IMPACT OF POLLUTANTS ON WATER QUALITY AND DISTRIBUTION OF AQUATIC MACROPHYTES IN RIVER SERLUI-A, MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

H. LALDINPUII
MZU REGISTRATION NO. 5923 0F 2012
PH.D REGISTRATION NO.: MZU/Ph. D/903 0F 13.04.2016

DEPARTMENT OF ENVIRONMENTAL SCIENCE
SCHOOL OF EARTH SCIENCE AND NATURAL RESOURCES MANAGEMENT

AUGUST, 2021

IMPACT OF POLLUTANTS ON WATER QUALITY AND DISTRIBUTION OF AQUATIC MACROPHYTES IN RIVER SERLUI-A, MIZORAM

BY

H. LALDINPUII
DEPARTMENT OF ENVIRONMENTAL SCIENCE

Supervisor: Prof. B.P. Mishra
Department of Environmental Science

Submitted
In partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Environmental Science of Mizoram University, Aizawl.

DECLARATION

I, **H. Laldinpuii** hereby declare that the subject matter of this thesis entitled "**IMPACT OF POLLUTANTS ON WATER QUALITY AND DISTRIBUTION OF AQUATIC MACROPHYTES IN RIVER SERLUI-A, MIZORAM**" is the record of work done by me. The content of the thesis does not form basis for the award of any previous degree or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me in any other University/ Institute for any research degree.

This is being submitted to the Mizoram University for the award of the degree of Doctor of Philosophy in Environmental Science.

(H. Laldinpuii)
Research Scholar

(Prof. B.P. Mishra)
Supervisor
Department of Environmental Science
Mizoram University

Head
Department of Environmental Science
Mizoram University

Date:
Place: Aizawl

ACKNOWLEDGEMENTS

First of all, I would like to thank the Almighty God for blessing me with good health, wisdom and knowledge for the successful completion of my research work.

I would like to express my deep and sincere gratitude to my supervisor Prof. B.P. Mishra, Department of Environmental Science for his support, encouragement and patience throughout the research work. I benefited greatly from his advice and his careful editing contributed immensely to the production of this thesis.

I express my deepest thanks to all the teaching and non-teaching staffs of the Department of Environmental Science for their constant support and help during the course of my research work.

I would like to thank my friends and research scholars for their valuable help and encouragement throughout the study period.

I extend my sincere gratitude to my parents, and family members who have given me their constant love, support and encouragement during the course of study.

I am deeply grateful to the staff at the Mizoram Pollution Control Board for allowing me to use the laboratory as well as for providing their support in terms of analysis of water quality.

(H. Laldinpuii)
Research Scholar

Date:
Place: Aizawl

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS AND PHOTO PLATES

CHAPTER-1

INTRODUCTION

1.1 Basic Concept

Water is one of the essential natural resource which is found around 75% in ocean comprises 97.4 % and the remaining in form of ice-caps and glacier, fresh water compartments of the hydrosphere. The largest portion of the Earth's freshwater is bound in ice or occurs as deep groundwater. The freshwater available for human uses is shallow groundwater and water in rivers, lakes, manmade reservoirs, and streams- about 4.6 million km^3 or 12% of the freshwater in the hydrosphere (Boyd, 2015). Water is essential for all forms of life and makes up to 50 to 97% by weight in plants and animals and about 70% human body.

The water (rain, river, sea and ground water) is one of the major components of environmental resources that is under threat either from over exploitation or pollution, exacerbated by human activities on the earth's surface (Efe, 2002). Water is the most abundant natural resource and is an essential requirement of human and industrial development (Das and Acharya, 2003). Due to rapid growth of human population and the accelerated pace of industrialization in the last few decades, there has been a tremendous increase in the demand for fresh water (Ramakrishnaiah *et al.*, 2009). Fresh water resources are used by humans for various purposes such as drinking, bathing and sanitation. In addition to these, people also depend on water resources for agriculture, commercial enterprises, mining, recreation, navigation and thermoelectric and hydroelectric power. Since ancient time, water availability and use have been implicit drivers for civilization. At a global scale, fresh water resources have become the fastest depleting natural resource now-a-days.

1.2. Water quality

The water quality is generally defined in terms of its physical, chemical and biological attributes (Ketata Mouna *et al.*, 2011).

Water quality assessment is an essential process in the development of water resources. Water quality may be defined in terms of specific characteristics of water usually physical, chemical and biological (including bacteriological) that are important with regards to a certain services (Tchobanoglous and Schroeder, 1987) and human health is at risk if values exceed acceptable limits (Tahera *et al*., 2016).

1.3. Rivers

Although river constitutes only 0.0002% of the earth's total water, it is one of the most important sources of fresh water available for our various uses (Gleick, 1996). Rivers are classified as a major, medium and minor depending upon the basin area. There are 14 major river systems in India such as Brahmaputra, Ganga, Brahmani, Cauvery, Godavari, Indus, Krishna, Mahanadi, Mahi, Narmada, Pennar, Sabarmati, Subernrekha and Tapti. These major systems share between them 83% of the drainage basin and account for 85% of the surface flow in the country. There are 44 medium and 55 minor rivers which normally originate in the coastal mountains and are monsoon-fed and fast flowing (Trivedy, 1988). Rivers play an important role in assimilation or carrying off municipal and industrial wastewater and runoff from agricultural land.

With the rapid development in agriculture, mining, urbanization, and industrialization activities, contamination of river water with hazardous waste and wastewater is becoming a common phenomenon (Prasanna and Ranjan, 2010). The past studies on water quality of a large number of rivers depict that the entity of majority river is under threat due to increased degree of pollution. The reports showed that the intensity of pollutants is markedly high in some rivers like Yamuna, Okhla, Ganga and Mahanadi (Dwivedi and Dwivedi, 2010). The National Environmental Engineering Research Institute (NEERI) at Nagpur argued that nearly 70% of available water in India is polluted and unfit for human-use.

1.4 Water Resources of Northeast India

The north eastern region of India consists of eight states namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The

North Eastern states cover a total area of 2,62,179 sq km which accounts for 7.9% of the country’s total geographical area.

North-east India has a bounty of accessible freshwater sources in the form of various rivers, streams, lakes, swamps, marshes, etc., with Brahmaputra river along with its numerous tributaries bifurcating the whole area. The surface water resources availability in the region amounting to 653 billion cubic meters (BCM) that accounts for 34% of the country's total surface water resources potential. Out of this, the Brahmaputra basin in NER alone has a potential of 573 BCM (87.8% of NER) the highest in the country, while the corresponding figure for the Barak basin is 48 BCM (7.4% of NER). Arunachal Pradesh has an average run-off of 350 BCM (53.6% of the region) which is the highest followed by Assam with 211 BCM (32.3% of NER) and Mizoram with 31 BCM (4.7 % of NER). The North-east region also has the distinction of having the highest hydro-power potential of 31, 857 MW out of the total of 84,044 MW of the country, which is about 37% of the nation (Brahmaputra Board, 2000).

1.5 Water Resources of Mizoram

Mizoram is under the influence of southwest monsoon and receives heavy rainfall during the months of May to September. Rainfall replenishes both Ground and Surface water. The surface water is found distributed in numerous streams and rivers flowing through the hilly terrain of the State which is the chief source of water for the people since underground water is not easily accessible due to hilly terrain. The climatic disturbances in the Bay of Bengal has a profound influence on the intensity of rainfall received. Heavy rains start in the month of June and continue up to August (RRC, 2019).

The surface water resources of the State include streams, rivers, lakes, ponds, wetlands, marshes and manmade reservoirs. All the rivers in Mizoram are monsoon fed and attain maximum volume in the monsoon and post monsoon seasons. A total of 21 rivers along with their tributaries exist across the State. There are total of15 major rivers in Mizoram, out of which Tuivawl, Tuivai, Tuirini, Tlawng, Tut and

Teirei flow northward and ultimately confluence with Barak river of Mizoram valley. Mat, Tuichang, Khawchhaktuipui, Tiau and Chhimtuipui (Kolodyne) flow towards south. The remaining rivers namely Tuichawng, De and Khawthlangtuipui flow to the west. Most of the rivers in Mizoram originate in the central part of the state and flow either northerly or southerly creating deep gorges between the N-S trending hill ranges. The drainage system in Mizoram comprises of three drainages namely, Barak (Ganga Brahmaputra basin), Karnaphuli and Kolodyne basin (RRC, 2019). Based on physiography, the Institute of Resource Development and Social Management have worked out a total of 22 well defined watersheds (Rao *et al*., 1994).

Table 1.1: Major watersheds in Mizoram.

No.	Catchments	Watershed area(km^2)	Length of watershed (km)	Maximum elevation (meters)	Total number of streams
1	Langkaih	394.6478	46.6329	2463	131
2	Teirei	678.2833	71.7235	2463	249
3	Tut	836.29	98.3367	1200	372 4
4	Tlawng	1701.45	157.3802	1536	702 5
5	Serlui	647.1796	60.6507	3813	326
6	Tuichhuahen	260.7131	31.68	3622	76
7	Tuirial+Tuirini	1795.2799	107.4585	1400	709
8	Tuivai+Tuivawl	2309.7767	105.6844	2000	744
9	Mat	963.9056	102.6432	1423	342
10	Tuipui	879.3337	66.9081	1897	215
11	Tuichang	1600.9972	90.478	1854	500
12	Ngenpui	711.7893	59.051	1556	144
13	Tuilianpui	1270.032	97.06752	990	523
14	Sazuklui(Bara Harina Chhara)	115.6117	33.7075	513	38
15	Khawthlangtuipui	149.0178	18.7545	6.6	30
16	Kau+Deh	977.1802	54.489	1387	354
17	Tuichawng	1275.8204	109.7395	1106	272
18	Kawrpui	356.2095	76.032	720	84
19	Chhimtuipui	2740.5582	137.6179	2158	629
20	Tiau	875.2657	87.9436	1962	212
21	Sakeilui	255.8567	41.8176	770	58
22	Salalui+Tinglo	289.8996	28.6387	600	68

Source: Rao *et al*. (1994).

1.4. Water Quality Index

The WQI provides a single number that expresses the overall water quality at certain location, based on several water quality parameters (Yogendra and Puttaiah, 2008). The water quality index (WQI) is considered as one of the simplest methods that is used for assessing the overall water quality. Water Quality Index (WQI) is a useful and efficient method to assess the suitability of water quality. It is also serves as a useful tool for communicating the information on overall quality of water to the concerned citizens and policy makers (Asadi *et al*., 2007; Buchanan and Triantafilis, 2009).

The WQI allows the reduction of vast amounts of data obtained from a range of physico-chemical and biological parameters to a single number in a simple reproducible manner. In fact, the WQI has been used for the assessment of water quality of many water bodies around the world (El-Sherbini and El-Moattassem, 1994; Mohanta and Patra, 2000; Bordalo *et al*., 2006; Dwivedi and Pathak, 2007; Kannel, 2007; Simoes *et al.*, 2008; Ramakrishnaiah *et al.*, 2009 and Abdul Hameed *et al*., 2010). Changes in water quality is recorded by water quality index in a particular river over a period of time following a set of standards and also allow comparison to be made at different locations of the river (Stoner, 1978). The WQI developed in the early 1970's can be used to monitor water quality changes in a particular water supply over time, or it can be used to compare a water supply quality with other water supplies in the region or from around the world. Water quality and its suitability for drinking purpose can be examined by determining its quality index.

The WQI is a set of standards that is used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. It also allows for comparisons to be made between different rivers. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life.

1.5 Macrophytes

Aquatic macrophytes are significant photosynthetic organisms of freshwater habitat which can be easily seen with the naked eye, normally found growing in or on the surface of water, or where soils are flooded or saturated long enough. Macrophytes are considered as important component of the aquatic ecosystem not only as a food source for aquatic invertebrates, but also act as an efficient accumulator of heavy metals (Devlin, 1967; Chung and Jeng, 1974). Their characteristics to accumulate heavy metals make them an interesting research objects for testing and modelling ecological theories on evolution and plant succession, as well as on nutrient and metal cycling (Forstner and Whittman, 1979). Aquatic plants interact with and influence the hydrological, geomorphological and physico-chemical environments and interact with a wide range of other organisms, from microbes to vertebrate (O' Hare *et al.,* 2018).

The study of plant community structure is called plant sociology or phytosociology. This study is important to understanding the functioning of community. The study of plant community implies knowledge of structure and composition of the component species (Singh and Singh, 2010). Various research work has been done on pollution parameters and biodiversity of lakes, rivers, ponds and their marginal wetlands (Kumar, 1991; Ambasht and Srivastava, 1997; Gupta, 2001; Tripathi, 2002; Kapoor, 2004). Mishra and Tripathi (2004) studied distribution of aquatic macrophytes in some water bodies of Varanasi, India. Pandey *et al.,* (1989) studied macrophytes of Ghagra belt in Gonda district. Aquatic macrophytes are vulnerable to alternation in the aquatic body which can be attributed to factors like acidification by atmospheric deposition, eutrophication, development of hydropower projects and habitat destruction (Arts, 2002)

The bio-monitoring is the latest emerging tool for instant and accurate monitoring of water quality and not only acts as a supplement for physico-chemical and bacteriological characteristics, but also provides precious information about the overall health of a water body (Mishra, 2008). Aquatic macrophytes have been used as bio-indicator of pollution as they respond to the changes in water quality (Tripathi and Shukla, 1991). They are frequently used to reduce different kinds of pollutants from polluted water (Tripathi, 1992). Aquatic macrophytes are extensively used as a long-term indicator for water quality or habitat characteristics. As they deliberately respond to any alteration in the nutrient content of any aquatic body (Melzer, 1999), the presence, absence or abundance of aquatic macrophytes reflect the nutrient status of the immediate surrounding or habitat (Mitsch and Gosselink, 2000; Cronk and Fennessy, 2001). Based on the kind of sampled organisms, it may be performed in two ways: i) "endemic" or native organisms (passive biomonitoring) and ii) introduced organisms (active biomonitoring) (Chaphekar, 1991).

From available literature, it is revealed that water resources have been explored at desired pace, and water quality of various aquatic bodies/underground reserves have been extensively studied at a large. But, there is paucity of information with respect to north east India in general and Mizoram in particular. Thus, the present study is aimed to assess impact of pollutants on water quality of Serlui-A river and distribution of aquatic macrophytes (weeds). This is well known fact that plants growing in aquatic body especially macrophytes, are best indicator of pollution and they act as a bio-monitor of pollution. Moreover, aquatic weeds (macrophytes) harvest significant amount of unwanted foreign substances from water/ wastewater (Mishra and Tripathi, 2004).

Objectives

1. To study the water quality of Serlui-A river at selected sites.
2. To study distribution of aquatic macrophytes along Serlui-A river at selected sites.
3. To assess impact of pollutants on water quality and distribution of aquatic macrophytes in Serlui-A river.

CHAPTER- 2

REVIEW OF LITERATURE

2.1 International

Gleick (1993) studied and explained various resources of water at global level. In his studies Falkenmark (1993) suggested the importance of pure water and its importance in the near future. The problem of water pollution was first recognized by Hippocrates in 450 B.C and has suggested filtration and boiling as remedial measures (Borchardt and Walton, 1971).

On a global scale, assessment of water quality has been carried out by Koshy and Nayar , 1999; Stark *et al*., 2001; Fytianos , 2002; Tassaduqe *et al*., 2003; Iqbal *et al.,* 2004; Ali *et al*., 2004; Fafioye *et al*., 2005; Abdo, 2005; Abel-Satar and Amaal, 2005, Gasim *et al.,* 2007; Kamal *et al.,* 2007; Atta *et al.,* 2008; Hasanzadeh, 2008; Dulo, 2008; Asrari *et al*., 2008; Jalal *et al.*, 2009; Hacioglu and Dulger, 2009; Toufeek and Korium, 2009; Chitmanat and Traichaiyaporn, 2010; Hoque *et al*., 2012; Dimowo, 2013; Okweye, 2013; Abdulwahid, 2013; Fella, 2013; Mbalassa *et al*., 2014; Aris *et al*., 2014 ; Al-Obadiy *et al*., 2015; Moyel and Hussain, 2015, Ghimire, 2016; Otieno *et al.,* 2017; Abbas and Hassam, 2017; Lim *et al*., 2017; Tawati *et al*., 2018.

Daniel *et al*., (2002) investigated the effects of urban sewage on the dissolved oxygen (O_2), dissolved inorganic (DIC) and organic carbon (DOC), and electrical conductivity (EC) in 10 small streams of the Piracicaba river basin, southeast region of Brazil and these streams were classified into two groups, one with heavy influence of urban sewage and another with less influence. The study revealed that in the polluted streams, concentrations of dissolved carbon forms and EC were higher and O_2 concentration lower during the low water period, while in the less polluted streams seasonal variations in concentrations were small. Milovanovic (2007) conducted water quality assessment and determination of pollution sources along the Axios/Vardar river, South-eastern Europe and found that the water quality was affected by human activities resulting from industrial, agricultural and domestic activities. Adekunle and Eniola (2008) assessed the water quality of Asa river within an industrial estate in Ilorin, Nigeria and revealed that industrial effluents cause pollution of the river. The study summarized that water from Asa river requires treatment before it can be used for domestic purposes. Ezzat *et al*., (2012) examined the water quality of river Nile at Rosetta branch through several physico-chemical and bacteriological analyses. The study revealed that the water quality along studied area is obviously influenced by drains discharge and high concentrations of NH_3, total dissolved solids (TDS), electric conductivity (EC), biological oxygen demand (BOD), total alkalinity, turbidity and recognizable depletion in dissolved oxygen (DO) were recorded. Seanego and Moyo (2013) carried out research on the effect of sewage effluent on the physico-chemical and biological characteristics of the Sand river in South Africa which revealed that Nitrogen and phosphorus levels are above the South African limits. Moyo and Rapatsa (2016) studied the impact of urbanization on the ecology of Mukuvisi River, Zimbabwe and concluded that river is severely polluted and can no longer support high diversity of aquatic life.

2.2 National

In India, several workers have studied the physico-chemical characteristics of different rivers namely Ganga river (Agarwal *et al*.,1976; Mishra *et al*., 2009; Singh, 2010; Yadav and Srivastava, 2011; Matta,2014; Singh *et al*., 2016), river Bhagirathi (Joshi *et al*., 1993), Brahmani river (Muduli *et al*., 2006), Yamuna river (Gupta *et al*., 2013; Chadetrik *et al*., 2015), river Betwa (Patel and Datar, 2014), Chandrabhaga River (Watkar and Barbte, 2015) Godavari river (Bhalla and Sekhon, 2010; Patil and Ghorade, 2013; Bhutekar *et al*., 2018), River Varuna (Barai and Kumar, 2013), River Krishna (Sarwade and Kamble, 2015), Penna river (Prasad *et al*., 2016), river Tawi (Gandotra *et al.*, 2008), river Ramganga (Gangwar *et al*., 2012), River Sone (Gunasekar and Isaac, 2015), river Cauvery (Raja *et al.*, 2008; Rajendran *et al*., 2015), Krishana, Gomuti, Hoogali, Ganga, Mahanadi, Cauveri river (Chandra *et al.*, 2011), river Wardha (Mithani *et al.,* 2012), Kali river (Kumar *et al*., 2014), Torsha river in West Bengal (Mandal and Amrita, 2011) and Parvara river in Maharashtra (Thitme and Pondhe, 2010).

Srivastava *et al.* (1996) examined the water quality of the river Ganga at Phaphamau (Allahabad) during Mahakumbh festival in 1989. Since the biological oxygen demand, chemical oxygen demand, and fecal coliforms were all elevated during bathing, it was concluded from the results that mass bathing causes significant changes in the river's water quality. The study revealed that the water was not fit for drinking or bathing purposes. Impact of mass bathing during Ardhkumbh on water quality status of river Ganga was conducted by Kulshrestha and Sharma (2006). The study indicated that water is not fit for either drinking or bathing purposes. The presence of faecal coliforms in water indicate potential presence of pathogenic microorganisms, which might cause water borne diseases. Dissolved oxygen content was found to be within the permissible limit while the values of BOD and COD exceeded the maximum permissible limit during bathing. Anushka and Deswal (2017) assessed the impact of anthropogenic activities on water quality of river Ganga.

Agrahari and Kushwaha (2012) observed an increase in electrical conductivity, TDS, free CO_2, bicarbonate alkalinity, total, Ca and Mg hardness, chloride, nitrate, phosphate, sulphate, BOD and COD while a decrease in pH, DO and carbonate alkalinity at sewage mixing point at river Rapti. However, these parameters gradually changed downstream and were within the limits of Indian standards indicating river water safe for growth of aquatic life. Chauhan and Sagar (2013) studied the impact of pollutants on water quality of river Sutlej in Nangal area of Punjab. The study revealed that the river water was moderately polluted due to inflow of silted muddy water from hilly terrain, physico-chemical dynamics and frequently dumping of pollutants. On the basis of primarily study, it was apparent that water was not suitable for drinking but can be used for propagation of wild life, fisheries and irrigation.

2.3 Regional

The available literature depicts that the study of water quality in northeast India is limited and major contribution comes from Assam. Water quality of Kolong river has been studied by Medhi *et al*., (2015); Kapili River in Assam by Saikia and

Das (2018); Dihing river in Assam by Bailung and Biswas (2018); Meleng river in Assam by Karmakar and Biswas (2016); river Siang in Arunachal Pradesh by Das *et al*., (2014); Singh and Gupta (2010 a) studied the physico-chemical characteristics of Imphal, Iril and Toubal rivers in Manipur. The study revealed that the water is becoming deteriorated due to anthropogenic activities. Singh *et al.,* (2010 b) studied the samples taken from Manipur river system. The result revealed that most of the physico-chemical parameters were within the WHO limits for drinking water and as such may be suitable for domestic purpose. Singh *et al.,* (2016) studied physiochemical parameters like pH, Temperature, Dissolved oxygen, Total hardness, Total alkalinity, Biochemical Oxygen Demand, Total dissolved Solids, Total Suspended solids and Chloride as well as heavy metals like chromium, lead, cadmium and Arsenic of river Haora in Agartala during Durga idol immersion; Singh and Gupta (2015) and Alam and laishram (2017) studied the water quality of Nambul river, Manipur; Saikia and Sarma (2011) studied the fluoride geochemistry of Kolong river basin, Assam; Dutta and Sarma (2013) studied the fluoride hydrochemistry of Dikrong river basin; Nongmaithen and Basudha (2017) studied the physico-chemical properties of different water bodies of Manipur. Swer and Singh (2004) studied the impact of coal mining on water quality in Meghalaya; Lamare and Singh (2016) studied the water quality of Lukha River and found that the water quality is affected by anthropogenic activities such as mining of coal and limestone and manufacturing of cement in the catchment area of the river; Lamare and Singh (2014, 2015) studied the impact of limestone mining on water quality in Meghalaya. Bharali *et al.,* (2008) studied the physico-chemical characteristics of water of the wetlands in Kaziranga National Park, Assam.

In Mizoram, a number of researches have been conducted on different aquatic bodies. Mishra and Lalhruaizeli (2009) studied the quality of spring water in western part of Aizawl city; Mishra (2009) studied the status of the quality of spring water; Lalchingpuii *et al*., (2011 b) studied sulphate, phosphate-P and nitrate-N contents in Tlawng river; Sabrina Lalhmangaihzuali *et al*., (2019) studied the physico-chemical properties of perennial spring water within Aizawl City; Lalparmawii (2012) conducted analysis of water quality and biomonitoring of Tuirial river in the Vicinity of the Hydel Project; Thasangzuala and Mishra (2014) studied physical characteristics of public drinking water in Aizawl city; Thasangzuala *et al*., (2014) assessed the chemical characteristics of public drinking water in Aizawl city; Mishra and Premeshowri (2014) studied the impact of sandstone quarry on water quality of Tlawng river; Lalzahawmi *et al*., (2016) studied the seasonal variation in physical characteristics of Tamdil lake and Lalzahawmi and Mishra (2016) assessed the chemical characteristics of Tamdil lake.

Lalchhingpuii *et al*., (2011 a) studied the water quality of Tlawng river and reported high DO content in winter months. The total hardness and calcium hardness values of the water samples were within the WHO standards. In case of magnesium, 1.9 % of samples were higher than the permissible limit. Except for a few months, most of fluoride content was within the permissible limit.

Lalparmawii and Mishra (2012) studied the water quality of Tuirial river in the vicinity of the hydel project taking into account the chemical parameters like pH, DO and BOD. The study revealed that the water was unpolluted but regular monitoring was required to assess the water quality.

Sunar and Mishra (2016) studied the impact of Hydroelectric Power Project on the water quality of Serlui river and revealed even though all the values fall within the permissible limit of water quality laid down by various scientific agencies, the significant increase in temperature, EC and BOD from Site 1 to Site 3 showed effect of hydroelectric power project on the water quality of the river which may be due to the direct discharge of treated water into the river system after power generation, and sewage containing more organic matter.

2.4 Water quality index

The computation of the WQI was attempted by numerous researchers and Horton (1965) proposed the first water quality index in the United States from selected sewage treatment based on his own judgment and experience. Brown *et al*., (1970) used the Delphi method developed by “Rand” corporation to develop a WQI for National Sanitation Foundation (NSF) of USA. Some of the water quality indices that have been frequently by the public for the purpose of water quality assessment are the NSF Water Quality Index (NSFWQI), British Columbia Water Quality Index (BCWQI), Canadian Water Quality Index (CWQI), Oregon Water Quality index (OWQI) and the Florida Stream Water Quality Index (FWQI) (Said *et al.,* 2004*).*

Sargaonker and Deshpande (2003) developed Overall index of pollution at National Environmental Engineering Research Institute (NEERI), Nagpur, India in order to assess the status of freshwater, specifically under Indian conditions. A general classification scheme has been formulated Based on a concept similar to the one proposed by Prati *et al.,* (1971), a general classification scheme has been formulated and giving due consideration to the classification scheme developed by CPCB.

Assessment of water quality using Water Quality Index was studied by Lohani and Todino (1984); Mathuthu *et al*., (1993); Stambuck-Giljanovic (1999); Pesce and Wunderlin (2000); Jonnalagadda and Mhere (2001); Debels *et al*., (2005); Bordalo *et al.*, (2006); Fulazzaky *et al*., (2010); Abdul *et al*., (2010); Massoud (2012); Al- Janabi (2012); Al-Shujairi (2013); Misaghi *et al*., (2017); Fathi *et al*., (2018); Alphayo and Sharma (2018); Wang *et al.,* (2019).

In India, studies relating to the assessment of water quality using Water Quality Index was carried out by several workers (Tiwari and Mishra, 1985; Tiwari *et al.,* 1986; Ram and Anandh, 1996; Chetana and Somashekar, 1997; Pandey and Sundaram,2002; Martin and Haniffa, 2003; Tiwari *et al*., 2005; Avvannavar and Shrihari, 2008; Samantray *et al*., 2009; Vasanthavigar *et al*., 2010; Yadav *et al.*, 2010; Kalavathy *et al*., 2011; Balan *et al*., 2012; Sharma *et al*., 2014; Kosha and Geeta, 2015; Krishna *et al*., 2015; Das *et al*., 2017; Ponsadailakshmi, 2018; Adimalla and Qian, 2019)

2.5 Correlation and linear regression

Regularly monitoring of all the parameters becomes a difficult task even if adequate manpower and laboratory facilities are available. Therefore, in recent years an easier and simpler approach for comparing the physico-chemical parameters has been developed based on statistical correlation (Shukla *et al*., 2017; Khatoon *et al*., 2013).

