	19	0	280
<i>Stauroneis acuta</i>	0	0	0	9	0	9
<i>Stauroneis kriegeri</i>	9	0	0	0	0	9
<i>Synedra ulna</i>	158	19	37	569	298	1081
<i>Tabellaria flucosa</i>	112	0	149	28	28	317