The closeness of the relationship between chosen independent and dependent variables is measured by correlation analysis. If the correlation coefficient between two variables is nearer to +1 or –1, it shows the probability of the linear relationship between the two variables. When the correlation between the parameters is in the range of +0.8 to 1.0, it is characterized as strong, moderate when the value is in the range of +0.5 to 0.8 and –0.5 to –0.8, weak when it is in the range of +0.0 to 0.5 and –0.0 to –0.5 (Nair *et al.*, 2005). Regression measures the nature and extent of correlation and predicts the unknown values of one variable from known values of another variable. Correlation coefficient and regression analysis attempts to establish the nature of the relationship between variables and thereby provides a mechanism for prediction or forecasting (Agarwal and Saxena, 2011; Kumar and Sinha, 2010; Mulla *et al*., 2007).

The available literature reveals that the correlation and regression analyses have been extensively used for water quality studies carried out by several researchers like Joarder *et al*., (2008); El-Korashey (2009); Nurcihan and Basaran. (2009); Ahmed *et al*., (2010); Daraigan *et al*., (2011); Mrazovac and Vojinovic-Miloradov (2011); Heydari *et al.*, (2013); Mustapha *et al.* (2013); Chandio *et al*., (2015); Shigut *et al*., (2017); Jung and Kim (2017).

In India, a number of researchers have undertaken statistical analysis and assessed the water quality of different water bodies in different parts of the country. (Thengaonkar and Kulkarni, 1971; Garg *et al*., 1990; Jain and Sharma, 2000; Bathusa and Safetharan, 2007; Shah *et al*., 2007; Bhandari and Nayal, 2008; Trivedi *et al*., 2009; Jothevenkalachalam *et al*., 2010; Agarwal and Saxena, 2011 a; Agarwal *et al*., 2011 b; Bhatnagar and Devi, 2012; Agarwal and Agarwal, 2013; Mallik, 2014; Chaubey and Patil, 2015; Indu and Chandra, 2015; Patela and Vaghanib, 2015; Gourkar *et al*., 2016; Senthilmanickam *et al*., 2016; Madhulekha *et al*., 2017; Dutta and Sarma, 2018; Sunar and Mishra, 2018).

2.6 Macrophytes

The term aquatic macrophyte refers to macroscopic vegetation including angiosperms, ferns, mosses, liverworts and some freshwater macro-algae that occur in seasonally or permanently in wet environments (Chambers *et al*., 2008). The macorphytic vegetation may be classify in to Submerged aquatic (SA), Floating aquatic (FA), Emergent aquatic (EA), Free-floating (FF) and Marshy amphibious (MA) (Sculthorpe, 1985; Padial *et al*., 2008). The aquatic macrophytes are the important source of food, fodder, herbal medicine and domestic household materials for the people residing in its vicinities. Aquatic macrophytic diversity and its role in understanding the beel ecosystem have tremendous significance. Aquatic macrophytes represent as an important habitat for fish. Many young fish need aquatic macrophytes as shelter and protection from predation or to avoid cannibalism. Aquatic macrophytes also serve some fish as a spawning habitat, for the attachment of eggs, and some fish form nesting sites among the macrophytes (Cowx and Welcomme, 1998).

The net primary productivity (NPP) and nutrient cycling which are associated with littoral freshwater macrophytes may prove to be important to the function of aquatic ecosystems (Westlake, 1965; Rich *et al*., 1971; Hutchinson, 1975; Brinson *et al*., 1981). Studies on macrophytes were conducted by several works like Sondergaard and Sand-Jensen (1979), Carpenter and Lodge (1986), Camargo and Esteves (1995), Pompeo and Moschini (1996), Bini *et al*. (1999), Keddy (2000), Henry-Silva *et al.* (2001), Burlakoti and Karmacharya (2004), Udomsri *et al*. (2005), Baattrup-Pedersen *et al*. (2006), Hrivnák *et al.* (2006), Clayton and Edwards (2006), Bianchini Jr. *et al*., (2008), Mormul *et al*., (2010), Niroula and Singh (2011), Tamire and Mengistou (2012, 2014), Ghimire (2016), Akomolafe and Nkwocha (2017), Wang *et al.*, (2019).

In India, Biswas and Calder (1937) published a comprehensive account of hydrophytic plants of India and Burma. Subramanyam (1962) published a volume on aquatic plants of India which is followed by an enumeration of aquatic plants of India by Deb (1976). Cook (1996) published a volume on aquatic and wetland plants of India covering northern boundary of India (Arunanchal Pradesh, Himanchal Pradesh, Jammu & Kashmir and Sikkim).

Studies on aquatic plants have been conducted by a number of authors like Chavan and Sabnis (1961), Vyas (1964), Unni (1971), Billore and Vyas (1981), Lavania *et al*., (1990), Dutta *et al*., (2002), Maliya and Singh (2004), Ravinder and

Pandit (2006), Kiran *et al.*, (2006), Reddy *et al.*, (2009), Muthulingam *et al.*, (2010), Ahmad *et al*., (2015),

Extensive research on macrophytes have been conducted at international and national level, but from available literature it is clear that the research is limited in North-East states particularly Mizoram. A number of researches on macrophytes have been conducted in Assam. Dey and Kar (1989) conducted a study on the aquatic macrophytes of Lake Sone, Assam. Pathak (1990) studied in detail the hydrophytic flora of Guwahati and its vicinity.

Islam (1999) conducted a study of the certain aquatic macrophytes of lentic habitat of Dibrugarh district, Assam. Sarma and Devi (1999) surveyed the aquatic flora of Goalpara District, Assam, Baruah and Baruah (2000) conducted a study on the hydrophytic flora of Kaziranga National Park in Assam. Dhar *et al.*, (2004) studied the aquatic macrophytes in Baskandi lake in Assam. Barooah and Mahanta (2006) investigated the aquatic angiosperms of Biswanath Chariali, Assam. Deka *et al.*, (2010) conducted phenological study of macrophytes of some selected wetlands of Goalpara district. Bordoloi (2014) made a comparative study of aquatic macrophytes and its primary productivity in the closed and open type wetlands of Brahmaputra river basin. Dutta *et al*., (2014) conducted a research on the diversity of aquatic macrophytes of Kapla beel (wetland) of Barpeta district, Assam. Deka and Sarma (2014) conducted ecological studies of macrophytes of four important wetlands of Nalbari district of Assam. In Manipur, Jain *et al.*, (2007) worked on a total number of 42 species of aquatic/semi-aquatic plants under 18 families and 25 genera which are used in herbal remedies by the ethnic communities of Manipur. In Tripura, Bhowmik and Datta (2011) studied the diversity of aquatic and marshand plants of Tripura and revealed the occurrence of 65 species of aquatic and Marshland plants belonging to 44 genera and spreadingover 26 families**.** Taran *et al.*, (2016) conducted a study on th**e** physico-chemical characteristics, biodiversity assessment and economic valuation of Kalyanthakur Para Lake: a community based lake of Tripura and identified a total of thirteen aquatic plants belonging to twelve families**.** In Mizoram, Sunar (2016) studied the diversity and distribution of aquatic macrophytes of Serlui-B river where a total of 28 aquatic macrophytes belonging to 24 genera and 13 families were recorded so far.

CHAPTER-3

METHODOLOGY

3.1 Description of Study Area

3.1.1 Mizoram: Location and extent

The State of Mizoram is situated in the extreme south of north-eastern part of India lies between 21º56`N- 24º31`N latitudes and 96º16`E-93º26`E longitudes. It is sandwiched between Bangladesh and Myanmar. The Tropic of cancer (23º30`N latitudes) divides the region in Aizawl district at the southern periphery of Aizawl into two almost equal parts. The total geographical area of 21,087 square kilometres with maximum dimension of 285 kilometres from north to south and 115 kilometres from east to west (Pachuau, 2009). It shares boundaries with Assam (123 km) and Manipur (95 km) on the north, and on the west by and Tripura (66 km). It shares international boundaries with Myanmar on the east and south (404 km) and on the west by Bangladesh (318 km) (Statistical handbook, 2019).

Mizoram is divided into eleven districts namely, Aizawl, Lunglei, Siaha, Kolasib, Mamit, Champhai, Serchhip, Lawngtlai, Saitual, Hanhthial, Khawzawl. Aizawl is the state capital of Mizoram, and lies between 23° 43' 44.18" N latitude and 92° 43' 4.48" E longitude with a total geographical area of 3,576.31 square kilometres and is situated at about 1132 meters above sea level. The population of Aizawl is 291,822 having sex ratio of 1029 per 1000 males. The average literacy rate of Aizawl city is 98.80 percent of which male and female literacy is 99.30 and 98.31 per cent respectively (Census, 2011).

3.1.2 Geology

The geology of the state of Mizoram is represented in general by repetitive succession of arenaceous and argillaceous sediments which were later thrown into approximately NNW - SSE trending longitudinal plunging anticlines and synclines.

Geologically, the two broad groups of Surma and Barail are eminent. Surma group consists of two main sub-groups of rocks- Bhuban and Bokabil.

3.1.3 Topography

The physiology of Mizoram is composed predominantly of mountainous terrain of tertiary rocks. Inclined north to south direction in parallel series, the mountain ranges are separated by deep river valleys. The elevation of these ranges from 21 metres at Tlabung to 2,157 metres at Phawngpui. The landforms of the state can be classified on the basis of relief, drainage, lithologic and structural set up as Mountainous Terrain Province, Ridge and Valley Province, Flat lands and Lakes.

3.1.4 Drainage

Surface configuration like relief, slope and dissection affects the development and pattern of drainage system of the area to a great extent. A number of rivers, streams and rivulets of varying lengths flow through the state. The rivers Tlawng (with its tributaries Teirei and Tut), Tivawl, Tuirial, Langkaih and Tuivai; drain the northern part of the region and ultimately fall into Barak river. The rivers Chhimtuipui on the east along with its tributaries Mat, Tuichang, Tiau and Tuipui drains the southern hills; Khawthlangtuipui with its tributaries Kawrpui, Tuichawng, Phairuang, Kau and De drains the western region; Tiau and Chhimtuipui; forms boundary with Myanmar in the east and south.

3.1.5 Climate

The state of Mizoram has a moderate climate despite its tropical location. Throughout the year it does not become very hot or very cold. The annual temperature during winter is between 11°C to 24°C and in summer between 18°C to 29°C (FSI, 2019). The lowest temperature during winter is observed at high altitude areas such as Champhai, Zote, Ngur etc. in the east; Bualpui (Ng) and Phawngpui in the south while maximum temperature in summer is observed at relatively lower areas like Kanhmun, Zawlnuam, Bairabi, Vairengte etc. in the north; Tlabung, Chawngte, Tuipang, Tuipuibari etc. in the south and west-end. The state receives an adequate amount of rainfall as it falls under the direct influence of the south-west monsoon. The state experience heavy rainfall during summer from May to September. The annual rainfall in the state ranges between 2,100 mm to 3,500 mm. (Forest survey of India, 2019).

Three different types of seasons are observed in the state, depending on temperature and general weather conditions. The seasons are- the cold or winter season which starts from November and can last till February; the warm season or spring which starts from march and last till the first part of May; and the rainy season or summer which starts from the second part of May till late October.

3.1.6 Soil

The soil of Mizoram is generally young, immature and sandy and are dominated by loose sedimentary formations. The soils are highly acidic and low in potash and phosphorus but has high nitrogen content in uneroded soil. As the soils in the valleys were brought down by the rain water from high altitudes, the soils are heavier.

The soil of the hilly terrain are dark, highly leached and poor in bases but rich in iron. The soil of the valley flat land is brown to dark brown, poor in bases, acidic in nature (pH ranging from 5.5.-6.0), medium to high organic carbon content, low available phosphate and medium to high available potash. The soil in some places below the plough layers is poorly drained and as a result water logging is common. The soil is normally fertile and productive. The soil of the narrow valleys has a light and coarse texture, is well drained, well aerated and skeletal and receives new deposits of alluvium at frequent intervals. According to Sanker and Nandy (1976), the soil of Mizoram can be classified into three orders of soil taxonomy namely: Entisols, Inceptisols and Ultisols.

3.1.7 Vegetation

Latitude, elevation, rainfall and nature of soil are the factors which influence the geographical distribution of forest in Mizoram naturally. There is a clear difference between vegetation of the western and eastern part of the state.

Out of the total geographical area of Mizoram, about 75 per cent of the area is covered by vegetation. Due to its tropical location it provides favourable climatic conditions such as an adequate rainfall, moderate temperature which result in luxuriant growth of vegetation.

Forest types of Mizoram can be classified into three broad categories as: Tropical Wet-Evergreen Forest, Tropical Semi-Evergreen Forest and Mountain Sub-Tropical forest (Pachuau, 2009). As per the classification of forest types by Champion & Seth (1968), the forests in Mizoram belong to four Type Groups, which are further divided into six Forest Types.

Some of the species found in the state include *Dipterocarpus turbinatus, Artocarpus chaplasha, Terminalia myriocarpa, Amoora wallichii, Michelia champaca, Mesua ferrea, Pinus kesiya, Quercus* spp, *Castanopsis* spp, *Schima wallichii, Rhododendron arboreum, Rhus semialata,* etc. Bamboos occur abundantly and the state of Mizoram is one of the leading producers supplying 14% of the country's commercial bamboo. A total of 27 species of bamboo are reported from the region (Forest Survey of India, 2019).

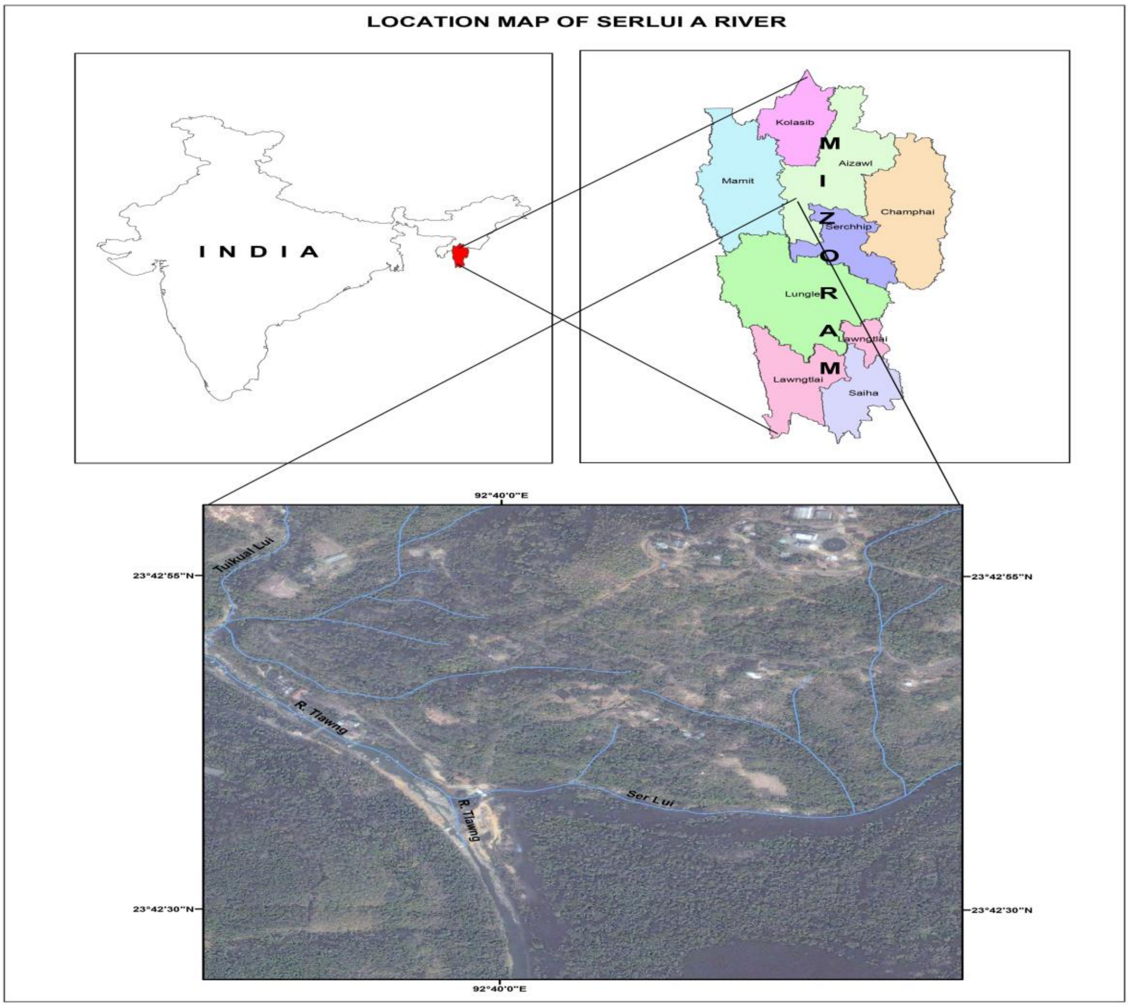
3.2 Selection of Study Site

For detailed investigation, Serlui-A river has been selected which is approximately 7-8 kms long and it flows from Lungleng village towards Maubawk where it merges with river Tlawng. This river is being used for 1 MW Serlui- A hydroelectric power station.

3.2.1 Selection of Sampling Sites

To fulfil the objectives of study, following sampling sites of river Serlui-A have been selected.

1. **Site 1:** situated near the source in Lungleng village, and considered as control/reference site to compare results from other sites selected towards downstream of river.
2. **Site 2:** situated just before hydroelectric power station.
3. **Site 3:** situated just after hydroelectric power station.
4. **Site 4**: situated at the point where Serlui-A river merges with river Tlawng.



Map 3.1: Location map of study area

Photo plate 3.1: Site 1- Control site: situated near the source in Lungleng village

Photo plate 3.2: Site 2- situated just before hydroelectric power station

Photo plate 3.3: Site 3- situated just after hydroelectric power station.

Photo plate 3.4: Site 4- situated at the point where Serlui-A river merges with river Tlawng.

3.3 Collection of water sample

The water samples were collected from selected study sites on monthly basis (in triplicates) for two consecutive years (October, 2016 to September 2017 and October 2017 to September, 2018) using wide mouth plastic bottles with necessary precautions. The water samples were brought to the laboratory in an ice box after collection. The various physico-chemical characteristics namely, Electrical Conductivity, Dissolved Oxygen, Biological Oxygen Demand, Total Hardness, Acidity, Total Alkalinity, Turbidity, Total Dissolved Solids, Chloride, Nitrogen-nitrite and Phosphate-P contents were analysed within 24 hrs of collection of water samples. Temperature and pH were recorded at sampling site, and samples were fixed at site for DO estimation. The samples were stored at 4℃ for further analysis. The findings were expressed seasonally i.e., Post-monsoon season (October-January), pre-Monsoon season (February-May) and Monsoon season (June-September).

3.4 Analytical Methods

For analysis of the various physico-chemical characteristics of the water samples, the methods as outlined in 'Standard Methods for Examination of Water and Wastewater' (APHA, 2005) and 'Handbook of Methods in Environmental Studies, Water and Waste Water Analysis (Maiti, 2001) were followed.

3.4.1 Temperature

Temperature of water was measured by means of a Digital thermometer.

3.4.2 Electrical conductivity

Electrical Conductivity was measured with an electrical conductivity cell.

3.4.3 Total Dissolved Solids

Total Dissolved solids (TDS) was measured by using filtration and evaporation method. Total Dissolved Solids was calculated by using the formula,

$$TDS = TS – TSS$$

Where,

TSS = Total Suspended Solids

TS = Total Solids

TDS = Total Dissolved Solids

Total Solids (TS) can be calculated by using the formula,

$$TS (g/L) = W_1\text{-}W_2 \text{ x } 1000/V$$

Where,

A = Final weight of the crucible

B = Initial weight of the crucible

C = Volume of water sample evaporated (ml)

Total Dissolved Solids (TDS) will be calculated by using the formula,

$$TDS (g/L) = W_1\text{-}W_2 \text{ x } 1000/V$$

Where,

W_1 = Final weight of the crucible

W_2 = Initial weight of the crucible

V = Volume of water sample evaporated (ml)

3.4.4 Turbidity

Turbidity was measured either by its effect on the transmission of light which is termed as Turbidity or by its effect on the scattering of light which is termed as Nephalometer. Nephalometer was used for measuring turbidity.

$$DO\ (mgL^{-1}) = \frac{VxNx8x1000}{\text{mL of water sample used}}$$

Where, V = volume of titrant; N = normality of titrant

3.4.5 pH

The pH was measured by using the digital pH meter.

3.4.6 Dissolved Oxygen

For estimation of the DO content of water samples "Modified Winkler's Azide Method" was followed. The DO content of water was calculated using the following formula

$$\text{DO content } (mgL^{-1}) = \frac{\text{VxNx8x1000}}{\text{mL of water sample used}}$$

Where,

V = volume of titrant used;

N = normality of titrant.

3.4.7 Biological Oxygen Demand

For the estimation of BOD content of water, initial and final DO of water samples were determined just after collection of sample and after 5 days incubation in BOD incubator at 20^0 C respectively. Calculation of BOD was done using the following formula

$$\text{BOD } (mgL^{-1}) = \frac{\text{DO(I)} - DO(F)}{\text{mL of water sample Dilution factor,if any}}$$

Where,

DO (I) = Dissolved Oxygen taken before incubation of the sample

DO (F) = Dissolved Oxygen taken after incubation of the sample

3.4.8 Chloride

The Chloride content of water was determined by using modified Mohr's method. Silver Nitrate (0.041N) solution was used as a titrant. Chloride content was calculated by using the following formula

$$\text{Chloride } (mgL^{-1}\ CaCO_3) = \frac{\text{Volume of titrant used x 0.041 x 36.46 } x \text{ 1000}}{\text{Volume of water sample used}}$$

Where,

0.041 = normality of Titrant

36.46 = atomic weight of chloride

3.4.9 Total Alkalinity

The total alkalinity of water was measured by using potentiometric titration method. Standard sulphuric acid (0.02N) was used as a titrant to lower down the pH sample at 8.3(phenolphthalein alkalinity) and to pH 3.7 (methyl orange alkalinity). Alkalinity was calculated using the following formula,

$$\text{Total Alkalinity (mgL}^{-1}\text{ CaCO}_3\text{)} = \frac{(A-B)x\ 1000}{\text{Volume of water sample used}}$$

Where,

A = Alkalinity due to Phenolphthalein

B = Alkalinity due to Methyl Orange

3.4.10 Acidity

The acidity of water was measured by using potentiometric titration method. Sodium hydroxide (0.02N) was used as a titrant. Acidity was calculated using the following formula

$$\text{Acidity (mgL}^{-1}\text{ CaCO}_3\text{)} = \frac{\text{Volume of titrant used (0.02N NaOH)}x1000}{\text{Volume of water sample used}}$$

3.4.11 Total Hardness

Total Hardness was measured by EDTA titration method; value was calculated by using the following formula,

$$\text{Total hardness as (mgL}^{-1}\text{ CaCO}_3\text{)} = \frac{\text{CxDx1000}}{\text{Volume of sample taken}}$$

Where,

C = Volume of EDTA required by sample

D = mg $CaCO_3$ equivalent to 1ml EDTA titrant (1ml for 0.01N EDTA).

3.4.12 Phosphate-P

The stannous chloride colorimetric method was used for the determination of Phosphate-P content of water and value was calculated using the following formula:

Conc. of Phosphate (mg/L) = R x mf

Where,

R = Absorbance reading of sample

$$mf = \frac{\text{absorbance}}{\text{Conc.}}$$

3.4.13 Nitrogen-Nitrite ($N\text{-}NO_2^-$)

Colorimetric method (Diazotization method) was used for the determination of $N\text{-}NO_2$ content of water and the value was calculated using the following formula,

Conc. of $N\text{-}NO_2$ in mgL^{-1}= R x m f x D (Dilution factor/no of times of dilution)

Where,

R= Absorbance reading of sample

$$mf = \frac{\text{absorbance}}{\text{Conc.}}$$

3.5 Water Quality Index (WQI)

The weighted arithmetic index method (Brown et al., 1972) has been used for the calculation of water quality index of the water body in the following steps:

Calculation of Sub Index of Quality Rating (q_n): The value of q_n is calculated using the following expression.

$$q_n = [(V_n - V_{id}]/S_n - V_{id})] \times 100$$

Where,

q_n =Quality rating for the n^{th} water quality parameter.

V_n = Estimated value of the n^{th} parameter at a given sampling station.

S_n = Standard permissible value of the nth parameter.

V_{id}= Ideal value of the n^{th} parameter in pure water.

All the ideal values (Vid) are taken as zero for drinking water except for pH=7.0 and DO=14.6mg/L (Tripathy and Sahu, 2005).

Calculation of Unit Weight (W_n): Calculation of unit weight (W_n) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$W_n = k/S_n$$

Where,

W_n= unit weight for the n^{th} parameters.

S_n= standard value for the n^{th} parameters.

k=constant for proportionality and is calculated by

$k = [1/(\Sigma 1/S_n=1,2,..n)]$

The overall water quality index is calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \Sigma q_n W_n / \Sigma W_n$$

3.6 Distribution of Aquatic macrophytes

The aquatic macrophytes were collected from selected study sites, identified using available literature.

3.7 Statistical Analysis

For validity and significance of the data, statistical analyses such as correlation coefficient, ANOVA and linear regression were computed using SPSS 16.0 and MS Excel 2016.

CHAPTER- 4

RESULTS

The findings of the present investigation on various physicochemical characteristics of water and impact of pollutants on the quality of water and distribution of macrophytes can be presented as under:

4.1 Water Quality Characteristics

4.1.1 Temperature

The temperature of water ranged from 19.2 ^{0}C (Site 1 in Post-monsoon season) to 26.7 ^{0}C (Site 4 in Monsoon season) during 2016-17. However, during 2017-2018 values were between 16.7 ^{0}C (Site 1 in Post-monsoon season) and 26.6 ^{0}C (Site 4 in Monsoon season). Overall findings state range of temperature between 16.7^{0}C to 26.7^{0}C. In both the years, a similar trend in results observed with higher values in Monsoon season and lower values during Post-monsoon season **(Fig. 4.1).**

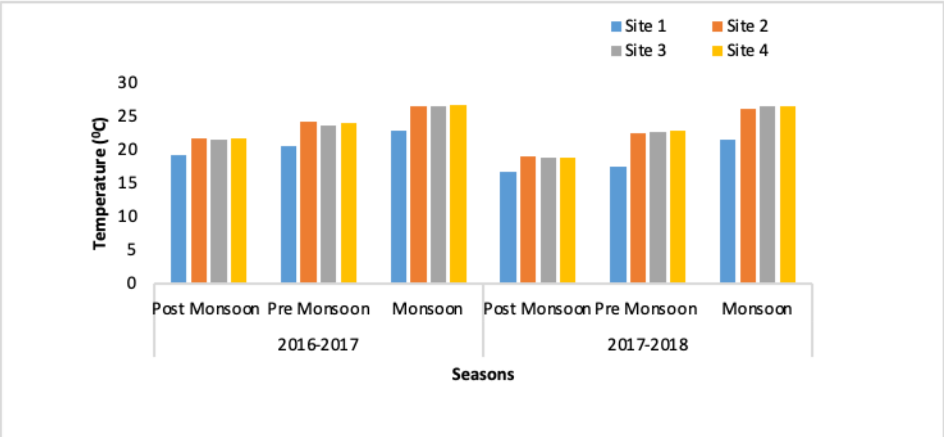


Fig. 4.1: Seasonal Variation in temperature of water at selected study sites.

A positive and significant correlation of temperature was established with EC (0.862**), TDS (0.819**), BOD (0.851**), turbidity (0.789**), phosphate (0.755**) and nitrite (0.786**). Moreover, a positive correlation of temperature was established with chloride, TA and TH. On the contrary, a negative and significant correlation of temperature was established with DO (-0.879**), and a negative correlation with pH and acidity. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on temperature of water as a function of variation between sites ($F=31.71$, $p<0.05$) and between seasons ($F=105.52$, $p<0.05$) is found to be significant.

Table 4.1: Two-way ANOVA for Temperature of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	29.65396	3	9.884653	31.7084	0.000447	4.757062663
Between season	65.79125	2	32.89563	105.5239	2.11E-05	5.14325285
Error	1.870417	6	0.311736			
Total	97.31563	11				

4.1.2 Electrical Conductivity

Like Temperature, the Electrical Conductivity of water ranged from 23 µS (Site 1 during Post-monsoon season) to 277.2 µS (Site 4 during Monsoon season) during 2016-17. Subsequently, during 2017-2018 the values were between 28.7 µS (Site 1 in Post-monsoon season) and 232 µS (Site 4 in Monsoon season). Overall findings state range of electrical conductivity as 23 µS to 277.2 µS. The electrical conductivity was found to be high in Monsoon season and low during Post-monsoon season in both the years **(Fig. 4.2)**.

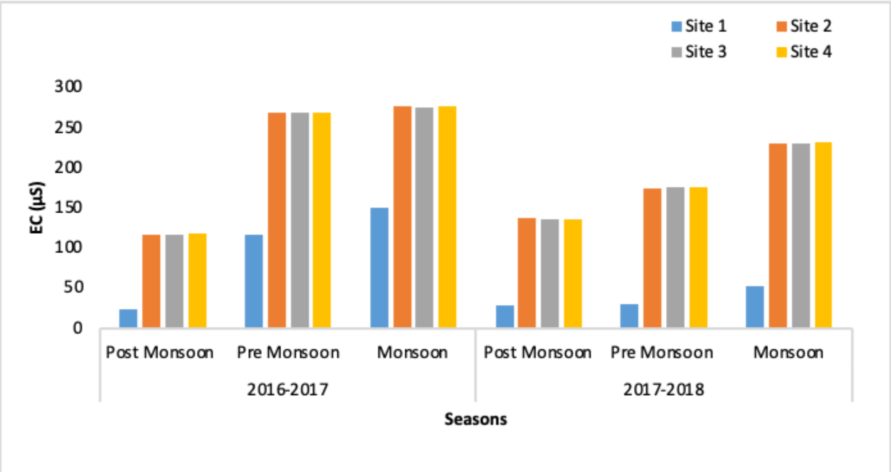


Fig. 4.2: Seasonal Variation in EC of water at selected study sites.

A positive and significant correlation of electrical conductivity was established with temperature (0.862**), TDS (0.912**), turbidity (0.836**), BOD (0.766**), chloride (0.408*), phosphate (0.765**) and nitrite (0.853**), and a positive correlation with pH, TA and TH. On the contrary, a negative and significant correlation of EC was established with DO (-0.843**), and a negative correlation with acidity. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on EC of water as a function of variation between sites ($F=64.48$, $p<0.05$) and between seasons ($F=66.85$, $p<0.05$) is found to be significant.

Table 4.2: Two-way ANOVA for EC of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	40350.5	3	13450.17	64.48406	5.89E-05	4.757062663
Between season	27888.52	2	13944.26	66.85288	7.92E-05	5.14325285
Error	1251.488	6	208.5813			
Total	69490.5	11				

4.1.3 Total Dissolved Solids

During 2016-17, the total dissolved solids of water ranged from 14.7 mgL^{-1} (Site 1 during Post-monsoon season) to 140 mgL^{-1} (Site 3 during Monsoon season). Subsequently, during 2017-2018 values were between 19 mgL^{-1} (Site 1 in Post-monsoon season) and 148.5 mgL^{-1}(Site 4 in Monsoon season). Overall findings state range of total dissolved solid between 14.7 mgL^{-1} and 148.5 mgL^{-1}. The values for Total dissolved solids were found to be low during Post-monsoon season and high during Monsoon season with regards to sites **(Fig. 4.3).**

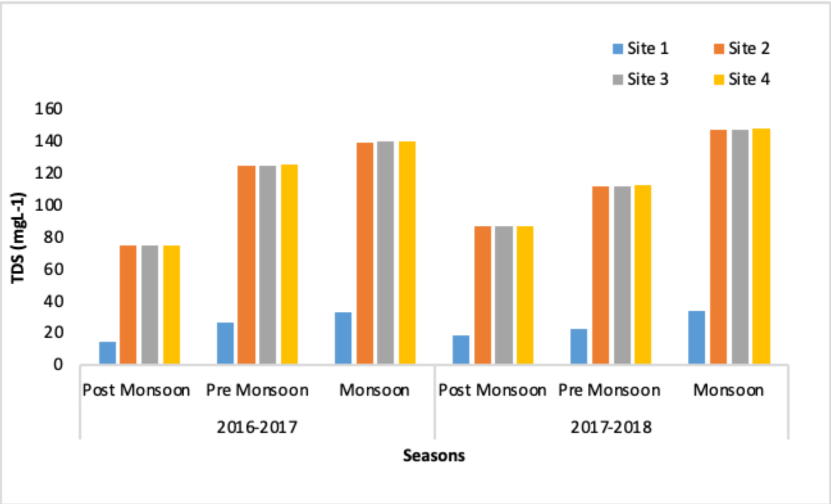


Fig. 4.3: Seasonal Variation in TDS of water at selected study sites.

A positive and significant correlation of TDS was established with temperature (0.819**), EC (0.912**), turbidity (0.750**), BOD (0.623**), chloride (0.436*), TH (0.414*), phosphate (0.666**) and nitrite (0.694**), and a positive correlation with pH and TA. On the contrary, a negative and significant correlation of TDS was established with DO (-0.717**), and a negative correlation with acidity. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on TDS of water as a function of variation between sites ($F=43.86$, $p<0.05$) and between seasons ($F=19.31$, $p<0.05$) is found to be significant.

Table 4.3: Two-way ANOVA for TDS of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	18023.41	3	6007.803	43.86474	0.000178	4.757062663
Between season	5290.561	2	2645.281	19.31397	0.00243	5.14325285
Error	821.7721	6	136.962			
Total	24135.74	11				

4.1.4 Turbidity

During 2016-17, the turbidity of water ranged from 3.1 NTU (Site 1 in Post-monsoon season) to 6.7 NTU (Site 2 and 3 in Monsoon season.) Subsequently, during 2017-2018 values were between 2.3 NTU (Site 1 in Post-monsoon season) and 5 NTU (Site 4 in Monsoon season). Overall findings state range of turbidity as 2.3 NTU to 5 NTU. The turbidity of water was found to be lower during Post-monsoon season and higher during Monsoon season in terms of study sites **(Fig. 4.4).**

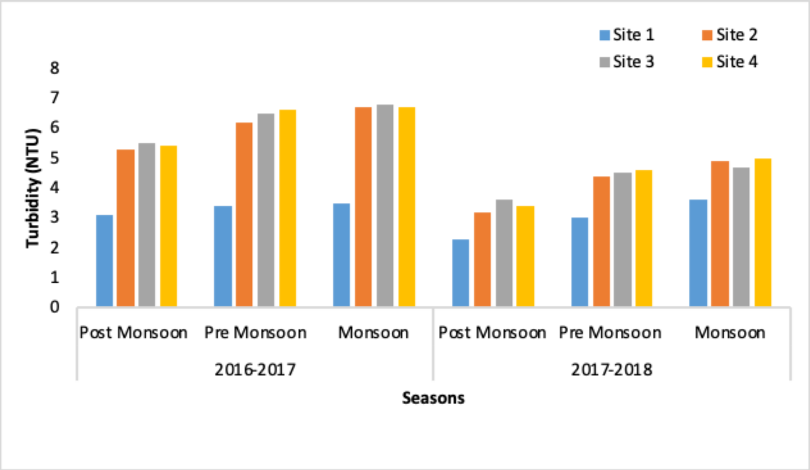


Fig. 4.4: Seasonal Variation in Turbidity of water at selected study sites.

A positive and significant correlation of Turbidity was established with temperature (0.789**), EC (0.836**), TDS (0.750**), pH (0.411*), BOD (0.899**), TH (0.456*), phosphate (0.961**) and nitrite (0.962**), and a positive correlation with chloride and TA. On the contrary, a negative and significant correlation of Turbidity was established with DO (-0.850**) and acidity (-0.473*). The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on turbidity of water as a function of variation between sites ($F=96.13$, $p<0.05$) and between seasons ($F=50.74$, $p<0.05$) is found to be significant.

Table 4.4: Two-way ANOVA for Turbidity of water

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	9.712292	3	3.237431	96.12165	1.84E-05	4.757062663
Between season	3.417917	2	1.708958	50.74021	0.000174	5.14325285
Error	0.202083	6	0.033681			
Total	13.33229	11				

4.1.5 pH

The pH of water ranged from 7.1 (Site 1 in Monsoon season) to 7.9 (Site 3 and Site 4 in Post-monsoon seasons) during 2016-17. Subsequently, during 2017-2018 values were between 6.1 (Site 1 in Monsoon season) and 7.7 (Site 4 in Post-monsoon season). Overall findings reveal that the range of pH as 6.1 to 7.9. The pH of water was found to be lower during monsoon season and higher during Post-monsoon season **(Fig. 4.5).**

Fig. 4.5: Seasonal Variation in pH of water at selected study sites**.**

A positive and significant correlation of pH was established with turbidity (0.411*), chloride (0.407*), TA (0.678**), TH (0.522**) and phosphate (0.427*) and a positive correlation with EC, TDS, BOD and nitrite. On the contrary, a negative and significant correlation of pH was established with acidity (-0.632**), and a negative correlation with temperature and DO. The correlation coefficient between various parameters and different sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on pH of water as a function of variation between sites ($F=103.54$, $p<0.05$) and between seasons ($F=175.29$, $p<0.05$) is found significant.

Table 4.5: Two-way ANOVA for pH of water

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	0.603958	3	0.201319	103.5357	1.48E-05	4.757062663
Between season	0.681667	2	0.340833	175.2857	4.76E-06	5.14325285
Error	0.011667	6	0.001944			
Total	1.297292	11				

4.1.6 Dissolved Oxygen (DO)

The DO content of water ranged from 5 mgL^{-1} (Site 3 in Monsoon season) to 7.9 mgL^{-1} (Site 1 in Post-monsoon) during 2016-17. Subsequently, during 2017-2018 the values were between 5.9 mgL^{-1} (Site 2 in Monsoon season) and 7.8 mgL^{-1} (Site 1 in Post-monsoon season). Overall findings state range of DO content of water as 5 mgL^{-1} to 7.9 mgL^{-1}. The DO content was found to be high in Post monsoon season and low during Monsoon season in both the years **(Fig. 4.6).**

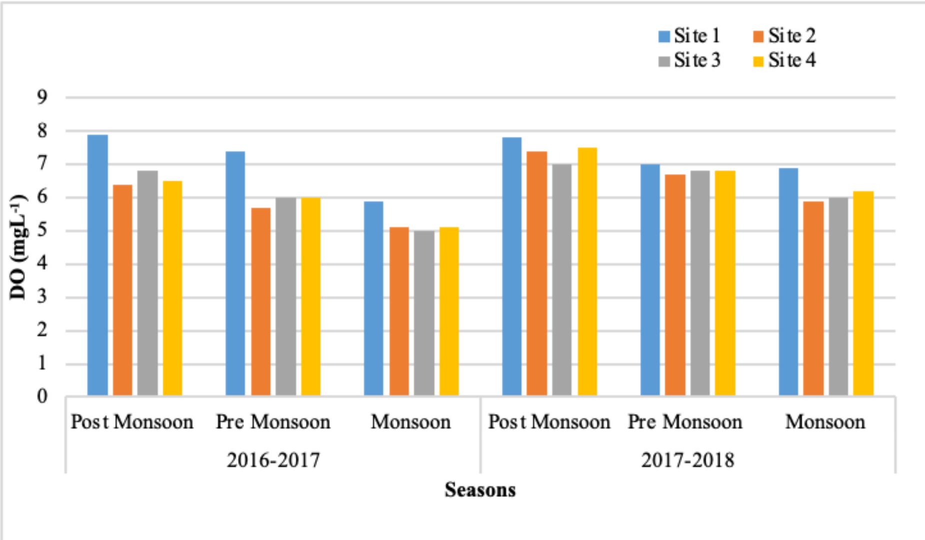


Fig. 4.6: Seasonal Variation in DO content of water at selected study sites.

A positive correlation of DO content was established with TA and acidity. On the contrary, a negative and significant correlation of DO content was established with temperature (-0.879**), EC (-0.843**), TDS (0.717**), turbidity (-0.850**), BOD (-0.919**), phosphate (-0.864**) and nitrite (-0.899**), and a negative correlation with pH, chloride and TH. The correlation coefficient between various parameters and different sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on DO of water as a function of variation between sites ($F=217.54$, $p<0.05$) and between seasons ($F=727.46$, $p<0.05$) is found to be significant.

Table 4.6: Two-way ANOVA for DO content of water

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	1.7675	3	0.589167	217.5385	1.65E-06	4.757062663
Between season	3.940417	2	1.970208	727.4615	6.93E-08	5.14325285
Error	0.01625	6	0.002708			
Total	5.724167	11				

4.1.7 Biological Oxygen Demand (BOD)

The BOD content of water ranged from 1.6 mgL^{-1} (Site 1 in Post-monsoon season) to 3.8 mgL^{-1}(Site 2 in Monsoon season) during 2016-17. Subsequently, during 2017- 2018 values were between 1.1 mgL^{-1} (Site 1 in Post-monsoon) and 2.6 mgL^{-1}(Site 2 and Site 3 in Monsoon season). Overall findings state range of BOD as 1.1 to 3.8 mgL^{-1}. BOD content of water was found to be higher during Monsoon season and lower during Post-monsoon season irrespective of year **(Fig. 4.7).**

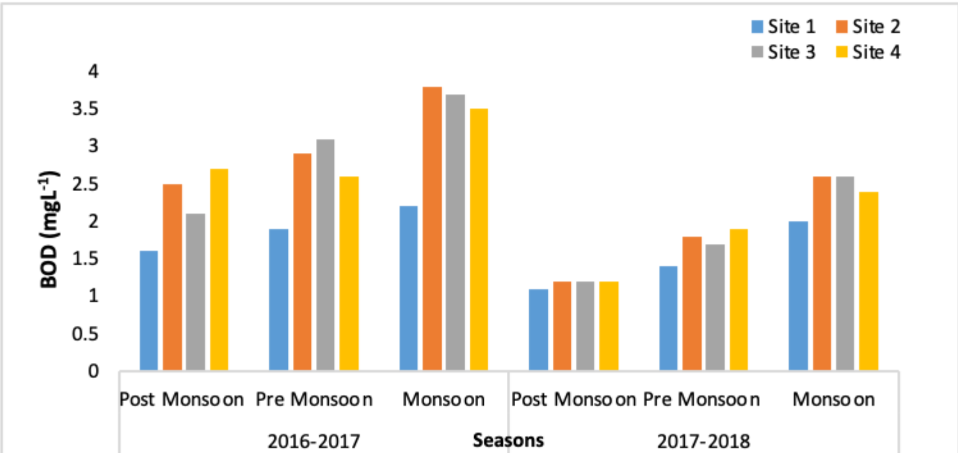


Fig. 4.7: Seasonal variation in BOD content of water at selected study sites.

A positive and significant correlation of BOD was established with temperature (0.851**), EC (0.766**), TDS (0.623**), turbidity (0.899**), phosphate (0.922**) and nitrite (0.934**), and a positive correlation with pH, chloride, TA and TH. On the contrary, a negative and significant correlation of BOD was established with DO (-0.919**), and a negative correlation with acidity. The correlation coefficient between different parameters and different sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on BOD of water as a function of variation between sites ($F=12.31$, $p<0.05$) and between seasons ($F=42.39$, $p<0.05$) is found to be significant.

Table 4.7: Two-way ANOVA for BOD content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	1.167292	3	0.389097	12.31429	0.005645	4.757062663
Between season	2.67875	2	1.339375	42.38901	0.000289	5.14325285
Error	0.189583	6	0.031597			
Total	4.035625	11				

4.1.8 Chloride

The chloride content of water ranged from 1.3 mgL^{-1} (Site 1 in Monsoon season) to 44 mgL^{-1} (Site 3 in Pre-Monsoon season) during 2016-17. Subsequently, during 2017-2018, the values were between 5.2 mgL^{-1} (Site 1 in Monsoon season) to 36 mgL^{-1} (Site 2, 3 and 4 in Pre-monsoon season). Overall findings state range of chloride as 1.3 mgL^{-1} to 44 mgL^{-1}. The chloride value was found to be lower during monsoon season and higher during pre-monsoon season **(Fig. 4.8).**

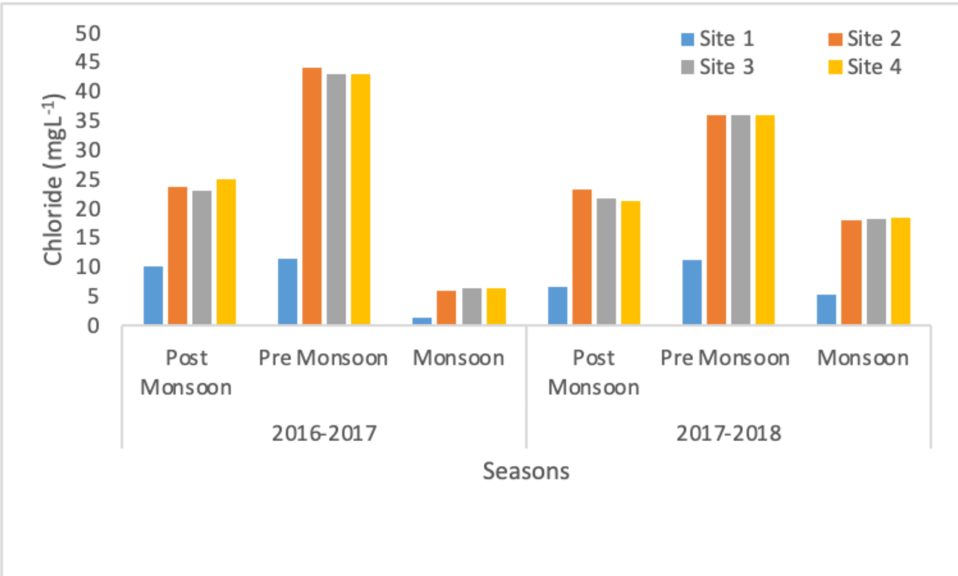


Fig. 4.8: Seasonal variation in Chloride content of water at selected study sites.

A positive and significant correlation of chloride was established with EC (0.408*), TDS (436*), pH (0.407*), TA (0.545**) and TH (0.849**), and a positive correlation with temperature, turbidity, BOD, phosphate and nitrite. On the contrary, a negative and significant correlation of chloride content was established with acidity (-0.622**), and a negative correlation with DO content. The correlation coefficient between different parameters and t sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on Chloride of water as a function of variation between sites ($F=6.40$, $p<0.05$) and between seasons ($F=15.04$, $p<0.05$) is found significant.

Table 4.8: Two-way ANOVA for Chloride content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	796.17	3	265.39	6.398368	0.026765	4.757062663
Between season	1247.352	2	623.676	15.0364	0.004602	5.14325285
Error	248.8666	6	41.47776			
Total	2292.389	11				

4.1.9 Total Alkalinity

The total alkalinity of water ranged from 25.6 mg L^{-1} $CaCO_3$ (Site 1 in Monsoon season) to 200 mgL^{-1} $CaCO_3$ (Site 2 in Post-monsoon season). Subsequently, during 2017-2018 values were between 54 mg L^{-1} $CaCO_3$ (Site 1 in Monsoon season) and 139 mgL^{-1} $CaCO_3$ (Site 3 in Post-monsoon season). Overall findings state range of total alkalinity as 25.6 mg L^{-1} $CaCO_3$ to 200 mg L^{-1} $CaCO_3$. The total alkalinity was lower during monsoon season and higher during the post-monsoon season irrespective of year **(Fig. 4.9).**

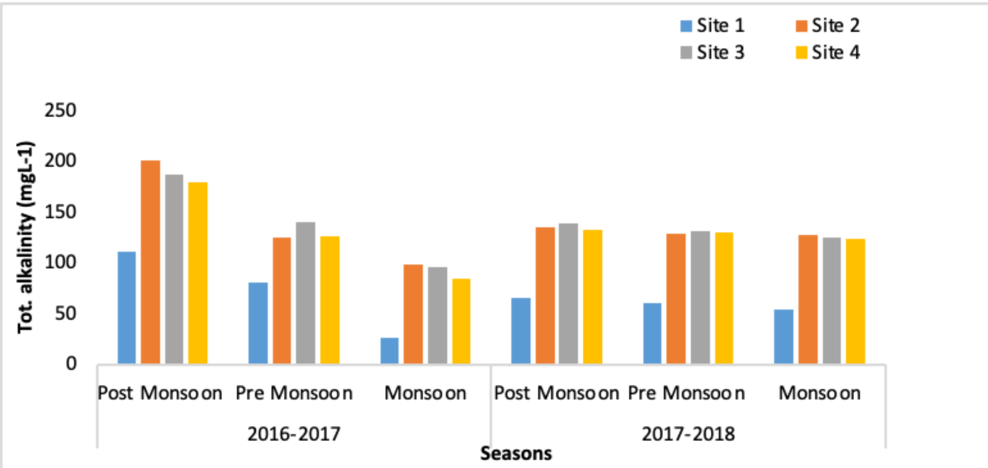


Fig. 4.9: Seasonal variation in Total Alkalinity of water at selected study sites.

A positive and significant correlation of TA was established with pH (0.678**), chloride (0.545**) and TH (0.714**), and a positive correlation with temperature EC, TDS, turbidity, DO, BOD, phosphate and nitrite. On the contrary, a negative correlation of TA was established with acidity. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on TA of water as a function of variation between sites ($F=146.43$, $p<0.05$) and between seasons ($F=114.67$, $p<0.05$) is found to be significant.

Table 4.9: Two-way ANOVA for Total alkalinity of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	10351.01	3	3450.335	146.427	5.32E-06	4.757062663
Between season	5403.97	2	2701.985	114.6681	1.66E-05	5.14325285
Error	141.3811	6	23.56352			
Total	15896.36	11				

4.1.10 Acidity

The acidity values ranged from 3.4 mgL^{-1} (Site 2 in Pre-monsoon season) to 8.8 mgL^{-1} (Site 1 Monsoon season) during 2016-17. Subsequently, during 2017-2018 values were between 6.5 mgL^{-1}(Site 1 in Pre-monsoon season) and 9 mgL^{-1} (Site 1 in Monsoon season). Overall findings state range of acidity as 3.4 mgL^{-1} to 9 mgL^{-1}. The acidity of water was found to be highest during Monsoon season and lowest during Pre-monsoon season in both the years, and at Site 1 only **(Fig. 4.10).**

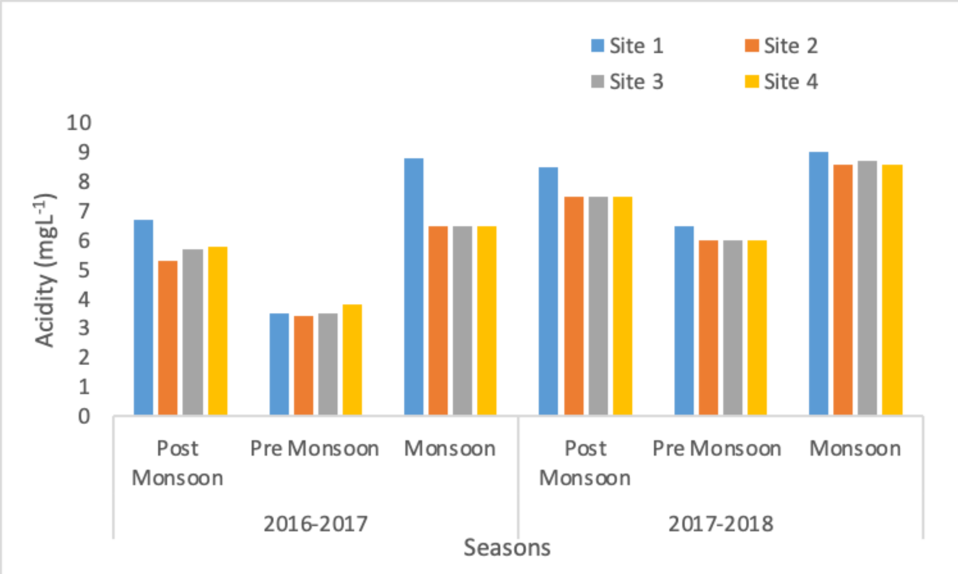


Fig. 4.10: Seasonal variation in Acidity of water at selected study sites.

A positive correlation of Acidity was established with DO content of water. On the contrary, a negative and significant correlation of acidity was established with turbidity (-0.473*), pH (-0.632**), chloride (-0.622**), TH (-0.551**) and nitrite (-0.410*), and a negative correlation with temperature, EC, TDS, BOD, TA and phosphate. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on acidity of water as a function of variation between sites ($F=6.43$, $p<0.05$) and between seasons ($F=108.10$, $p<0.05$) is found to be significant.

Table 4.10: Two-way ANOVA for Acidity of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	1.716056	3	0.572019	6.430338	0.026472	4.757062663
Between season	19.23258	2	9.61629	108.1013	1.97E-05	5.14325285
Error	0.533738	6	0.088956			
Total	21.48237	11				

4.1.11 Total Hardness

The total hardness of water ranged from 18 mgL^{-1} $CaCO_3$ (Site 1 in Monsoon season) to 141 mgL^{-1} $CaCO_3$ (Site 4 in Pre-monsoon season) during 2016-17. Subsequently, during 2017-2018, values were between 28.3 mgL^{-1} $CaCO_3$ (Site 1 in

Monsoon season) and 86 mgL^{-1} $CaCO_3$ (Site 3 in Pre-monsoon season). Overall findings state range of total hardness as 18 mgL^{-1} $CaCO_3$ to 141 mgL^{-1} $CaCO_3$. The total hardness values were found to be higher during pre-monsoon season and lower during Monsoon season irrespective of year **(Fig. 4.11).**

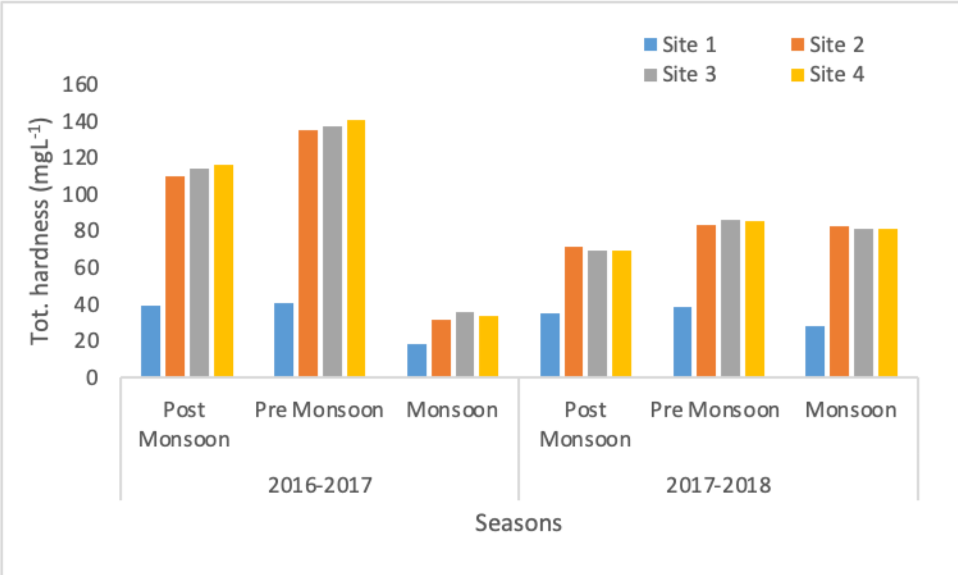


Fig. 4.11: Seasonal variation in Total hardness of water at selected study sites.

A positive and significant correlation of TH was established with TDS (0.414*), turbidity (0.456*), pH (0.522**), chloride (0.849**) and TA (0.714**), and a positive correlation with temperature, EC, BOD, phosphate and nitrite. On the contrary, a negative and significant correlation of TH was established with acidity (-0.551**), and a negative correlation with DO content of water. The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on TH of water as a function of variation between sites ($F=11.19$, $p<0.05$) and between seasons ($F=10.75$, $p<0.05$) is found to be significant.

Table 4.11: Two-way ANOVA for Total Hardness of water

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	6539.167	3	2179.722	11.19236	0.007175	4.757062663
Columns	4188.311	2	2094.155	10.75299	0.010379	5.14325285
Error	1168.506	6	194.751			
Total	11895.98	11				

4.1.12 Phosphate-P

The phosphate-P content of water ranged from 0.029 mgL^{-1} (Site 1 in Post-monsoon season) to 0.246 mgL^{-1} (Site 4 in Monsoon season) during 2016-16. Subsequently, during 2017-2018, the values were between 0.005 mgL^{-1} (Site 1 in Post-monsoon season) to 0.107 mgL^{-1} (Site 4 in Monsoon season). Overall findings state range of phosphate-P as 0.005 mgL^{-1} to 0.246 mgL^{-1}. The phosphate-P values were found to be highest during monsoon season and lowest during Post-monsoon season in both the years **(Fig. 4.12).**

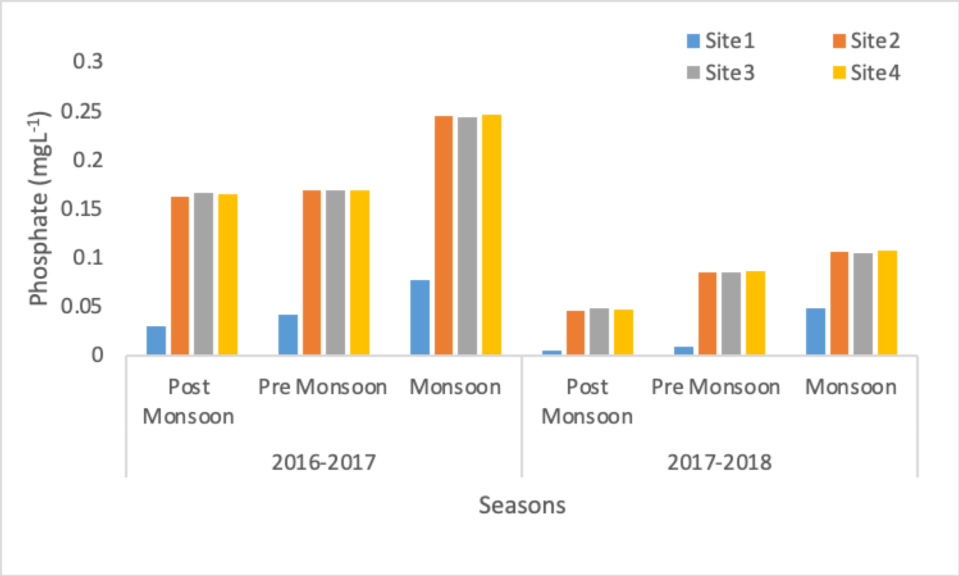


Fig. 4.12: Seasonal Variation in Phosphate-P content of water at selected study sites.

A positive and significant correlation of phosphate was established with temperature (0.755**), EC (0.765**), TDS (0.666**), turbidity (0.961**), pH (0.427*) and BOD (0.922**), and a positive correlation with chloride, TA and TH. On the contrary, a negative and significant correlation of Phosphate-P was established with DO (-0.864**), and a negative correlation with acidity.The correlation coefficient between different parameters and sites has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on Phosphate-P content of water as a function of variation between sites ($F=198.03$, $p<0.05$) and between seasons ($F=112.07$, $p<0.05$) is found to be significant.

Table 4.12: Two-way ANOVA for Phosphate-P content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	0.022905	3	0.007635	198.0274	2.18E-06	4.757062663
Between season	0.008642	2	0.004321	112.0656	1.77E-05	5.14325285
Error	0.000231	6	3.86E-05			
Total	0.031778	11				

4.1.13 Nitrite

The nitrite content of water ranged from 0.012 mgL^{-1} (Site 1 in Post-monsoon season) to 0.087 mgL^{-1} (Site 4 in Monsoon season) during 2016-17. Subsequently, during 2017-2018, the values were between 0.008 mgL^{-1} (Site 1 in Post-monsoon season) to 0.045 mgL^{-1} (Site 3 & 4 in Monsoon season). Overall findings state range of nitrite as 0.008 mgL^{-1} to 0.087 mgL^{-1}. The nitrite values were found to be highest during monsoon season and lowest during post-monsoon season in both the years **(Fig. 4.13).**

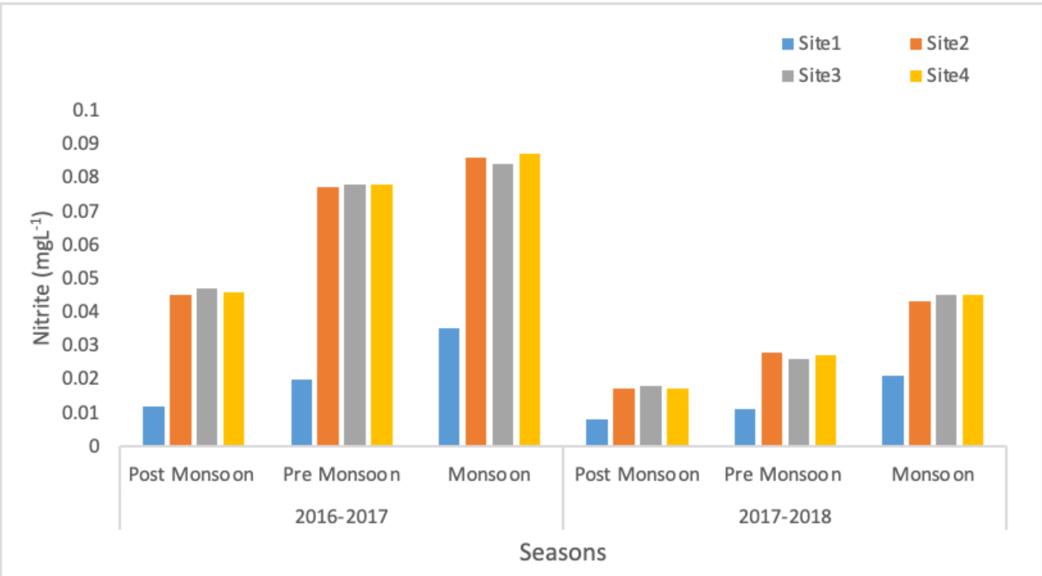


Fig. 4.13: Seasonal variation in Nitrite content of water at selected study sites.

A positive and significant correlation of temperature was established with temperature (0.786**), EC (0.853**), TDS (0.694**), turbidity (0.962**), BOD (0.934**) and phosphate (0.949**), and a positive correlation with pH, chloride, TA and TH. On the contrary, a negative and significant correlation of Nitrite was established with DO (-0.899**) content. The correlation coefficient between different parameters and sites during the study period has been given in **Appendix 2 to 5**.

Statistically, two-way ANOVA on nitrite of water as a function of variation between sites ($F=38.51$, $p<0.05$) and between seasons ($F=44.38$, $p<0.05$) is found to be significant.

Table 4.13: Two-way ANOVA for Nitrite content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between sites	0.002281	3	0.00076	38.50686	0.000258	4.757062663
Between season	0.001753	2	0.000876	44.38375	0.000254	5.14325285
Error	0.000118	6	1.97E-05			
Total	0.004152	11				

4.2 Linear Regression Analysis between water quality characteristics

Linear regression is used to get an indication of water quality by determining a few factors experimentally. The regression equation graph was plotted for the pairs of parameters possessing high and significant correlation. The regression equation so obtained can be used to estimate the unknown values (independent variable) by substituting the known values (dependent variable) in the equation. The value of R^2 or the square of the correlation from the regression analysis was used to show how strong the correlation and relationship between the variables X and Y are? The value is a fraction between 0.0 and 1.0, where R^2 value of 1.0 means that the correlation becomes strong and all points lie on a straight line and R^2 value of 0.0 means that there is no correlation and no linear relationship between X and Y.

Linear regression model at Site 1 was plotted for Temperature (dependent variable) with BOD, phosphate and nitrite (independent variables); EC (dependent variable) with phosphate-P and nitrite (independent variables); TDS (dependent variable) with DO (independent variable); Turbidity (dependent variable) with BOD and Phosphate-P (independent variables); DO (dependent variable) with Total Alkalinity, Total Hardness and Nitrite (independent variables); Chloride (dependent variable) with Total Hardness (independent variable); Total Alkalinity (dependent variable) with Total Hardness (independent variable); BOD (dependent variable) with Phosphate-P and Nitrite (independent variables); Total Hardness (dependent variable) with Nitrite (independent variable); and Phosphate-P (dependent variable) with Nitrite (independent variable). **Fig. 4.14(a) to 4.14(j)**.

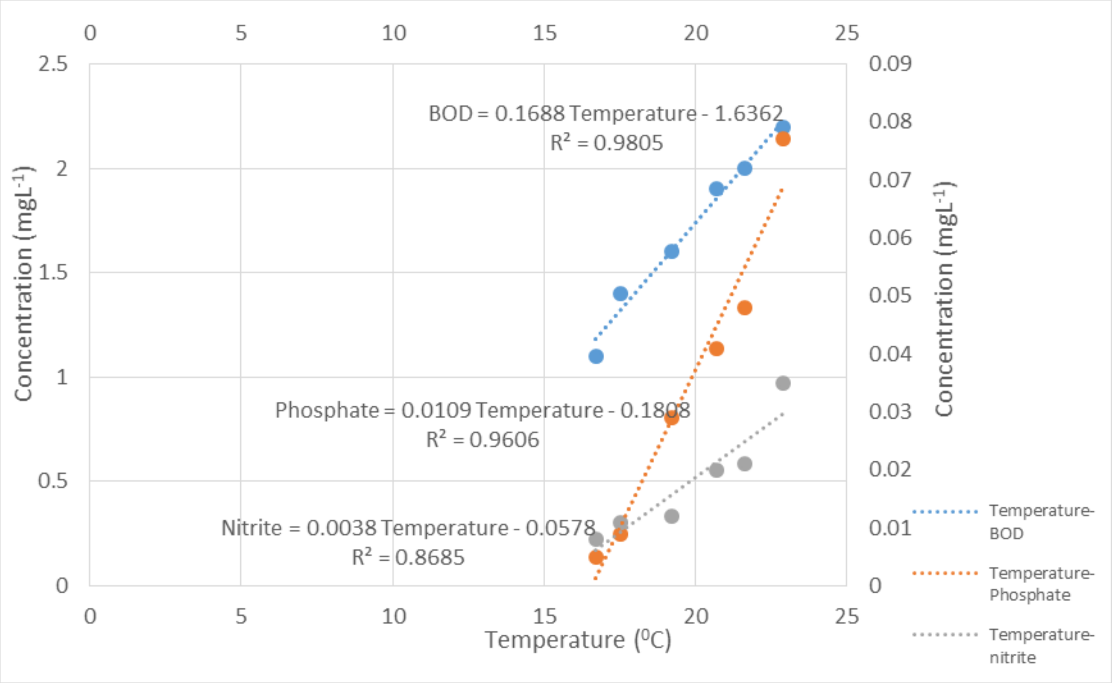


Fig. 4.14(a): Plots of water quality parameters as a linear regression model at Site 1.

The regression equations for the linear regression model **[**Fig. 4.14(a)] are:

BOD = 0.1688 Temperature - 1.6362

This depicts that as temperature increase BOD will also increase gradually

Phosphate = 0.0109 Temperature - 0.1808

This depicts that as temperature increase Phosphate will also increase gradually

Nitrite = 0.0038 Temperature - 0.0578

This depicts that as temperature increase Nitrite will also increase gradually

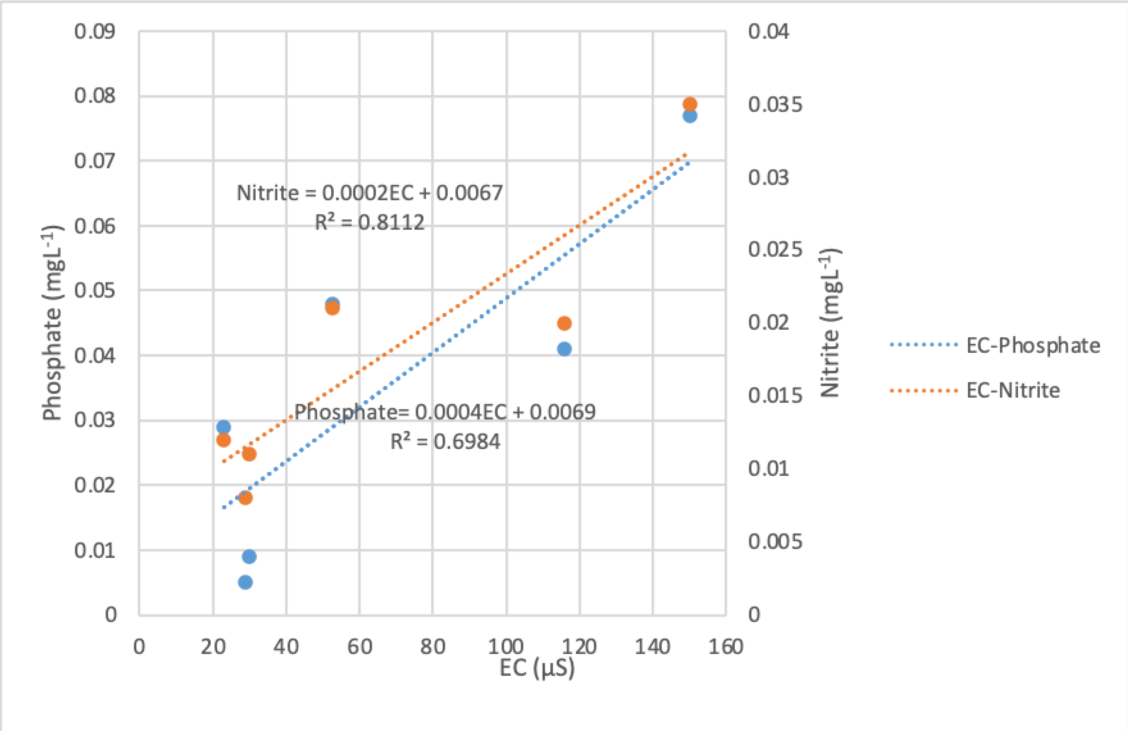


Fig. 4.14(b): Plots of water quality parameters as a linear regression model at Site 1.

The regression equations for the linear regression model [Fig. 4.14(b)] are:

Phosphate= 0.0004EC + 0.0069

This depicts that as EC increase Phosphate will also increase.

Nitrite = 0.0002EC + 0.0067

This depicts that as temperature increase Nitrite will also increase.

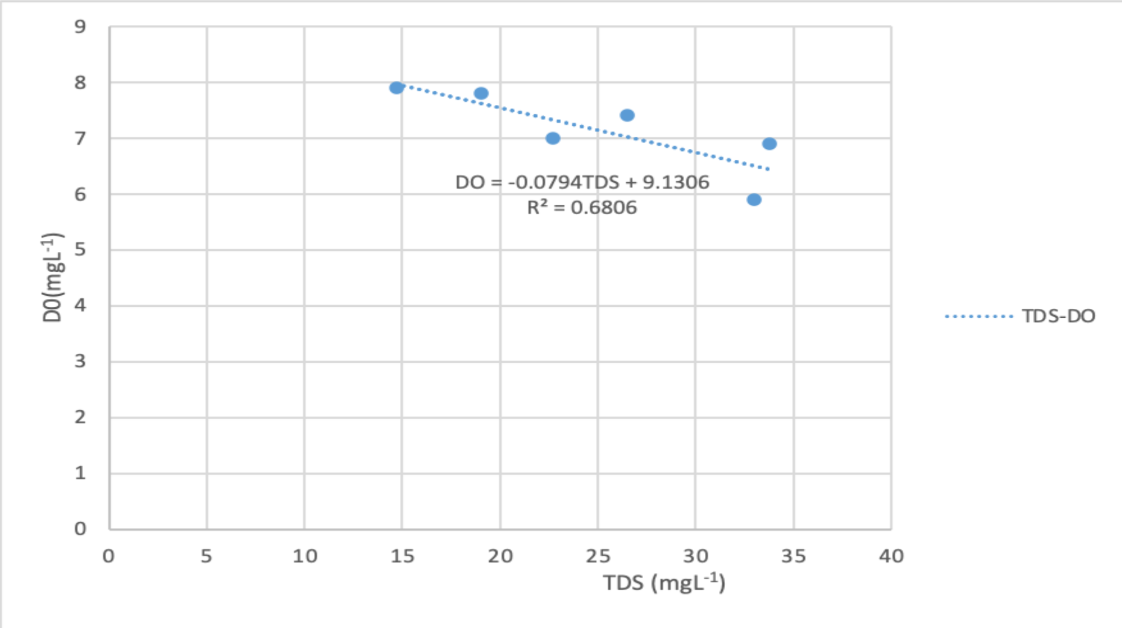
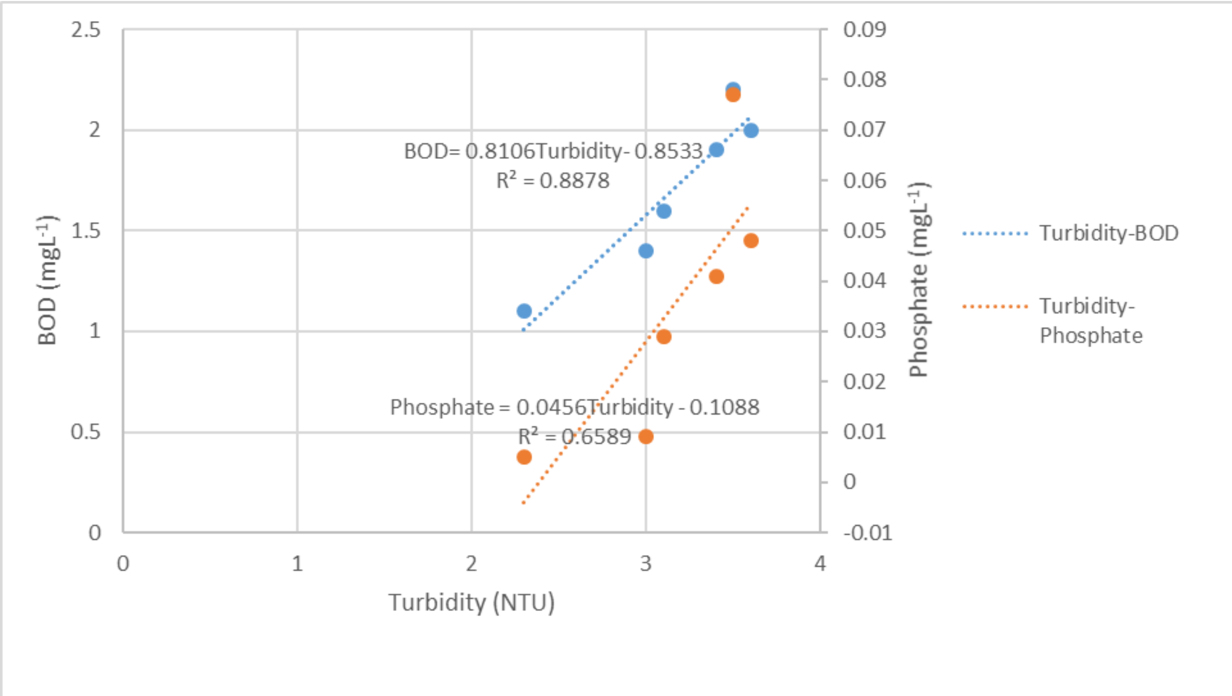


Fig. 4.14(c): Plots of water quality parameters as a linear regression model at Site 1.

The regression equation for the linear regression model [Fig. 4.14(c)] is as follows:

DO = -0.0794TDS + 9.1306

This depicts that as TDS increases, DO decreases.



The regression equations for the linear regression model [Fig. 4.14(d)] are:

BOD = 0.8106Turbidity - 0.8533

This depicts that as Turbidity increases, BOD increases gradually.

Phosphate = 0.0456Turbidity - 0.1088

This depicts that as Turbidity increases, Phosphate increases gradually.

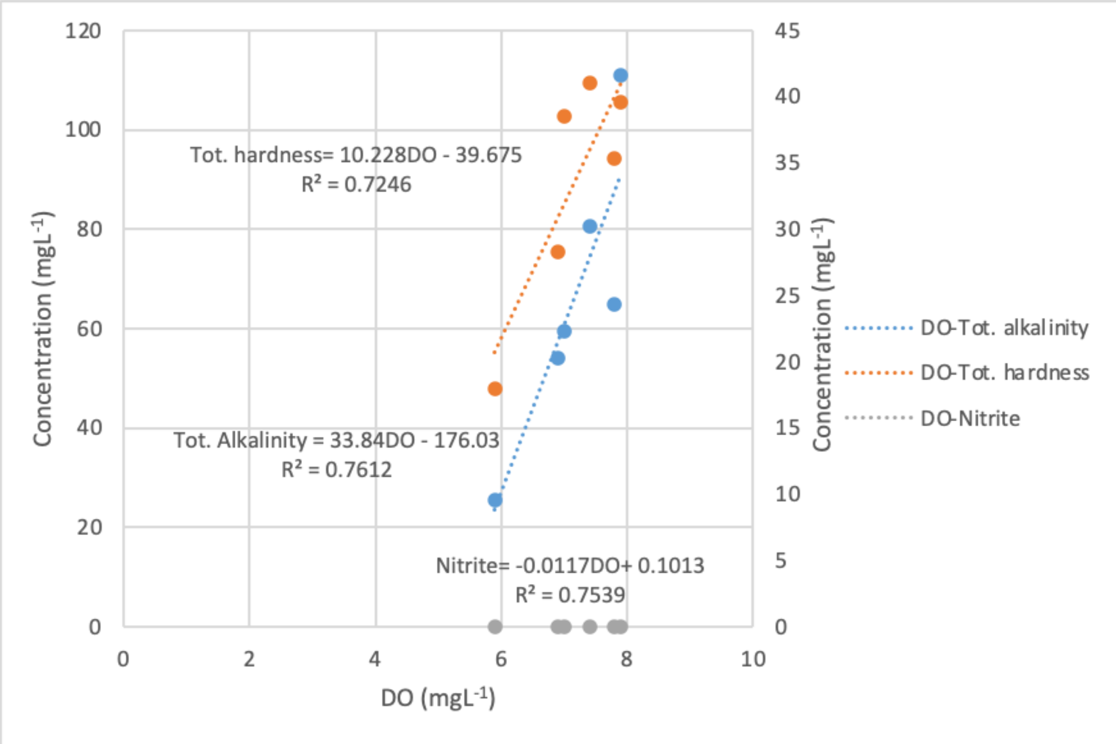


Fig. 4.14(e): Plots of water quality parameters as a linear regression model at Site 1

The regression equations for the linear regression model [Fig. 4.14(e)] are:

Total hardness= 10.228DO - 39.675

This depicts that as DO increases, Total hardness also increases gradually.

Total Alkalinity = 33.84DO - 176.03

This depicts that as DO increases, Total alkalinity also increases gradually.

Nitrite= -0.0117DO+ 0.1013

This depicts that as DO increases, Nitrite decreases.

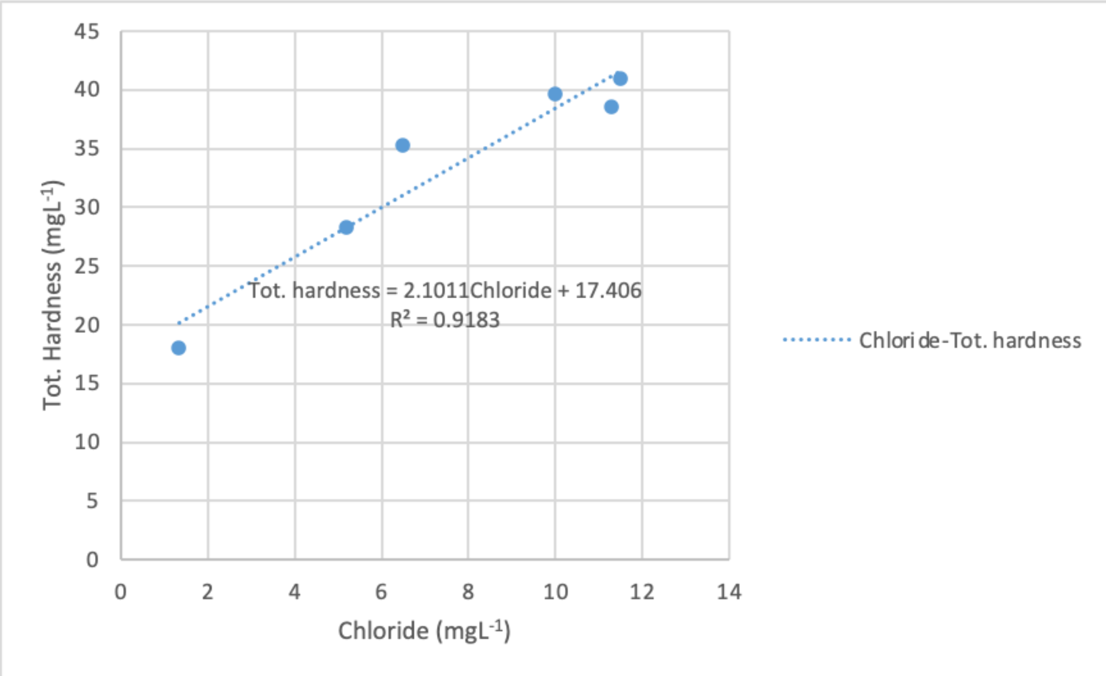


Fig. 4.14(f): Plots of water quality parameters as a linear regression model at Site 1.

The regression equation for the linear regression model [Fig. 4.14(f)] is

Total Hardness = 2.1011Chloride + 17.406

This depicts that as Chloride increases, total hardness also increases.

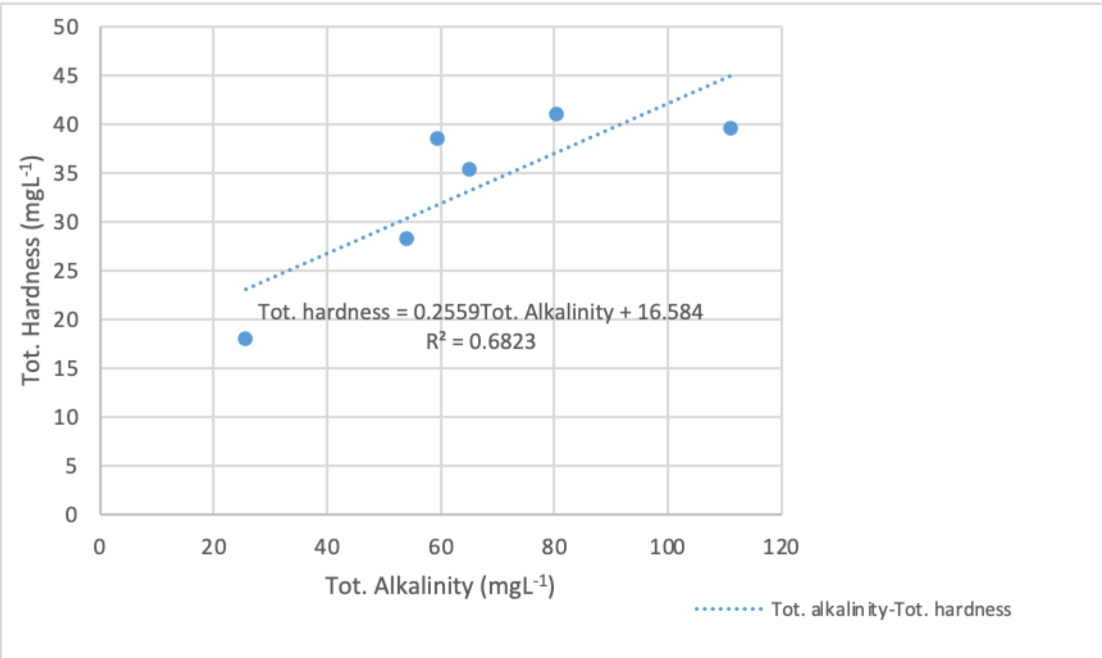


Fig. 4.14(g): Plots of water quality parameters as a linear regression model at Site.

The regression equation for the linear regression model [Fig. 4.14(g)] is

Total Hardness = 0.2559Tot. Alkalinity + 16.584

This depicts that as Total alkalinity increases, total hardness also increases.

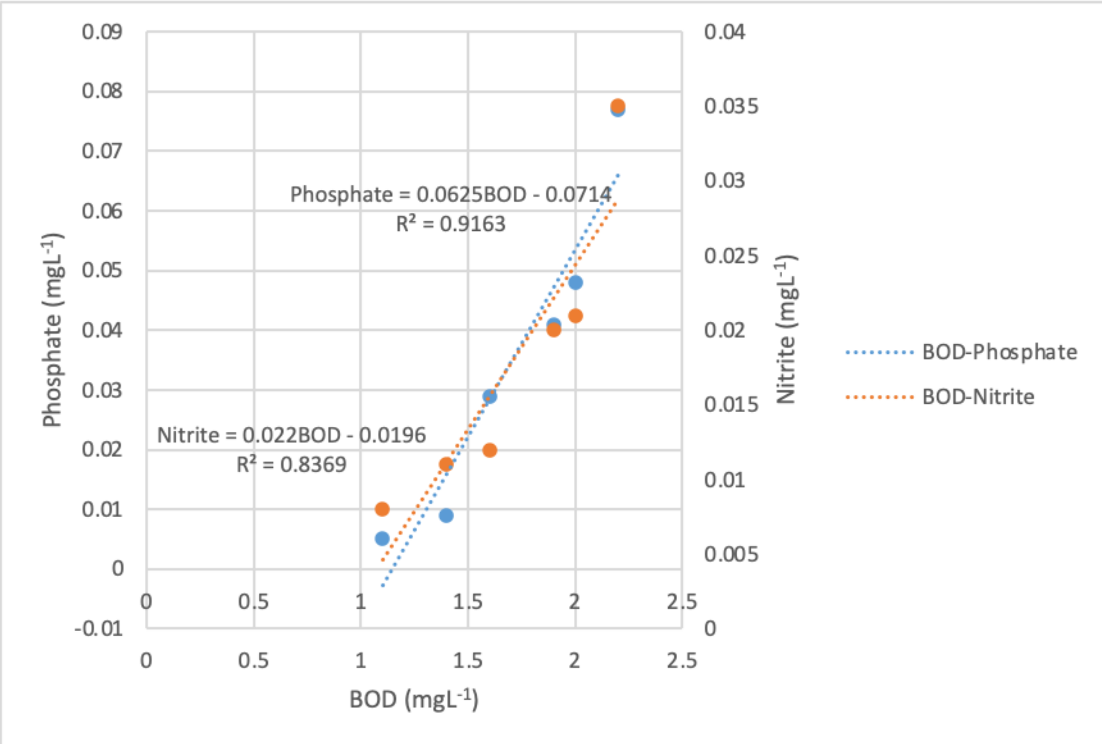


Fig. 4.14(h): Plots of water quality parameters as a linear regression model at Site 1.

The regression equations for the linear regression model [Fig. 4.14(h)] are as follows

Phosphate-P = 0.0625BOD - 0.0714

This depicts that as BOD increases, Phosphate-P also increases gradually.

Nitrite = 0.022BOD - 0.0196

This depicts that as BOD increases, Nitrite also increases gradually.

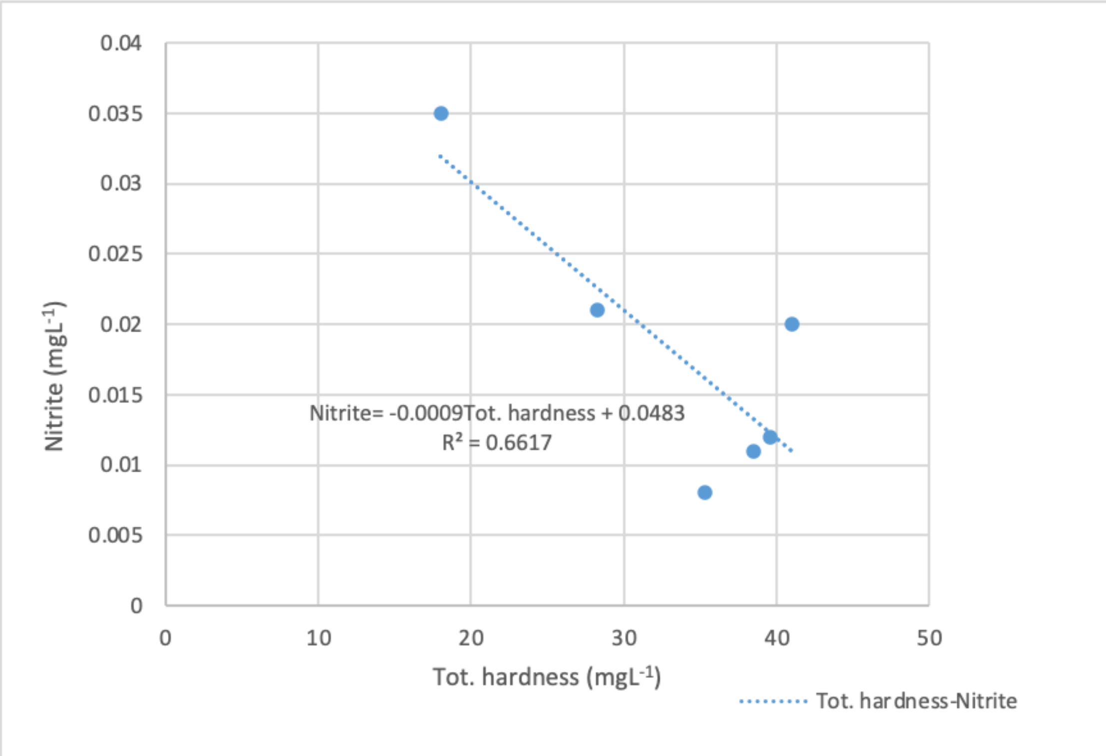


Fig. 4.14(i): Plots of water quality parameters as a linear regression model at Site 1.

The regression equation for the linear regression model [Fig. 4.14(i)] is

Nitrite= -0.0009 Total Hardness + 0.0483

This depicts that as Total Hardness increases, Nitrite decreases.

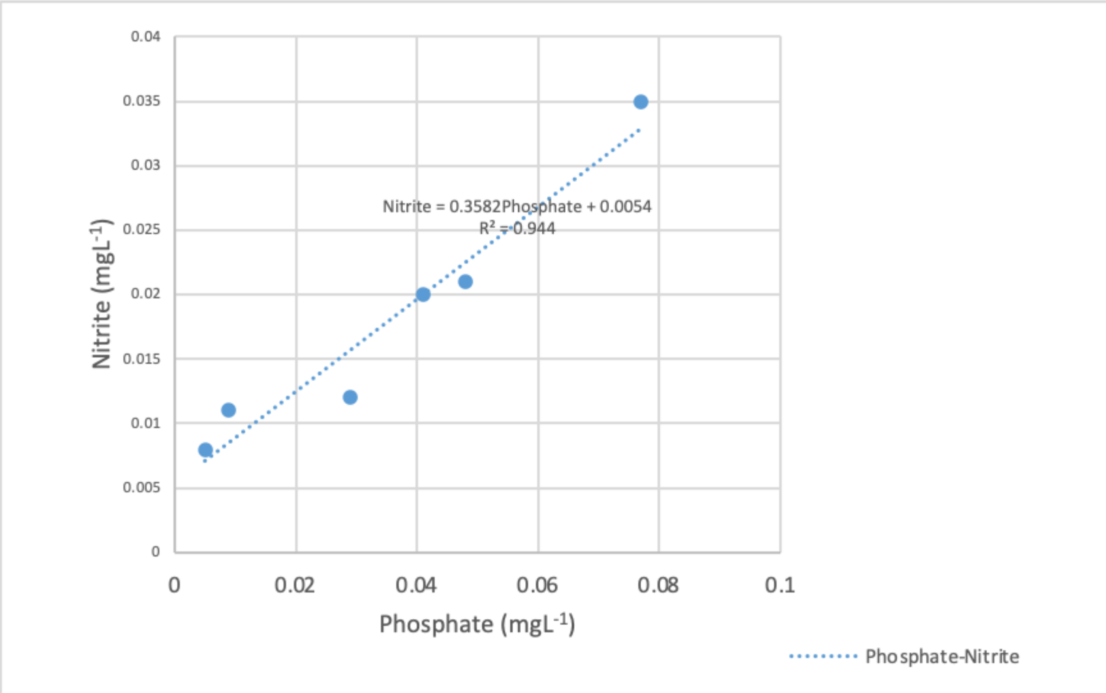


Fig. 4.14(j): Plots of water quality parameters as a linear regression model at Site 1**.**

The regression equation for the linear regression model [Fig. 4.14(j)] is

Nitrite = 0.3582Phosphate + 0.0054

This depicts that as Phosphate increases, Nitrite also increases.

The linear regression model at Site 2 was plotted for Temperature (dependent variable) with EC, TDS, DO and BOD (independent variables); EC (dependent variable) with TDS and DO (independent variables); Turbidity (dependent variable) with DO, BOD, Phosphate-P and Nitrite (independent variables); DO (dependent variable) with BOD, Phosphate-P and Nitrite (independent variables); BOD (dependent variable) with Phosphate-P and Nitrite (independent variables); and Phosphate-P (dependent variable) with Nitrite (independent variable). **Fig. 4.15(a) to 4.15(f).**

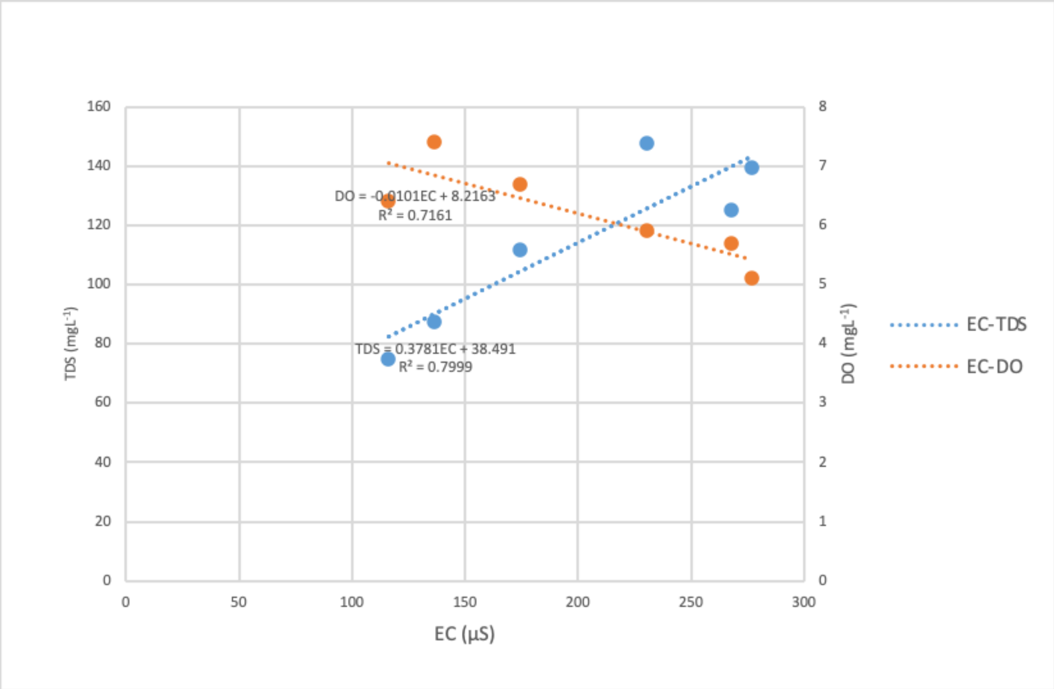


Fig. 4.15(a): Plots of water quality parameters as a linear regression model at Site 2.

The regression equations for the linear regression model Fig. 4.15(a) are:

DO = -0.0101EC + 8.2163

This depicts that as EC increases, DO decreases.

TDS = 0.3781EC + 38.491

This depicts that as EC increases, TDS also increases.

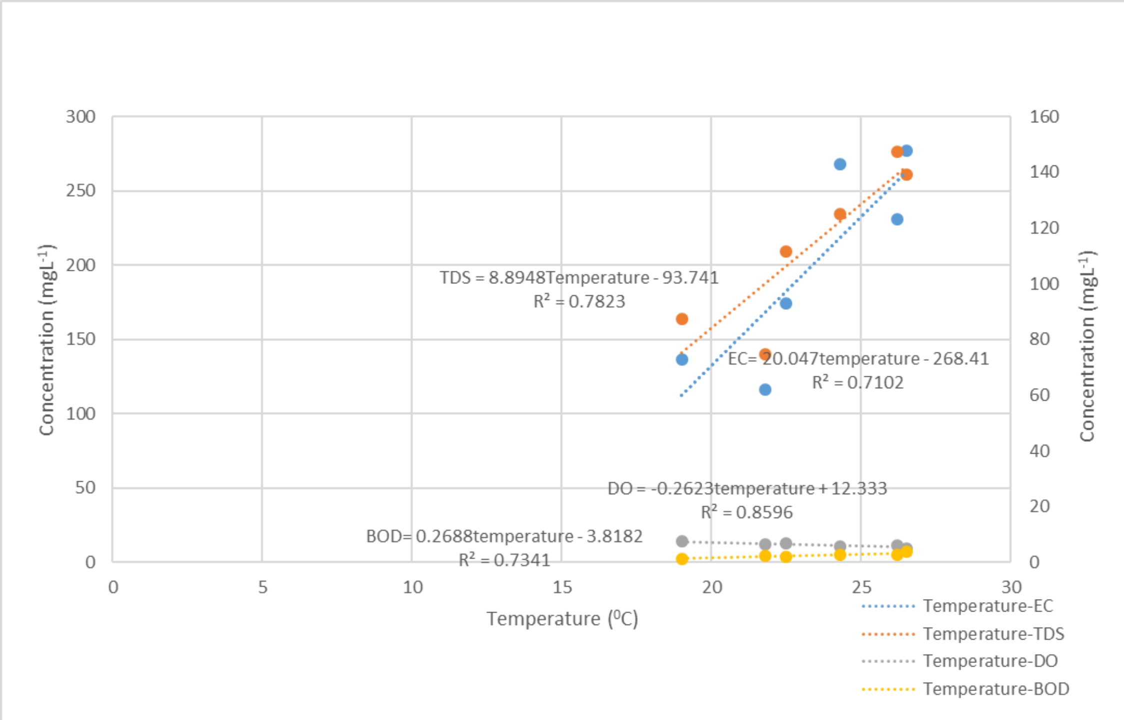


Fig. 4.15(b): Plots of water quality parameters as a linear regression model at Site 2.

The regression equations for the linear regression model [Fig. 4.15(b)] are:

TDS = 8.8948Temperature - 93.741

This depicts that when temperature increases, TDS also increases gradually.

EC= 20.047temperature - 268.41

This depicts that when temperature increases, EC also increases gradually.

DO = -0.2623temperature + 12.333

This depicts that when temperature increases, DO decreases.

BOD= 0.2688 temperature - 3.8182

This depicts that when temperature increases, BOD also increases gradually.

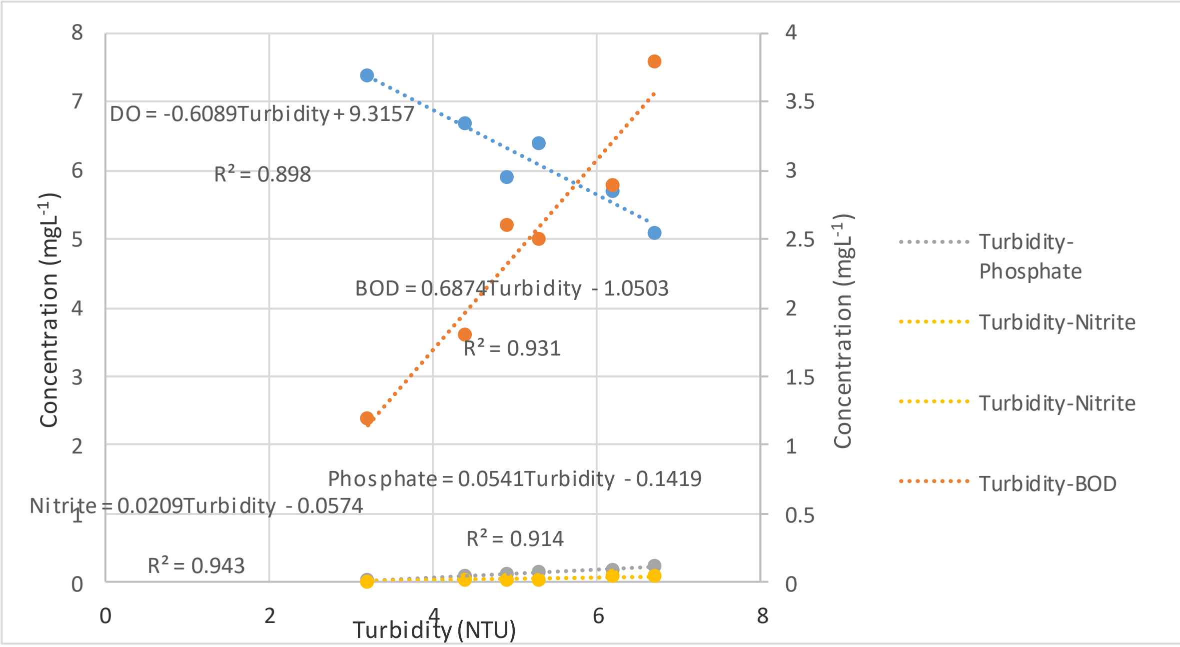


Fig. 4.15(c): Plots of water quality parameters as a linear regression model at Site 2.

The regression equations for the linear regression model [Fig. 4.15(c)] are:

DO= -0.6089 Turbidity+ 9.3157

This depicts that when Turbidity increases, DO decreases.

BOD = 0.6874 Turbidity- 1.0503

This depicts that when Turbidity increases, BOD also increases gradually.

Phosphate-P = 0.0541 Turbidity - 0.1419

This depicts that when Turbidity increases, Phosphate-P also increases gradually.

Nitrite = 0.0209 Turbidity - 0.0574

This depicts that when Turbidity increases, Nitrite also increases gradually.

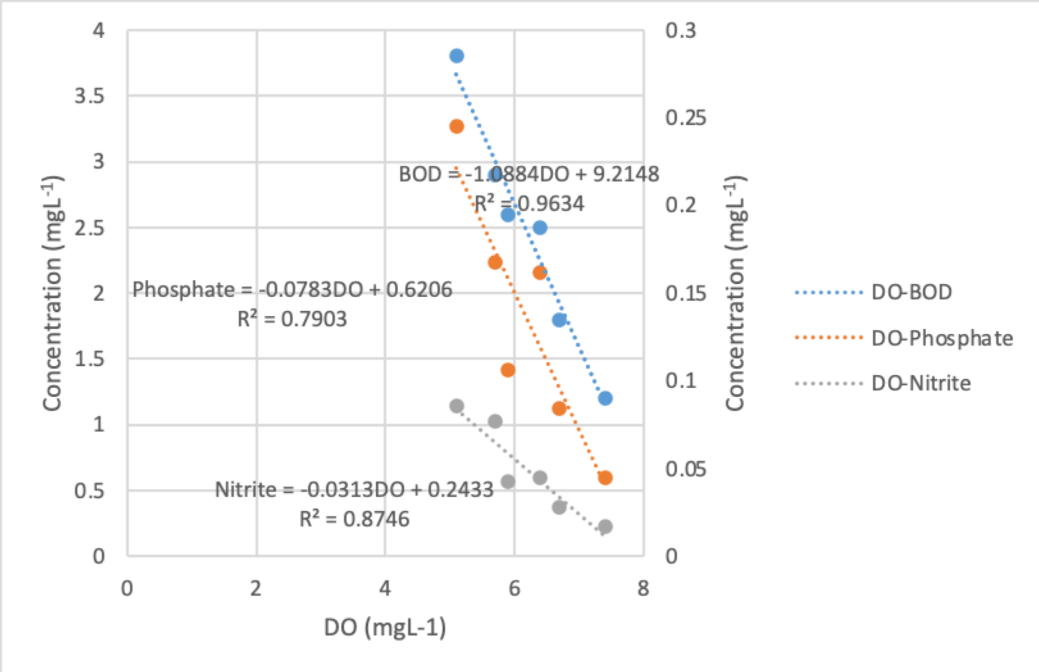


Fig. 4.15(d): Plots of water quality parameters as a linear regression model at Site 2.

The regression equations for the linear regression model [Fig. 4.15(d)] are:

BOD = -1.0884DO + 9.2148

This depicts that when DO increases, BOD decreases.

Phosphate-P = -0.0783DO + 0.6206

This depicts that when DO increases, Phosphate-P decreases.

Nitrite = -0.0313DO + 0.2433

This depicts that when DO increases, Nitrite decreases.

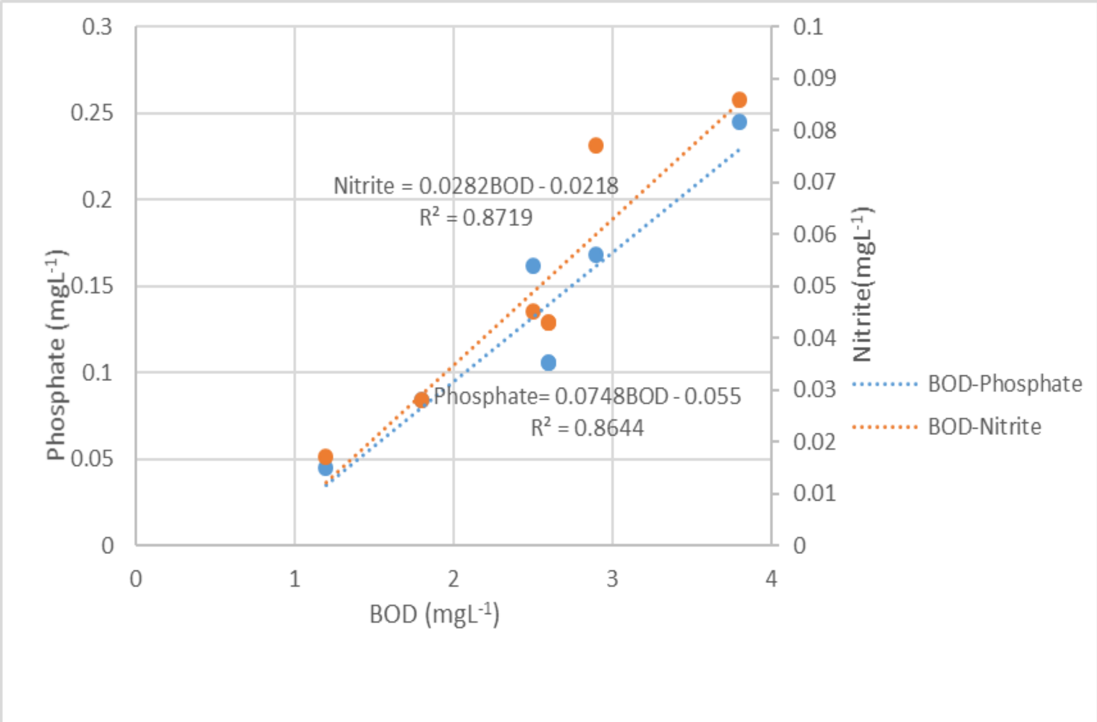


Fig. 4.15(e): Plots of water quality parameters as a linear regression model at Site 2.

The regression equations for the linear regression model [Fig. 4.15(e)] are:

Phosphate-P = 0.0748BOD- 0.055

This depicts that when BOD increases, Phosphate-P also increases gradually.

Nitrite = 0.0282BOD - 0.0218

This depicts that when BOD increases, Nitrite also increases gradually.

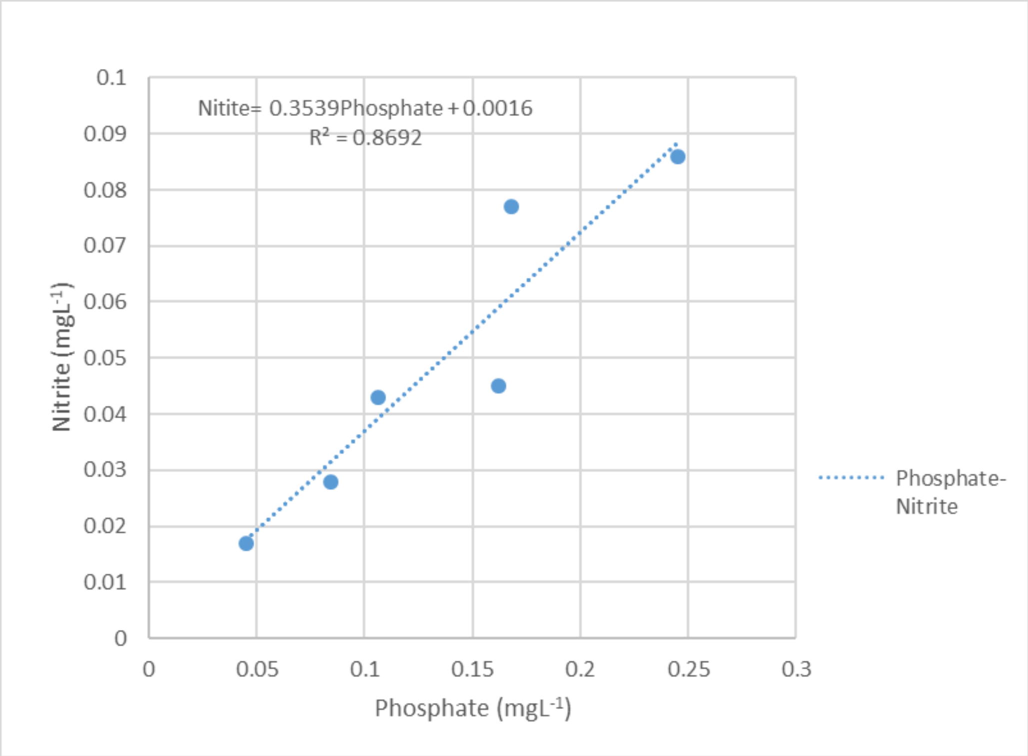


Fig. 4.15(f): Plots of water quality parameters as a linear regression model at Site 2.

The regression equation for the linear regression model [Fig. 4.15(f)] is:

Nitrite = 0.3539Phosphate + 0.0016

This depicts that when phosphate increases, nitrite also increases.

The linear regression model at Site 3 was plotted for Temperature (dependent variable) with EC, TDS, DO and BOD (independent variables); EC (dependent variable) with TDS, DO and BOD (independent variables); Turbidity (dependent variable) with BOD, Phosphate-P and Nitrite (independent variables); DO (dependent variable) with BOD and Nitrite (independent variables); BOD (dependent variable) with Phosphate-P and Nitrite (independent variables); Chloride (dependent variable) with Total Hardness (independent variable); and Phosphate-P (dependent variable) with Nitrite (independent variable) **Fig. 4.16(a) to 4.16(g).**

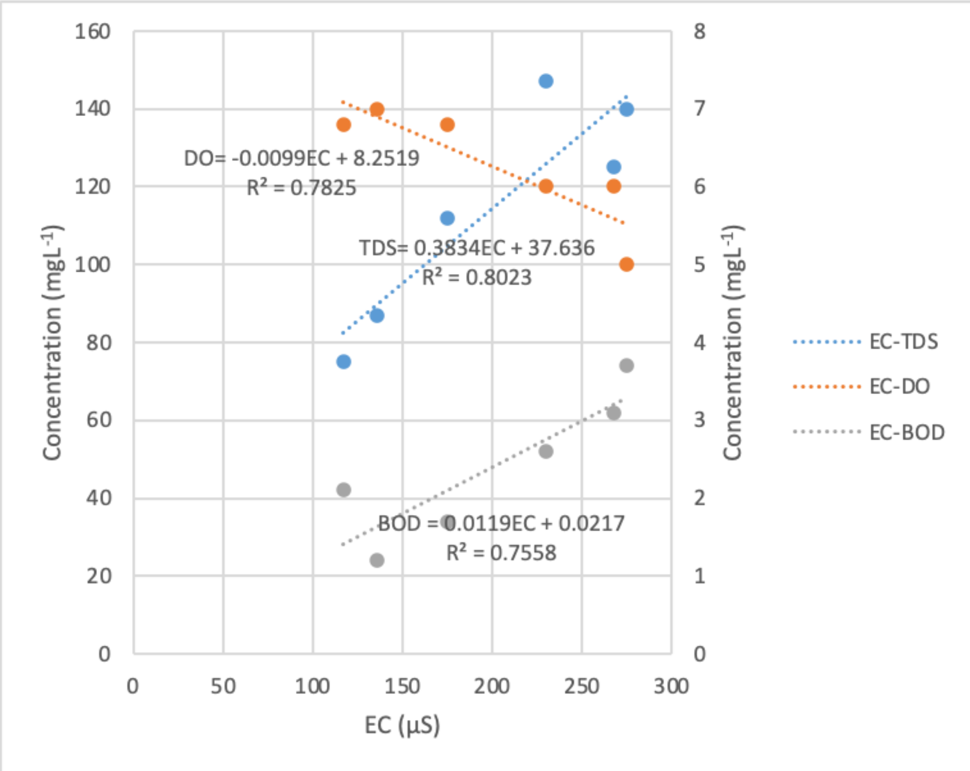


Fig. 4.16(a): Plots of water quality parameters as a linear regression model at Site 3.

The regression equations for the linear regression model [Fig. 4.16(a)] are:

DO= -0.0099EC + 8.2519

This depicts that as EC increases, DO decreases.

TDS= 0.3834EC + 37.636

This depicts that as EC increases, TDS also increases.

BOD = 0.0119EC + 0.0217

This depicts that as EC increases, BOD also increases.

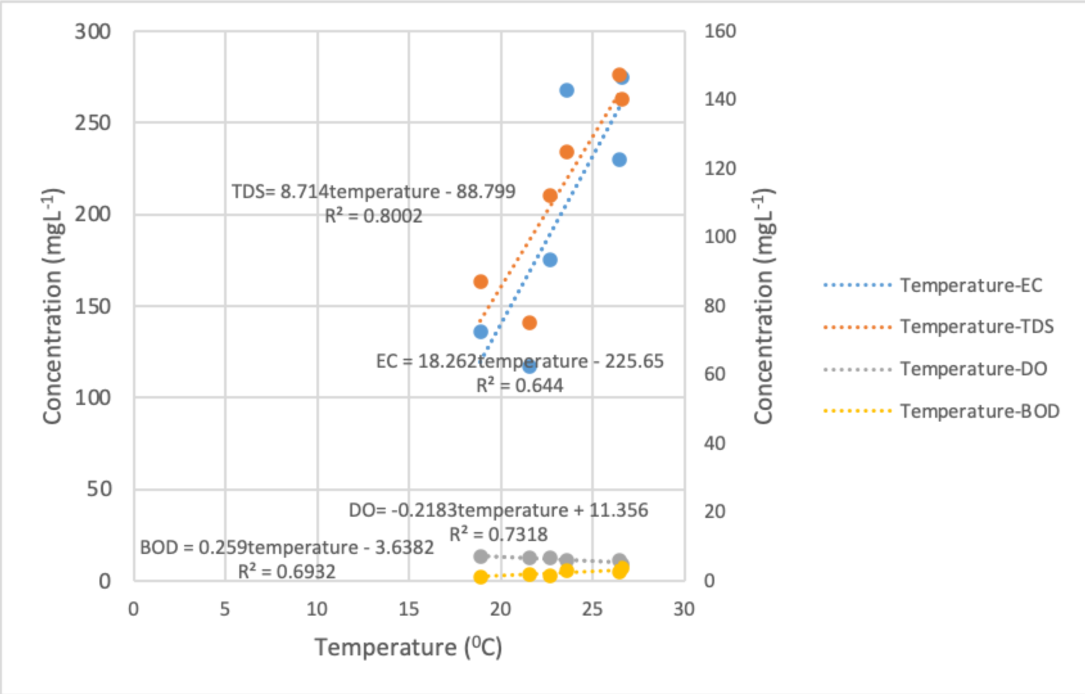


Fig. 4.16(b): Plots of water quality parameters as a linear regression model at Site 3.

The regression equations for the linear regression model [Fig. 4.16(b)] are:

TDS= 8.714temperature - 88.799

This depicts that as Temperature increases, TDS also increases gradually.

EC = 18.262temperature - 225.65

This depicts that as Temperature increases, EC also increases gradually.

DO= -0.2183temperature + 11.356

This depicts that as Temperature increases, DO decreases.

BOD = 0.259temperature - 3.6382

This depicts that as Temperature increases, BOD also increases gradually.

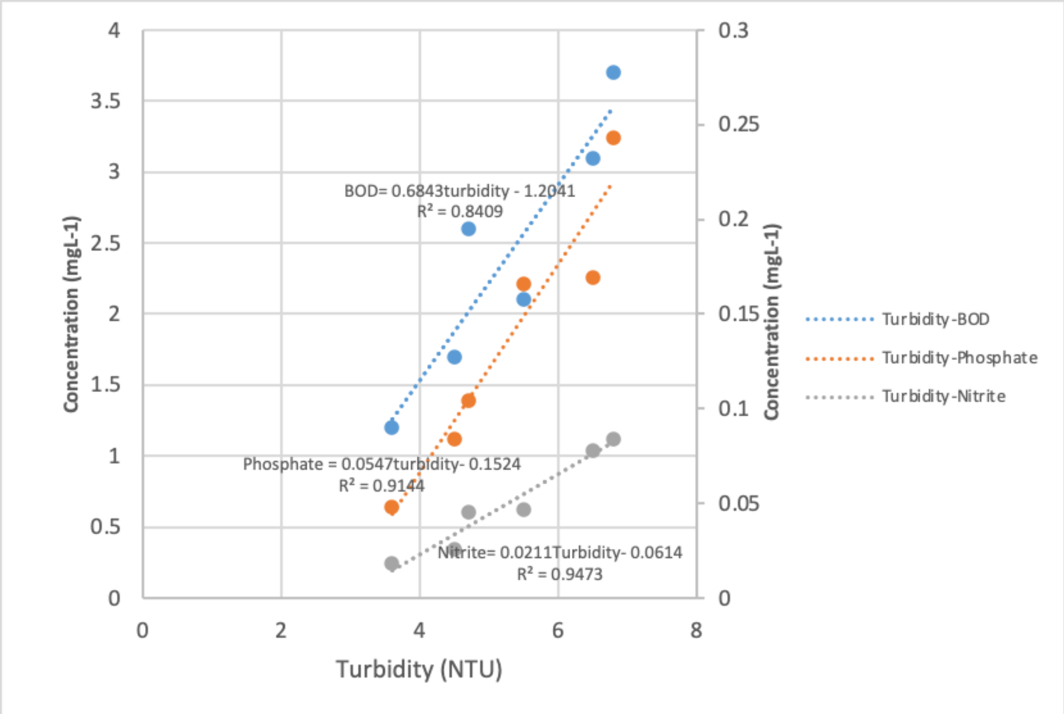


Fig. 4.16(c): Plots of water quality parameters as a linear regression model at Site 3.

The regression equations for the linear regression model [Fig. 4.16(c)] are:

BOD= 0.6843 Turbidity - 1.2041

This depicts that as Turbidity increases, TDS also increases gradually.

Phosphate-P = 0.0547 Turbidity- 0.1524

This depicts that as Turbidity increases, Phosphate-P also increases gradually.

Nitrite= 0.0211 Turbidity- 0.0614

This depicts that as Turbidity increases, Nitrite also increases gradually.

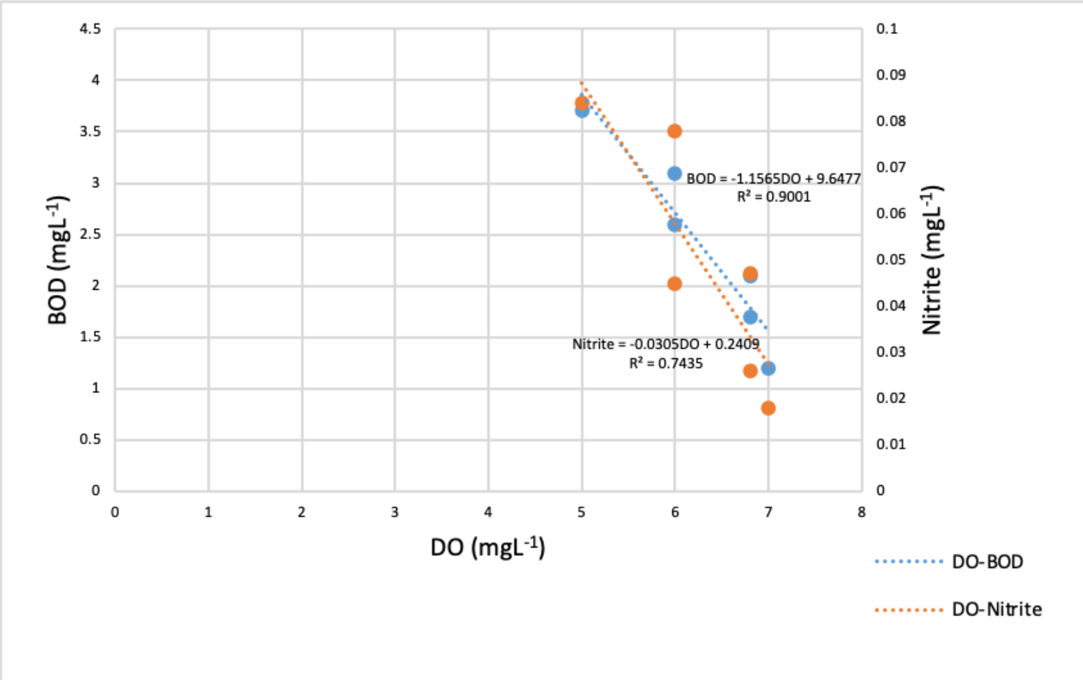


Fig. 4.16(d): Plots of water quality parameters as a linear regression model at Site 3.

The regression equations for the linear regression model [Fig. 4.16(d)] are:

BOD = -1.1565DO + 9.6477

This depicts that as DO increases, BOD decreases.

Nitrite = -0.0305DO + 0.2409

This depicts that as DO increases, Nitrite decreases.

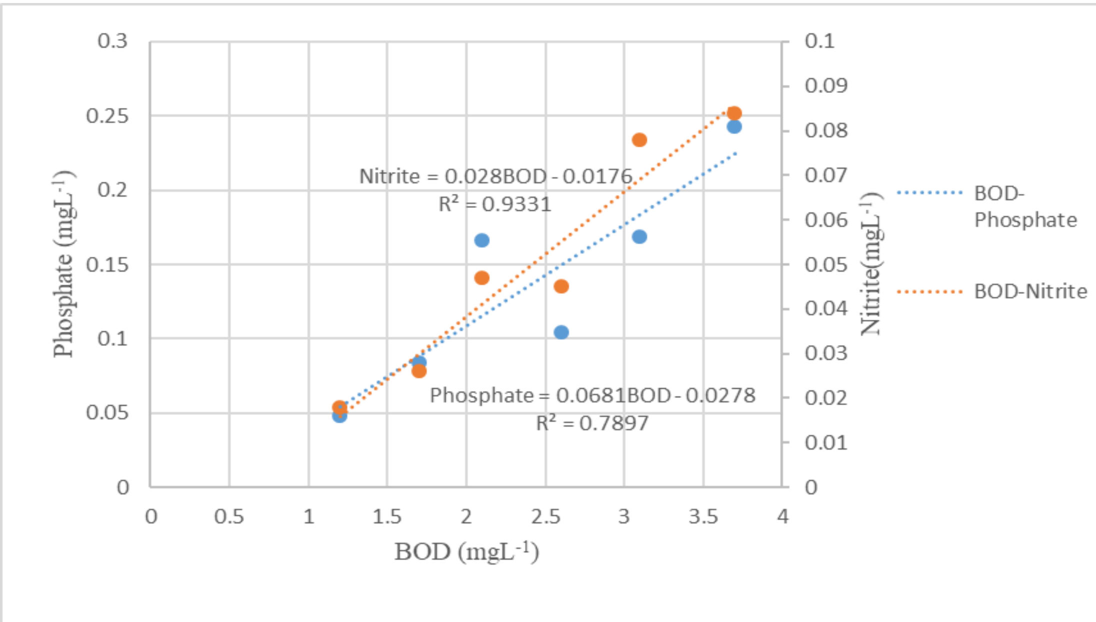


Fig. 4.16(e): Plots of water quality parameters as a linear regression model at Site 3.

The regression equations for the linear regression model [Fig. 4.16(e)] are:

Phosphate-P= 0.0681 BOD - 0.0278

This depicts that as BOD increases, Phosphate-P also increases gradually.

Nitrite= 0.028BOD - 0.0176

This depicts that as BOD increases, Nitrite also increases gradually.

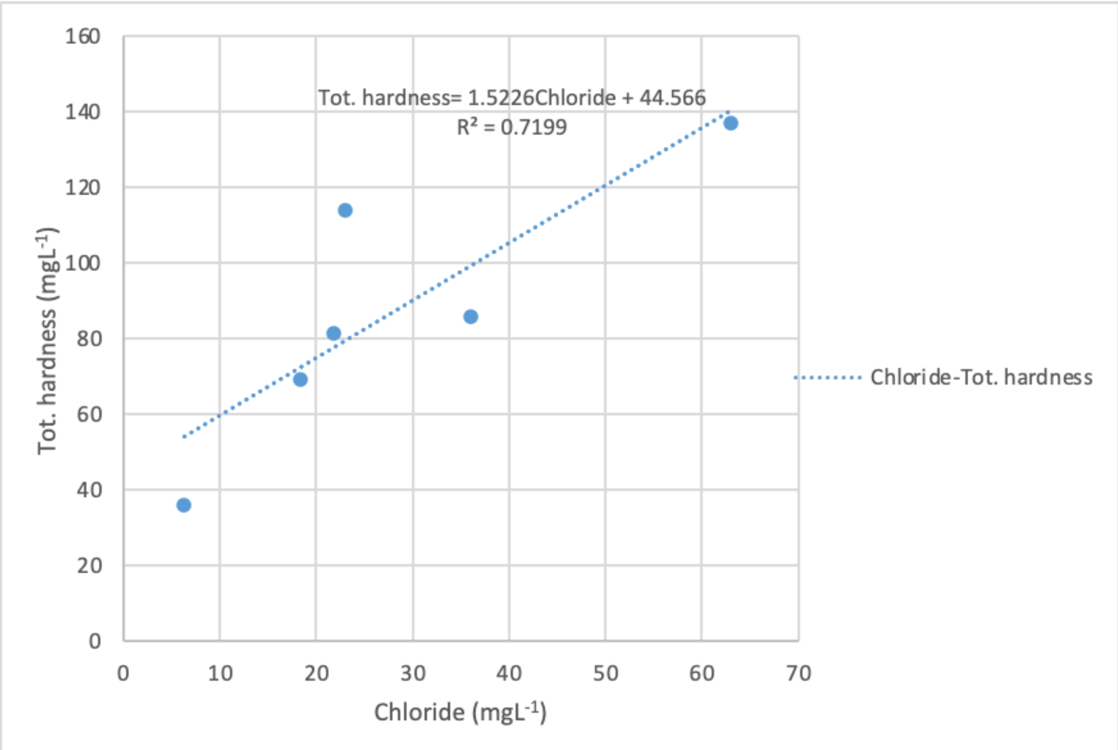


Fig. 4.16(f): Plots of water quality parameters as a linear regression model at Site 3.

The regression equation for the linear regression model [Fig. 4.16(f)] is:

Total Hardness= 1.5226 Chloride + 44.566

This depicts that as Chloride increases, Total Hardness also increases.

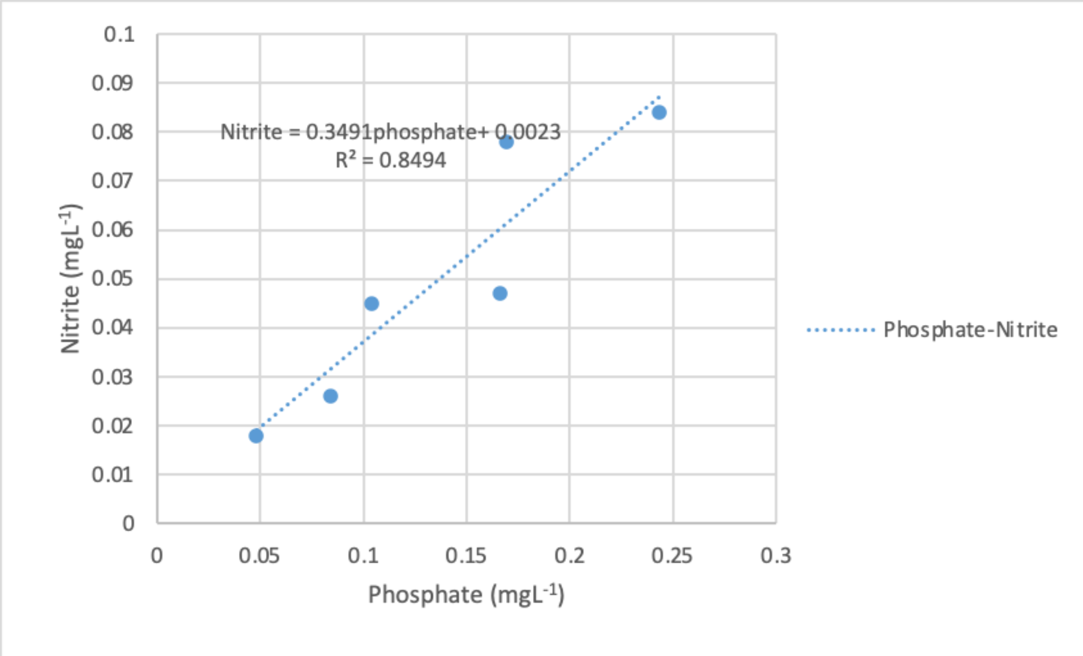


Fig. 4.16(g): Plots of water quality parameters as a linear regression model at Site 3.

The regression equation for the linear regression model [Fig. 4.16(g)] is:

Nitrite = 0.3491phosphate+ 0.0023

This depicts that as Phosphate-P increases, Nitrite also increases.

The linear regression model at Site 4 was plotted for Temperature (dependent variable) with EC and TDS (independent variables); EC (dependent variable) with TDS (independent variable); TDS (dependent variable) with pH (independent variable); Turbidity (dependent variable) with DO, BOD, Phosphate-P and Nitrite (independent variables); DO (dependent variable) with BOD, Phosphate-P and Nitrite (independent variables); BOD (dependent variable) with Phosphate-P and Nitrite (independent variables); Chloride (dependent variable) with Total Hardness (independent variable); and Phosphate-P (dependent variable) with Nitrite (independent variable). **Fig. 4.17(a) to 4.17(h).**

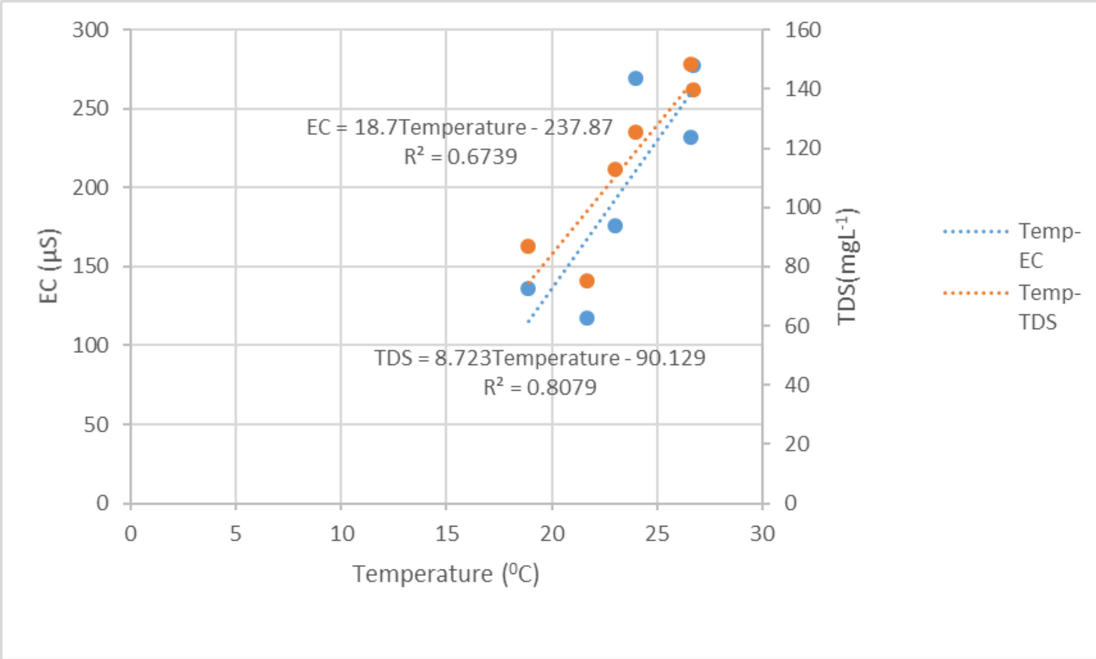


Fig. 4.17(a): Plots of water quality parameters as a linear regression model at Site 4.

The regression equations for the linear regression model [Fig. 4.17(a)] are:

TDS = 8.723Temperature - 90.129

This depicts that as Temperature increases, TDS also increases gradually.

EC = 18.7 Temperature - 237.87

This depicts that as Temperature increases, EC also increases gradually.

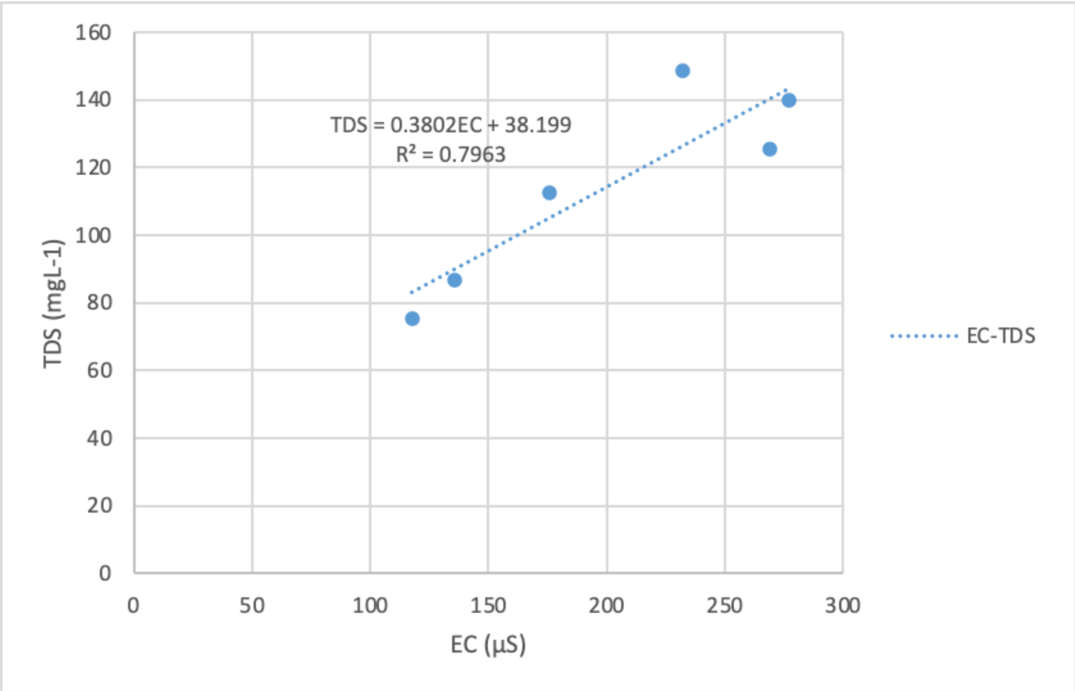


Fig. 4.17(b): Plots of water quality parameters as a linear regression model at Site 4.

The regression equation for the linear regression model [Fig. 4.17(b)] is:

TDS = 0.3802EC + 38.199

This depicts that as EC increases, TDS also increases.

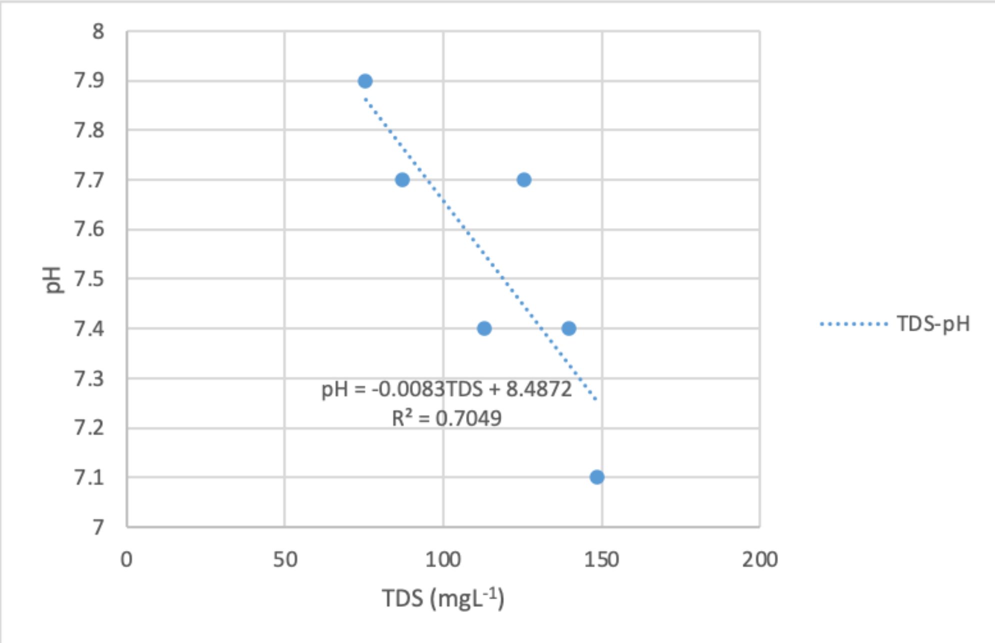


Fig. 4.17(c): Plots of water quality parameters as a linear regression model at Site 4.

The regression equation for the linear regression model [Fig. 4.17(c)] is:

pH = -0.0083TDS + 8.4872

This depicts that as TDS increases, pH decreases.

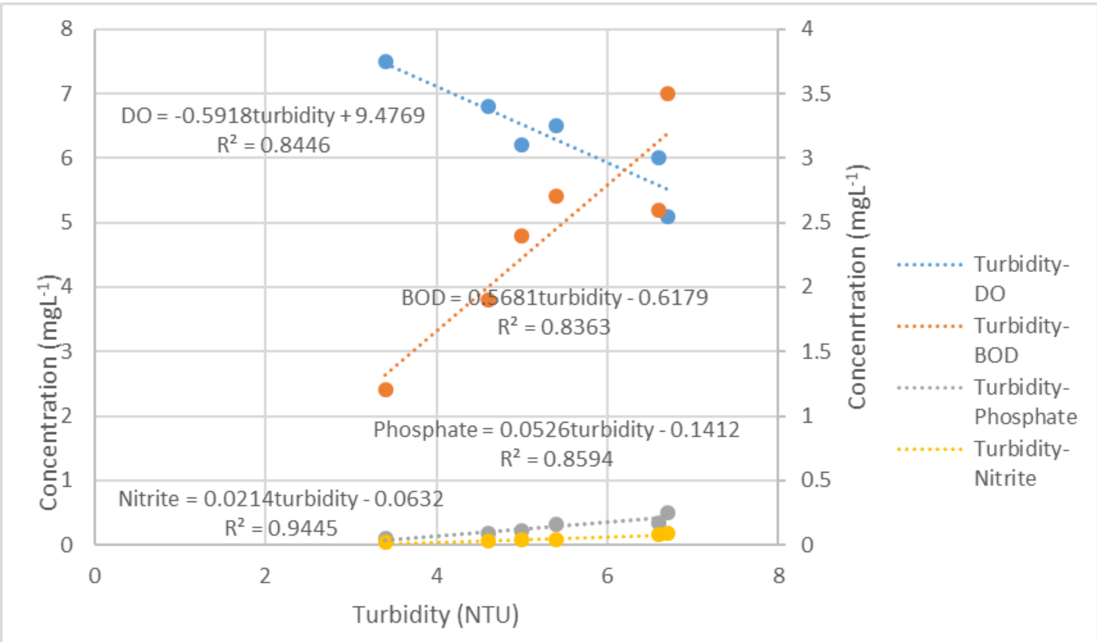


Fig. 4.17(d): Plots of water quality parameters as a linear regression model at Site 4.

The regression equations for the linear regression model [Fig. 4.17(d)] are:

DO = -0.5918 Turbidity + 9.4769

This depicts that as Turbidity increases, DO decreases.

BOD = 0.5681Turbidity - 0.6179

This depicts that as Turbidity increases, BOD also increases gradually.

Phosphate = 0.0526 Turbidity - 0.1412

This depicts that as Turbidity increases, Phosphate-P also increases gradually.

Nitrite = 0.0214 Turbidity - 0.0632

This depicts that as Turbidity increases, Nitrite also increases gradually.

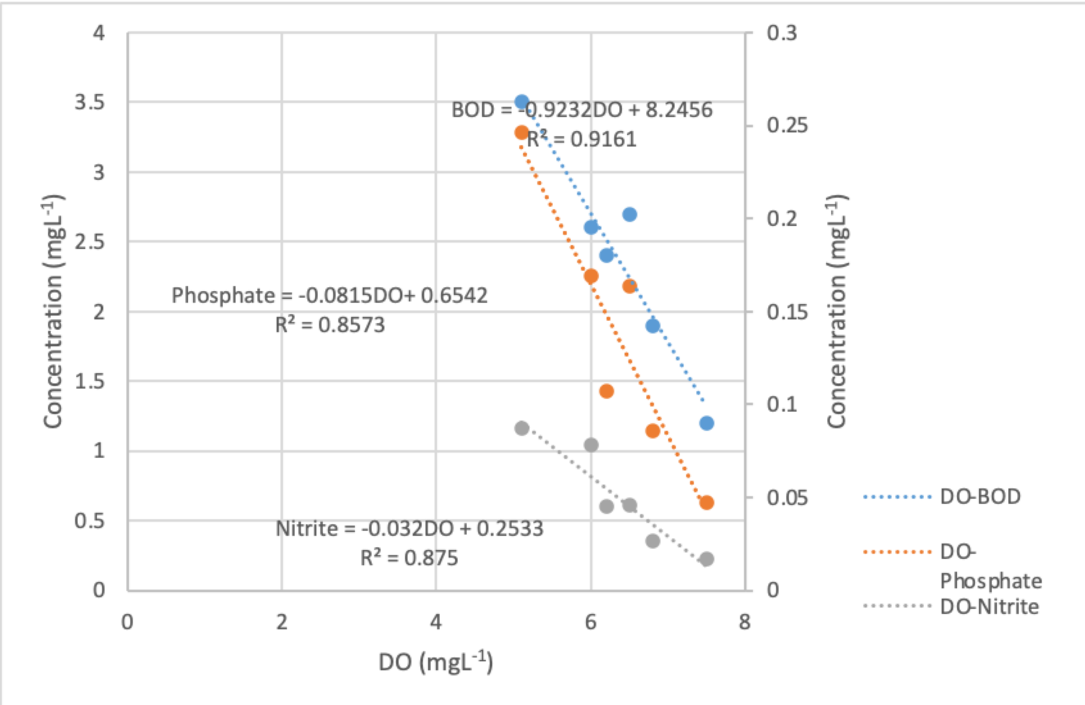


Fig. 4.17(e): Plots of water quality parameters as a linear regression model at Site 4.

The regression equations for the linear regression model [Fig. 4.17(e)] are:

BOD = -0.9232DO + 8.2456

This depicts that as DO increases, BOD decreases.

Phosphate-P = -0.0815 DO+ 0.6542

This depicts that as DO increases, Phosphate-P decreases.

Nitrite = -0.032DO + 0.2533

This depicts that as DO increases, Nitrite decreases.

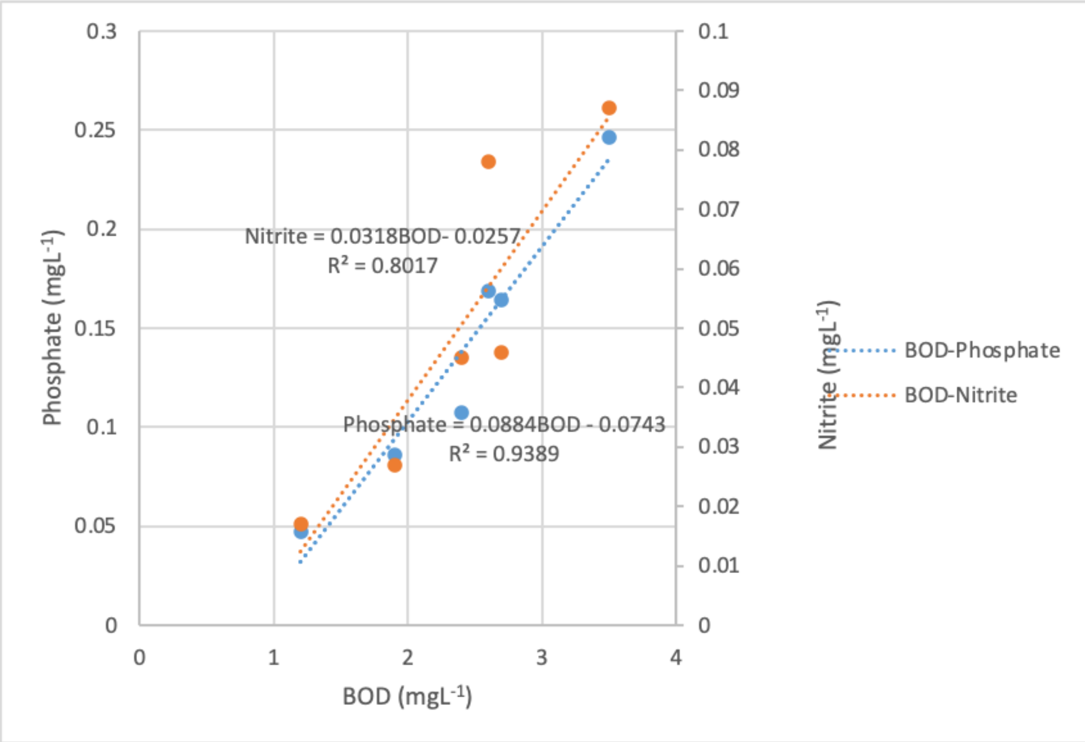


Fig. 4.17(f): Plots of water quality parameters as a linear regression model at Site 4.

The regression equations for the linear regression model [Fig. 4.17(f)] are:

Phosphate = 0.0884 BOD - 0.0743

This depicts that as BOD increases, phosphate also increases gradually.

Nitrite = 0.0318BOD- 0.0257

This depicts that as BOD increases, Nitrite also increases gradually.

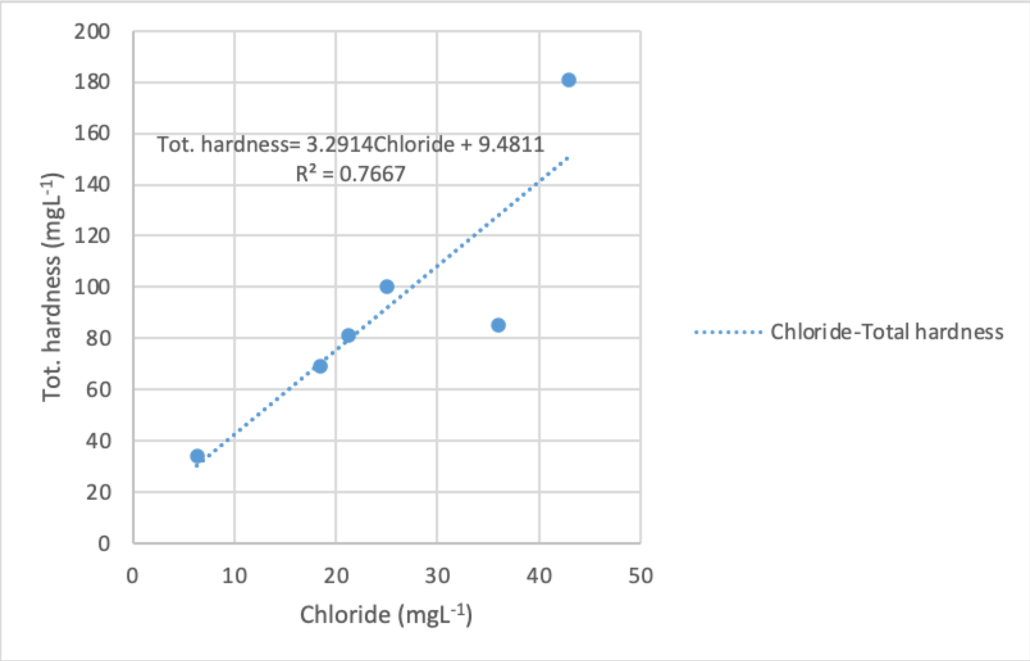


Fig. 4.17(g): Plots of water quality parameters as a linear regression model at Site 4.

The regression equation for the linear regression model [Fig. 4.17(d)] is:

Total Hardness= 3.2914 Chloride + 9.4811

This depicts that as Chloride increases, Total Hardness also increases.

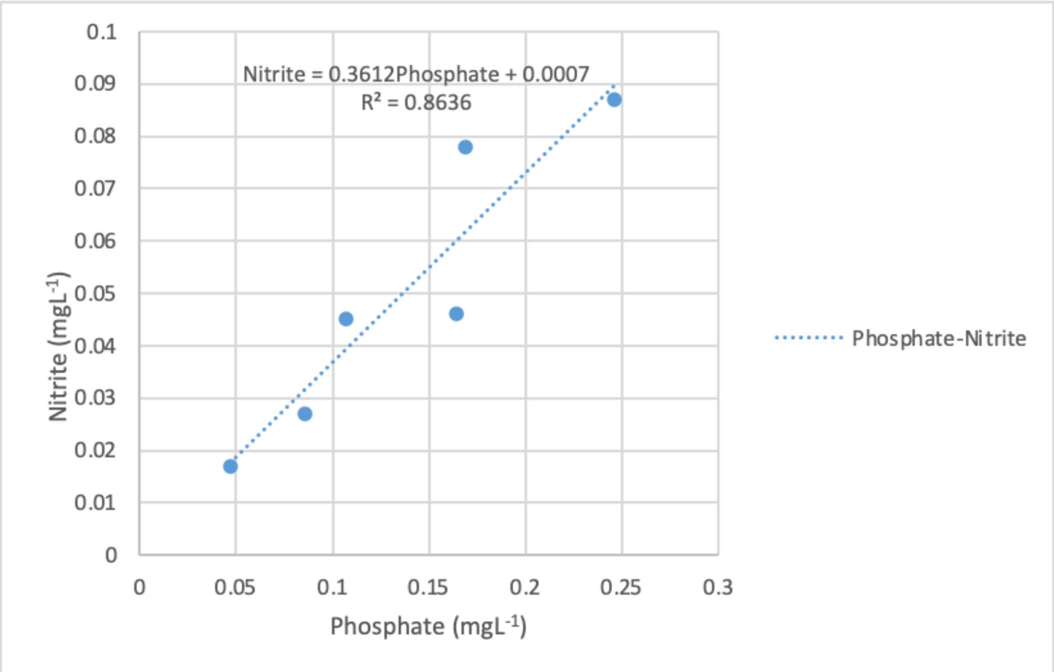


Fig. 4.17(h): Plots of water quality parameters as a linear regression model at Site 4.

The regression equation for the linear regression model [Fig. 4.17(h)] is

Nitrite = 0.3612 Phosphate-P + 0.0007

This depicts that as Phosphate-P increases, Nitrite also increases.

4.3 Water Quality Index (WQI)

The WQI of Serlui-A river was calculated to determine the impact of pollutants on the water quality and the suitability of the river water for drinking purpose. The recommending agencies, standard values and their corresponding ideal values, and k value of water quality parameters are presented in **Table 4.14**. The calculation was done following Arithmetic Index method **(Table 4.15 to Table 4.18)**.

Table 4.14: Recommending agencies, Standard values and their corresponding ideal values, and k value of water quality parameters

Sl. No	Parameters	Recommending agencies	Standard Values (S_n)	Ideal value (V_{id})	k value
1	EC	ICMR	300	0	0.094
2	TDS	ICMR/BIS	500	0	0.094
3	pH	ICMR/BIS	7.5	7	0.094
4	DO	ICMR/BIS	5	14.6	0.094
5	BOD	ICMR	5	0	0.094
6	Chloride	ICMR	250	0	0.094
7	Tot. Alkalinity	ICMR	120	0	0.094
8	Tot. hardness	ICMR/BIS	300	0	0.094
9	Phosphate	USPH	0.1	0	0.094

The WQI at Site 1 was found to be 35. The calculation reveals that the water quality of Site 1 (Reference/Control site) falls within Grade B (26-50) of the water quality classification based on weighted arithmetic WQI method as given in **Table 4.15**. It therefore, indicates that the water of Site 1 is of good quality.

The WQI at Site 2, Site 3 and Site 4 were found to be 132, 132, and 133, respectively. The calculation reveals that the water quality of Site 2, Site 3 falls within Grade E (>100) of the water quality classification based on weighted arithmetic WQI method as given in **Table 4.16, 4.17 and 4.18**.

Table 4.15: Water Quality Index (WQI) at Site 1.

Parameters	S_n	Ideal value V_{id}	k value	Weight (w_i)	Observed values(V_n)	Unit weight (W_n)	$qn=(V_n-V_{id})/(S_n-V_{id})x100$	W_nq_n
EC	300	0	0.094	5	66.683	0.00031	22.22778	0.00696
TDS	500	0	0.094	4	24.950	0.00019	4.99000	0.00094
pH	7.5	7	0.094	4	6.950	0.01253	-10.00000	-0.12533
DO	5	14.6	0.094	5	7.150	0.01880	77.60417	1.45896
BOD	5	0	0.094	5	1.650	0.01880	33.00000	0.62040
Chloride	250	0	0.094	3	1.650	0.00038	0.66000	0.00025
Tot. Alkalinity	120	0	0.094	2	65.933	0.00078	54.94444	0.04304
Tot. hardness	300	0	0.094	2	33.455	0.00031	11.15167	0.00349
Phosphate	0.1	0	0.094	2	0.035	0.94000	34.83333	32.74333
					$\Sigma W_n=0.992107$		$\Sigma W_nq_n=34.75204$	
							WQI=35.02851	

Table 4.16: Water Quality Index (WQI) at Site 2.

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values (Vn)	unit weight (Wn)	qn=(Vn-Vid)/(Sn-Vid)x100	W_nq_n
EC	300	0	0.094	5	200.355	0.00031	66.785	0.02093
TDS	500	0	0.094	4	114.250	0.00019	22.85	0.00430
pH	7.5	7	0.094	4	7.467	0.01253	93.33333	1.16978
DO	5	14.6	0.094	5	6.200	0.01880	87.5	1.64500
BOD	5	0	0.094	5	2.450	0.01880	49	0.92120
Chloride	250	0	0.094	3	2.450	0.00038	0.98	0.00037
Tot. Alkalinity	120	0	0.094	2	133.667	0.00078	111.38889	0.08725
Tot. hardness	300	0	0.094	2	80.722	0.00031	26.90722	0.00843
Phosphate	0.1	0	0.094	2	0.135	0.94	135	126.90
					$\Sigma W_n=0.992107$		$\Sigma W_nq_n=130.7573$	
							WQI=131.7975	

Table 4.17: Water Quality Index (WQI) at Site 3.

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values (V_n)	unit weight (W_n)	qn=(V_n-V_{id})/(S_n-V_{id})x100	W_nq_n
EC	300	0	0.094	5	200.167	0.00031	66.72222	0.02091
TDS	500	0	0.094	4	114.383	0.00019	22.87667	0.00430
pH	7.5	7	0.094	4	7.517	0.01253	103.33333	1.29511
DO	5	14.6	0.094	5	6.267	0.01880	86.80556	1.63194
BOD	5	0	0.094	5	2.317	0.01880	46.33333	0.87107
Chloride	250	0	0.094	3	2.317	0.00038	0.92667	0.00035
Tot. Alkalinity	120	0	0.094	2	135.992	0.00078	113.32639	0.08877
Tot. hardness	300	0	0.094	2	87.300	0.00031	29.10000	0.00912
Phosphate	0.1	0	0.094	2	0.136	0.94	135.66667	127.52667
					ΣWn=0.992107		ΣWnqn=131.4482	
							WQI=132.494	

Table 4.18: Water Quality Index (WQI) at Site 4.

Parameters	S_n	ideal value V_{id}	k value	weight (w_i)	observed values	unit weight (W_n)	q_n=(V_n-V_{id})/(S_n-V_{id})x100	W_nq_n
EC	300	0	0.094	5	201.267	0.00031	67.08889	0.02102
TDS	500	0	0.094	4	114.717	0.00019	22.94333	0.00431
pH	7.5	7	0.094	4	7.600	0.01253	120.00000	1.50400
DO	5	14.6	0.094	5	6.350	0.01880	85.93750	1.61563
BOD	5	0	0.094	5	2.300	0.01880	46.00000	0.86480
Chloride	250	0	0.094	3	2.300	0.00038	0.92000	0.00035
Tot. Alkalinity	120	0	0.094	2	129.100	0.00078	107.58333	0.08427
Tot. hardness	300	0	0.094	2	91.767	0.00031	30.58889	0.00958
Phosphate	0.1	0	0.094	1	0.137	0.94	136.50000	128.31000
					ΣWn=0.992107		ΣWnqn=132.414	
							WQI=133.4674	

Based on Water Quality Index analysis, it can be argued that the water is unfit for direct use at Site 2, Site 3 and Site 4. However, Site 1 possessed good water quality which can be recommended for use. **Table 4.19.**

Table 4.19: Status of Water at Selected Study Sites based on Water Quality Index (WQI).

Grade	WQI	Status	Serlui-A grade
A	0-25	Excellent water quality	
B	26-50	Good water quality	Site 1
C	51-75	Poor water quality	
D	76-100	Very poor water quality	
E	>100	Unsuitable for drinking	Site 2,3 and 4

4.4 Distribution of Macrophytes

All together a total of 17 macrophytes were reported from the study sites. The study Site 1 was represented by 6 species namely *Ageratum conyzoides, Colocasia affinis, Commelina benghalensis, Juncus effuses, Murdannia nudiflora,* and *Polygonum barbatum.* However, Site 2, 3 and 4 by 15 species each namely *Ageratum conyzoides, Alternanthera sessilis, Canna indica, Colocasia affinis, Cynodon dactylon, Cyperus scariosus, Dichrocephala integrifolia, Drymaria cordata, Echinochloa stagmina, Eichhornia crassipes, Murdannia nudiflora, Pistia stratoise Polygonum barbatum, Polygonum hydropiper and Pteridium aquilinum. Commelina benghalensis* and *Juncus effuses* were present only at Site 1. Four species namely *Ageratum conyzoides, Colocasia affinis, Murdannia nudiflora* and *Polygonum barbatum* were found at all study Sites. The species present at Site 1 (Control Site) only, may be regarded as pollution sensitive species and referred to as pollution indicator, as they are unable to survive in polluted water at other sites. **Table 4.20.**

Table 4.20: Distribution of macrophytes at selected study sites.

S. No.	Scientific names	Family	Life form	Site 1	Site 2	Site 3	Site 4
1	*Ageratum conyzoides* L.	Asteraceae	Emergent	+	+	+	+
2	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	Emergent	-	+	+	+
3	*Canna indica* L.	Cannaceae	Emergent	-	+	+	+
4	*Colocasia affinis* Schott.	Araceae	Emergent	+	+	+	+
5	*Commelina benghalensis* Linn.	Commelinaceae	Emergent	+	-	-	-
6	*Cynodon dactylon* (L.)Pers	Poaceae	Emergent	-	+	+	+
7	*Cyperus scariosus* R.BR.	Cyperaceae	Emergent	-	+	+	+
8	*Dichrocephala integrifolia* (L.f)Kuntze	Asteraceae	Emergent	-	+	+	+
9	*Drymaria cordata* Linn.	Caryophyllaceae	Emergent	-	+	+	+
10	*Echinochloa stagmina* (Retz.) P. Beauv.	Poaceae	Emergent	-	+	+	+
11	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Free floating	-	+	+	+
12	*Juncus effuses* L.	Juncaceae	Emergent	+	-	-	-
13	*Murdannia nudiflora* (L.) Brenan.	Araceae	Emergent	+	+	+	+
14	*Pistia stratoise* Linn.	Araceae	Free floating	-	+	+-	+
15	*Polygonum barbatum* L.	Plygonaceae	Emergent	+	+	+	+
16	*Polygonum hydropiper* L.	Polygonaceae	Emergent	-	+	+	+
17	*Pteridium aquilinum* (L.) Kuhn	Polypodiaceae	Emergent	-	+	+	+

Abbreviations: +, Present and -, Absent.

s

CHAPTER- 5

DISCUSSION

5.1 Impacts of Pollutants on Water Quality Characteristics

Water pollution is the contamination of water by foreign matter such as microorganisms, chemicals, industrial or other wastes, or sewage that deteriorate the quality of the water and renders it unfit for its intended uses.

Water quality deals with the physical, chemical and biological characteristics in relation to all other hydrological properties. The physico-chemical and biological characteristics of water determine the health of an aquatic ecosystem (Venkatesharaju *et al*., 2010). The major concerns in terms of water quantity and quality are unequal distribution of water on the surface of the earth and fast declining availability of useable fresh water (Boyd and Tucker, 1998).

The river water quality is of paramount importance as river water is generally used for drinking domestic and residential water supplies, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water (Venkatramanan *et al*., 2014).

The first criterion for drinking water was reported in the year 1921 when the United States published USPH standard for drinking water, which specify only bacteriological parameters. Since then, various scientific agencies like World Health Organization (WHO, 2008), Bureau of Indian Standards (BIS, 2003), United State Public Health (USPH, 1962), Indian Council of Medical Research (ICMR, 1996) have established water quality standards for different parameters. The water quality standards for potable water given by various scientific agencies are presented in **Table 5.1.**

Table 5.1: Water quality standards for different physico chemical parameters and range of values in present investigation.

Parameter	Water Quality Standards				Water quality range during present investigation
	BIS	ICMR	USPH	WHO	
Temperature (^{0}C)	-	-	-	-	16.7-26.7
EC (µS)	-	-	300	-	23-277.2
TDS (mgL^{-1})	-	500-1500	-	500	24.7-148.5
Turbidity (NTU)	10	-	-	-	2.3-5
pH (nano mole L^{-1})	6.5-8.5	7-8.5	6.5-8.5	6.5-8.5	6.1-7.9
DO (mgL^{-1})	>5	-	>4	-	5-7.9
BOD (mgL^{-1})	<3	-	-	-	1.1-3.8
Chloride(mgL^{-1} $CaCO_3$)	250	120	250	200	1.3-44
Total Alkalinity (mgL^{-1} $CaCO_3$)	200	120	-	-	25.6-200
Acidity(mgL^{-1} $CaCO_3$)	-	-	-	-	3.4-9
Total hardness (mgL^{-1} $CaCO_3$)	-	300	500	-	18-141
Phosphate-P (mgL^{-1})	-	-	0.1	-	0.005-0.246
Nitrite-N (mgL^{-1})					0.008-0.087

-, Value not available.

5.1.1 Temperature

Water is an important factor which has a profound influence on the biochemical, chemical and biological characteristic of the aquatic system and is known to influence the pH, alkalinity and DO concentration in water (Kumar *et al.*, 2010). Temperature a direct effect on aquatic life because it reduces the dissolved oxygen (DO) concentration in the water, thus making oxygen less available for respiration (Firozia and Sanalkumar, 2013). The variation of water temperature usually depends on the season, geographic location, ambient air temperature and chemical reaction in water body (Ahipathi and Puttaiah, 2006). The temperature in aquatic ecosystem rarely exceeds 37˚C (Warren, 1971).

The temperature was found to be high in Monsoon season for both the years. This may be due to the discharge of organic matters through surface runoff and subsequently the release of catabolic energy in the form of heat due to microbial decomposition resulting in the increase of water temperature. The control site (Site 1) possessed lower temperature as compared to the other sites for all the seasons. Similar findings were made by Mishra and Tripathi (2000, 2001 and 2003), Zafar and Sultana (2008), Singh and Gupta (2010 a), Lalparmawii (2012), Khatoon *et al.*, (2013), Mishra and Premeshowr (2014),) Sunar and Mishra (2016) and Karmakar and Biswas (2016).

5.1.2 Electrical Conductivity

Electrical conductivity (EC) is a measure of the capacity of an aqueous solution to carry an electric current, and is dependent on the concentration of ions and nutrients load such as chloride, nitrate, phosphate, and sulphate. EC is an excellent indicator of TDS, which measures the salinity which affects the taste of potable water. EC increases with increase in TDS. Higher the value of TDS in water, greater is the amount of ions (Bhatt *et al.*, 1999). Conductivity in water is primarily determined by the presence and levels of concentration of sodium and magnesium ions and to some degree calcium ions. These ions help lessen the effect of bicarbonate and carbonate ions and thus maintain the pH (Ikhuoriah and Oronsaye, 2016).

EC values was found to be high during Monsoon season and low during Post-Monsoon season. Increased EC content during rainy season may be due to the high concentration of dissolved solids, decomposition and mineralization of organic matters while lower value during post-monsoon season may be attributed to the presence of low inorganic material followed by low ionic state. The control site possessed lower value as compared to all the other sites. The values fall within the permissible limit given by USPH. Similar trend of observations was made by Mishra and Tripathi (2000, 2001, 2003), Drusilla *et al.,* (2005), Singh *et al.,* (2010 b), Yadav and Srivastava (2011) and Khatoon *et al.,* (2013).

5.1.3 Total Dissolved Solids

TDS is the measure of impurities of water in a dissolved state. Increase in TDS content indicates pollution by extraneous sources (Kataria *et al.*, 1996). The high amount of dissolved, suspended and total solids in water samples adversely affects the quality of running water and makes it unsuitable for irrigation and drinking purposes. The TDS content in water vary from season to season and affects the density of water and thereby the quality of water (Imtiyaz *et al.*, 2012). The high concentration of TDS leads to an increase in the nutrient status of water, resulting in eutrophication of aquatic bodies (Singh and Mathur, 2005).

The TDS value was found to be higher during Monsoon season and lower during Post-monsoon season. Higher values during rainy season may be due to runoff of materials from the catchment areas and erosion of the river bank. The values during the assessment period lie within the prescribed limit given by ICMR and WHO. Similar trend of result were observed by Tiwari (2005), Singh *et al.,* (2010 b), Imtiyaz *et al.,* (2012), Das *et al.,* (2014), Singh and Sharma (2016), Pawar and Shendge (2016) and Rout *et al.,* (2016).

5.1.4 Turbidity

Turbidity of water influences the light penetration inside water and thus affect the aquatic life. Turbidity showed an inverse relationship with light penetration i.e., when turbidity is low, light penetration is high and vice versa. It is mainly due to the presence of suspended solids, organic colloidal substances and coarse dispersion of sewage (Kataria, 1995). Increase in water turbidity can be attributed to soil erosion caused by heavy rain that brought sand, silt and other organic debris from the surrounding mountains (Eyarin Jehamalar *et al.*, 2010; Munshi *et al.*, 1991).

The turbidity of water was found to be higher during Monsoon season. Monsoon season shows higher turbidity values due runoffs as it carries many particles like sand, clay silts, agricultural runoffs etc. The values at all sites during all the seasons during the study period fall within the permissible limit given by BIS. Similar results were found by Joshi *et al.*, (2009), Trivedi *et al.,* (2010), Gangwar *et al.,* (2012), Singh *et al.,* (2012), Thasangzuala and Mishra (2014), Sunar (2018) and Padmaja, (2019).

5.1.5 pH

pH range measures the presence of hydrogen ion concentration. The pH of water is of great practical importance as most of the chemical and biochemical reaction are influenced by it. Most of the acids have an adverse effect below pH 5 and alkalis above the pH 9.5 (Abed and Jazie, 2014) while a greater toxicity is observed in acidic water than in alkaline water (Singh *et al.*, 1989). Since most of the metabolic activities aquatic organisms are pH dependent, it affects the chemical and biological processes of aquatic ecosystems like growth of aquatic biota especially fish population (Jehangir *et al.*, 2011).

pH value was found to be higher during Post-monsoon season and lower during monsoon season. Low pH may be due to atmospheric dissolution leading to high concentration of carbon dioxide (Neal *et al.*, 1998). The pH range between 6.7 and 8.4 is considered to be safe for aquatic life to maintain productivity (Krishnaram *et al.,* 2007). During the assessment period the range of pH was 6.1 to 7.9. The water was found to be slightly acidic in Site 1 during the year 2017-2018 and this can be attributed to the deposition of acid forming substances and high organic content which results into decrease in pH because of the carbonate chemistry (Fella *et al.*, 2013). Similar results were observed by Bhanja and Patra (2000), Mishra and Tripathi (2000,2001, 2003), Prasannakumari *et al.,* (2003), Gandotra *et al.,* (2008), Suresh *et al.,* (2011), Khatoon *et al.,* (2013) and Selakoti and Rao (2015).

5.1.6 Dissolved Oxygen

DO content plays an important role in supporting aquatic life and is sensitive to slight environment changes. High community respiration results in oxygen depletion and hence DO has been extensively used as a parameter to define water quality and to evaluate the degree of freshness of a river (Fakayode, 2005). Photosynthesis, chemical oxidation, exchange of oxygen between water and atmosphere and respiration of plants and bacteria in water are among the numerous factors that alter the DO content of water. (Rawson, 1937). DO content in water is directly or indirectly dependent on water temperature, partial pressure of air etc. (Chaurasia and Pandey, 2007).

The DO content was found to be high during Post-monsoon season and lower during Monsoon season for both the years. Higher value of DO during Post-monsoon season may be due to its greater solubility, reduced microbial decomposition of dead organic matter and low organism respiratory demand at low temperature and increased progressive growth of submerged macrophytes while lower oxygen content during monsoon season may be due to low water, high temperature and decay of macrovegetation. The value of DO during the study period range from 5 mgL^{-1} and 7.9mg L^{-1} and was found to be within the permissible limit given by different scientific agencies. Mishra and Tripathi (2001, 2003), Jitendra *et al.,* (2008), Srivastava *et al.,* (2009), Yadav and Srivastava (2011), and Rios- Villamizar *et al.*, (2017) made similar observation.

5.1.7 Biological Oxygen Demand

Biological Oxygen Demand (BOD) is an important parameter of surface water quality which indicates the level of organic matter contamination in surface water (Kumari and Chaurasia, 2015). Biological Oxygen Demand (BOD) indicates the level of organic matter contamination in surface water (Metclaf and Eddy, 2003). Low BOD content indicates good quality water, while a high BOD indicates polluted water. As the oxygen available in the water get consumed by the bacteria, BOD level increase and DO level decrease (Agarwal and Rozgar, 2010).

BOD was found to be higher during monsoon and lower during post-monsoon season. Increased BOD content during monsoon season might be due to addition of more organic matter from surface runoff which leads to acidification of water due to increase in microbial activities at elevated temperature while lower values during post-monsoon season may be due to low decomposition rate of organic matter. All the values during the study period except at Site 2 during Monsoon season (2016-2017), all lie within the acceptable range. The high value of BOD at Site 2 during Monsoon season (2016-2017) may be due to more inflow of domestic waste and sewage. Similar trend was observed by Mishra and Tripathi (2000, 2001), Lalparmawii and Mishra (2001), Rajiv *et al* (2012) and Sunar and Mishra (2016).

5.1.8 Chloride

Chloride occurs naturally in all types of aquatic water bodies and is soluble in water and moves freely with water through soil and rocks. Chloride in aquatic bodies are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). Chloride content in water may increase due to decomposition of organic matter. The greater source of chlorides in water bodies is disposal of sewage and industrial waste (Sirsath *et al*., 2006) and the human body release very high quantity through urine and feces.

The chloride content in water was found to be high during Pre-Monsoon season and low during Monsoon season. Low values during Monsoon season may be due to dilution by rainwater and higher values during pre-monsoon season may be attributed to the release of municipal and agricultural waste. The control site possessed lower values for all the seasons. All the values during the assessment period all lie within the prescribed limit as given by different scientific agencies. Mishra and Tripathi (2000, 2001, 2003), Yadav and Srivastava (2011), Hafizurrahman *et al.,* (2016) and Rout *et al.,* (2016) reported similar trend of result.

5.1.9 Total Alkalinity

Alkalinity is a measure of the concentration of such ions in water that would react to neutralize hydrogen ions and is also regarded as a measure of productivity of natural waters (Erondu and Chindah, 1991) and it reflects carbonate, hydroxide content, phosphates, sulphates, nitrates of surface water (Shinde *et al.,* 2011). Total alkalinity of water is primarily caused by the carbonate and bicarbonate ions (Singh *et al,* 2010). Schaeperclaus (1990) categorized the aquatic systems into three major categories based on alkalinity values.

Water Quality	**Total Alkalinity values ($mgL^{-1}CaCO_3$)**
Less Productive	0-15
Medium Productive	15-100
Highly Productive	100-250

Alkalinity was reported to be lower during Monsoon season and higher during Post-monsoon season. During rainy season low values of alkalinity was possibly due to dilution of river water with rain-water (Yadav and Srivastava, 2011). Higher values during Post-monsoon season may be attributed to the release of CO_2 during decomposition. The CO_2 thus released reacts with water to form bicarbonate which is limited to low level of water. On the basis of the above classification, the water quality falls under medium productive at Site 1 during Pre-monsoon season (2016-2017), Site 1,2,3 and 4 during Monsoon season (2016-2017) and Site 1 for all seasons (2017-2018) while Site 2, 3 and 4 during Pre-monsoon season (2016-2017), Site 1,2,3 and 4 during Post-monsoon season (2016-2017), Site 2,3 and 4 for all the seasons (2017-2018) fall under highly productive category. All the values during the study period are within the prescribed values given by scientific agencies. Similar trend of observations was also reported by Mishra and Tripathi (2000, 2001, 2003), Ayoade *et al.,* (2009), Gangwar *et al.,* (2012), Khatoon *et al.,* (2013) and Selakoti and Rao (2015).

5.1.10 Acidity

Acidity of water is its quantitative capacity to react with a strong base to a designated pH. Acid influences the rate of chemical reactions, chemical speciation and biological activities. It also contributes to corrosiveness. The major component which contributes to acidity in natural waters is CO_2. Factors like uncombined CO_2**,** organic acids and salts of strong and weak bases are also responsible for acidity of water (Mishra, 2009). Acidity of water is of two types namely mineral acidity which has a designated pH<4 and CO_2 which has a designated pH of 8.5 (due to dissolution of CO_2 in water and algal photosynthesis).

Acidity was found to be higher during Monsoon season and lower during Pre-monsoon season. CO_2 from rainwater as well as high bacterial oxidation with heavier influx of organic matters from leaching of domestic sewage may lead to high acidity values while lower acidity values may be due to low rainfall and less organic loads. The control site possessed higher values as compared to other sites for all the seasons. This may be due to more inflow of organic substances containing humic acid from catchment areas. Singh *et al.,* (2010 b), Venkatesharaju *et al.,* (2010), Lalchhingpuii (2011) and Lalparmawii (2012) also reported similar trend of results.

5.1.11 Total hardness

Total hardness can be defined as the sum of calcium and magnesium concentrations expressed as $CaCO_3$. The hardness of water indicates water quality mainly in terms of Ca^{2+} and Mg^{2+} but is not a pollution indicator parameter. Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solution (Kalra *et al*., 2012). Temporary hardness is due to the presence of bicarbonates of Ca and Mg salts present in the water where as permanent hardness is due to the presence of chlorides and sulfates of Ca and Mg ions.

Sawyer (1960) and Saravanakumar and Kumar (2011) have classified water on the basis of hardness values into four types as follows:

Water Quality	**Total hardness value (mgL^{-1} $CaCO_3$)**
Soft	0 to <75
Moderately hard	75 to <150
Hard	150 to <300
Very hard	300 and above

On the basis of the above classification, the water quality falls under soft and moderately hard. The water quality in Site 1 during all seasons for both years as well as Site 2, 3 and 4 during monsoon season (2016-2017) and Post-monsoon season (2017-2018) falls under soft. The water quality in Site 2, 3 and 4 during Post-monsoon season (2016-2017), Pre-monsoon season for both the years and monsoon season (2017-2018) falls under moderately hard. Total hardness value was found to be higher during Pre-monsoon season as compared to Monsoon and Post-monsoon season. High value during the pre-monsoon season may be due to evaporation of water, addition of calcium and magnesium salt from inflow of sewage as well as soaps and detergents used for washing and bathing whereas excessive dilution by rainwater during the monsoon can be one of the important factors responsible for lowering the hardness during monsoon (Bozniak *et al.*, 1968; Chhetry and Pal, 2012). The control site possessed lower values than all the other sites during different seasons which may be due to least anthropogenic activity. The values during assessment period all lies within the prescribed limit as given by different scientific agencies. Similar trend of result was reported by Mishra and Tripathi (2000, 2001, 2003), Singh and Gupta (2010 a), Yadav and Srivastava (2011) and Hafizurrahman *et al.*, (2016).

5.1.12 Phosphate-P

Phosphorus is one of the limiting nutrients for floral growth in freshwater bodies which regulate the phytoplankton production (Sharma *et al*, 2004). The high concentration of phosphate in the rivers leads to eutrophication and depletion of dissolved oxygen concentrations (Davie, 2003). The major sources of Phosphate in water are domestic sewage, agricultural runoff, industrial effluents and fertilizers (Koshy and Nayar, 2000).

Phosphate-P content was found to be high during Monsoon season and lower during Pre-monsoon and Post-monsoon season. Increase in phosphorous contents during rainy season might be possibly due to inflow of water, rich in colloidal clay particles containing various salts from extraneous sources. Phosphate-P values recorded were higher at Site 2, 3 and 4 during all seasons than the permissible limit as given by USPH. High phosphate-P content may be due to agricultural run-off containing phosphate fertilizers caused by heavy rain and inflow of sewage waste. Similar trend of result was also observed by Sah *et al.,* (2000), Singh *et al.,* (2010 b), Lalzahawmi and Mishra (2016) and Singh and Sharma (2016).

5.1.13 Nitrite-Nitrogen

The determination of the levels of nitrite as nitrogen in surface waters is usually an important part of basic water quality assessment as its concentration is a general indicator of the nutrient status and the degree of organic pollution of the affected water body (Fadiran and Mumba, 2005)

The value of nitrite was found to be higher during monsoon season. This could be due to variation in phytoplankton excretion, oxidation of ammonia and reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007) and also due to denitrification and air-sea interaction exchange of chemicals (Rajasegar, 2003). Similar trend of result was also observed by Prabu *et al.,* (2008), Manikannan *et al* (2011) and Fatema *et al.,* (2014).

The water quality parameters namely, temperature, EC, TDS, turbidity, DO, BOD, pH, total hardness, total alkalinity, chloride, phosphate and nitrite all lie within the permissible limit as given by different scientific agencies except phosphate values for Site 2, Site 3 and Site 4 during all the seasons. Higher values of phosphate at these sites may be due to agricultural runoff that contains phosphate fertilizers. The control site possessed much lower values than other sites may be due to the lower anthropogenic activity at the site.

5.2 Water quality index

WQIs are particularly useful tools for the qualitative assessment of aquatic bodies as they provide the opportunity to evaluate existing quality conditions by classifying water bodies into certain quality categories such as excellent, good, poor, very poor or unsuitable for drinking (Ishaku *et al.*, 2012; Omonona *et al.,* 2014; Igwe and Idris, 2019).

The water quality attributes and WQI depict that the river water at Site 1 (Control/Reference Site) is clean, and intensity of pollutants is increased from upstream to downstream of river (Site 2 to 4)

The WQI calculated for Site 2, 3 and 4 showed that the water is unsuitable for drinking while site 1 is of good water quality. The WQI calculated for Serlui-A river exhibits poor quality of water at Site 2, site 3 and Site 4 when compared to Site 1 indicating the negative impact of pollutants on the water quality. Similar trend of result was also observed by Sangeeta (2018). The high WQI for site 2, 3 and 4 might be due to increase value of EC, TDS, chloride, TA, hardness, phosphate and nitrite at site 2, 3 and 4 as compared to site 1.

WQI allows for a general analysis of water quality on many levels that affect a stream's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water (Akkaraboyina and Raju, 2012).

The completed WQI indicates that the water quality at Site 2, 3 and 4 is poor and not totally safe for human consumption due higher value of EC, TDS, chloride, TA, hardness, phosphate and nitrite at site 2, 3 and 4 as compared to site 1. So, proper treatment is highly needed for low risk of immediate or long-term harm.

5.3 Impacts of Pollutants on Distribution of Macrophytes

The variability of macrophytic vegetation in rivers is associated with several factors like water depth and flow velocity; distance from source, river connectivity, catchment area; and water conductivity and nutrients (Hrivnak *et al.*, 2007). Swierk and Krzyzaniak (2019) showed that a statistically significant positive correlation between air temperature and macrophyte growth concerns only a few species: *Juncus effusus* L., *Lycopus europaeus* L., *Polygonum hydropiper* L., *Glyceria fluitans* (L.) R. Br., and *Rumex palustris* Sm.

In the present study, maximum number of emergent macrophytes were observed and this can be attributed to the high tolerance to any fluctuation in the water level (Van der Valk and Davis, 1976). Site 1(Control/Reference Site) was represented by 8 species namely *Ageratum conyzoides*, *Colocasia affinis*, *Commelina benghalensis*, *Juncus effuses*, *Murdannia nudiflora,* and *Polygonum barbatum.* It can be argued that there is no effect of pollutants on distribution of such species. *Commelina benghalensis* and *Juncus effuses* were restricted to Site 1 (Control site) only and may be considered as pollution indicator species. They can be regarded as bio-indicator of pollution as they are found in clear and highly oxygenated water. On the other hand, species such as *Ageratum conyzoides, Alternanthera sessilis, Canna indica, Colocasia affinis, Cynodon dactylon, Cyperus scariosus*, *Dichrocephala integrigolia*, *Drymaria cordata*, *Eichhornia crassipes, Pistia stratiotes, Polygonum barbatum*, *Polygonum hydropiper* and *Pteridium aquilinum*, were found in Site 2, 3 and 4 and may be considered as tolerant to pollution stress and these species grow well in polluted water. *Ageratum conyzoides*, *Colocasia affinis, Murdannia nudiflora* and *Polygonum barbatum* were found at all study Sites, indicating high ecological amplitude towards pollution. *Eichhornia crassipes*, *Pistia stratiotes*, *Lemna perpusilla*, *Azolla pinnata*, and *Amaranthus spinosus* are indicative of organic enrichment and hence may be considered as indicators of organic pollution (Kshirsagar and Gunale, 2013). The presence of *Alternanthera sessilis*, *Eichhornia crassipes* and *Pistia stratiotes* at site 2, 3 and 4 may be due to due to the accumulation of sewage containing more organic load. *Pistia stratiotes* has a high growth rate and adaptive capacity to a wide range of pH and temperature due to which it is considered as a good phytoremediator (Galal and Farhat, 2015).

CHAPTER-6

SUMMARY AND CONCLUSIONS

Water is an essential requirement for the life supporting activities. Surface water generally available in Rivers, Lakes, Ponds and Dams is used for drinking, irrigation and power supply etc. A majority of developing countries are in the tropical zone and have fast growing human population. There is constant increase in the demand of food, fuel, fiber, medicine and constructions due to increasing population which results in the exploitation of natural resources. Surface water quality in various areas is largely affected by both natural process and anthropogenic activities like domestic sewage, industrial pollution, and agricultural activities (Varol *et al*., 2011). The rivers in India are polluted due to the discharge of untreated sewage and industrial effluents. The growing problem of degradation of our river ecosystem has necessitated the Monitoring of water quality of various rivers all over the country has become necessary to evaluate their production capacity, utility potential and to plan restorative measures due to the growing problem of degradation of Indian river ecosystem. Water quality parameters provide the basis of considering the suitability of water for its designated uses and to improve existing conditions. The present study was taken up with the following objectives:

1. To study the water quality of Serlui-A river at selected sites.
2. To study distribution of aquatic macrophytes along Serlui-A river at selected sites.
3. To assess impact of pollutants on water quality and distribution of aquatic macrophytes in Serlui-A river.

For detailed study, four sampling sites of Serlui-A river were selected namely, Site 1 (situated near the source in Lungleng village, and considered as control/reference site to compare results from other sites selected towards downstream of river), Site 2 (situated just before hydroelectric power station), Site 3 (situated just after hydroelectric power station) and Site 4 (situated at the point where Serlui-A river merges with river Tlawng).

During the study period, water samples were collected on a monthly basis for two consecutive years (October 2016- September 2018). The water samples were then analysed for various physico-chemical characteristics namely, temperature, EC, turbidity, TDS, pH, DO, BOD, total alkalinity, acidity, total hardness, chloride, phosphate and nitrite. The methods as outlined in the 'Standard Methods for Examination of Water and Wastewater' (APHA, 2005) and 'Handbook of Methods in Environmental Studies, Water and Waste Water Analysis (Maiti, 2001) were followed. The observations were computed and expressed seasonally i.e., Post-monsoon (October-January), Pre-Monsoon (February-May) and Monsoon (June-September) seasons. To check the validity and significance of the observed data, analysis of variance (ANOVA) and correlation coefficient was carried out.

The findings of the present study on water quality and impacts of pollutants can be summarized as follows:

1. The temperature ranged from 16.7^0C (Site 1, Post-Monsoon season) to 26.7^0C (Site 4, Monsoon season). The values were found to be high in Monsoon season and low during Post-monsoon season for both the years.
2. The electrical conductivity ranged from 23 µS (Site 1, Post-Monsoon Season) to 277.2 µS (Site 4, Monsoon season). The values found to be high in Monsoon season and low during Post-monsoon season for both the years
3. The total dissolved solids ranged from 14.7 mgL^{-1} (Site 1, Post-monsoon season) to 148.5 mgL^{-1} (Site 4, Monsoon season). The values were found to be low during Post-monsoon season and high during Monsoon season.
4. The turbidity as 2.3 NTU (Site 1, Post-monsoon season) to 6.7 NTU (Site 2 & 3, Monsoon season). The values were found to be lowest during Post-monsoon season and highest during Monsoon season.
5. The pH ranged from 6.1 (Site 1, Monsoon) to 7.9 (Site 3 & 4, Post-monsoon season). The values were found to be lower during monsoon season and higher during Post-monsoon season.

6. The DO ranged from 5 mgL^{-1} (Site 3, Monsoon season) to 7.9 mgL^{-1} (Site 1, Post-monsoon season). The values were found to be high in Post monsoon season and low during Monsoon season for both the years.
7. The BOD ranged from 1.1 mgL^{-1} (Site 1, Post- monsoon season) to 3.8 mgL^{-1} (Site 2, Monsoon season). The values were found to be high during Monsoon season and low during Post-monsoon season.
8. The chloride ranged from 1.33 $mgL\text{-}^{1}$ (Site 1, Monsoon season) to 44 mgL^{-1} (Site 3, Pre-monsoon season). The values were found to be lowest during monsoon season and highest during pre-monsoon season.
9. The total alkalinity ranged from 25.6 mg L^{-1} $CaCO_3$ (Site 1, Monsoon season) to 200 mg L^{-1} $CaCO_3$ (Site 2, Post-monsoon season). The values were found to be lowest during monsoon season and highest during the post-monsoon season.
10. The acidity ranged from 3.4 mgL^{-1} (Site 2, Pre-monsoon season) to 9 mgL^{-1} (Site 1, monsoon season). The values were found to be slightly higher during Monsoon season and lower during Pre-monsoon season.
11. The total hardness ranged from 18 mgL^{-1} $CaCO_3$ (Site 1, Monsoon season) to 141 mgL^{-1} $CaCO_3$ (Site 4, Pre-monsoon season). The values were found to be highest during pre-monsoon season as compared to post monsoon and monsoon season.
12. The phosphate-P ranged from 0.005 mgl^{-1} (Site 1, Post-monsoon season) to 0.246 mgl^{-1} (Site 4, Monsoon season). The values were found to be highest during monsoon season and lowest during pre-monsoon season.
13. The nitrite ranged from 0.008 mgl^{-1} (Site 1, Post-monsoon season) to 0.087 mgl^{-1} (Site 4, Monsoon season). The values were found to be highest during monsoon season and lowest during post-monsoon season.
14. The WQI at Site 1 (Control site) was found to be **35** and falls within Grade B (26-50) of the water quality classification based on weighted arithmetic WQI method.
15. The WQI at Site 2, Site 3 and Site 4 were found to be **131,132** and **134** respectively, and fall within Grade E (>100) of the water quality classification (polluted) based on weighted arithmetic WQI method.

16. The water quality attributes and WQI depict that the river water at Site 1 (Control/Reference Site) is clean, and intensity of pollutants is increased from upstream to downstream of river (Site 2 to 4).
17. Statistical analysis namely, ANOVA, correlation coefficient and linear regression and ANOVA were computed to check the significance and validity of data on water quality analysis.
18. A total of 17 macrophytes belonging to 12 families were reported from the study sites.
19. The study Site 1 was represented by 6 species namely *Ageratum conyzoides, Colocasia affinis, Commelina benghalensis, Juncus effuses, Murdannia nudiflora*, and *Polygonum barbatum.* It can be argued that there is no effect of pollutants on distribution of such species.
20. Site 2, 3 and 4 by 15 species each namely *Ageratum conyzoides, Alternanthera sessilis, Canna indica, Colocasia affinis, Cynodon dactylon, Cyperus scariosus, Dichrocephala integrifolia, Drymaria cordata, Echinochloa stagmina, Eichhornia crassipes, Murdannia nudiflora, Pistia stratoise Polygonum barbatum, Polygonum hydropiper and Pteridium aquilinum* These species are tolerant to pollution and growing well in polluted water.
21. Four species namely *Ageratum conyzoides*, *Colocasia affinis, Murdannia nudiflora* and *Polygonum barbatum* were found at all study Sites, indicating high ecological amplitude towards pollution.
22. The species present only at Site I (Control/Reference Site) are sensitive to pollutants and regarded as pollution indicator species, and used for biomonitoring of water bodies.

The overall findings show that there was a seasonal fluctuation in the values of various physico-chemical characteristics in the river. All the water quality parameters lie within the permissible limit as given by different scientific agencies except phosphate values for Site 2, Site 3 and Site 4 during all the seasons. High phosphorus value may be attributed to discharge of waste through run-off containing phosphorus.

Proper treatment of water is of great importance as long term use may adversely affect both human and aquatic lives. The pollutants present in the river has some effect on the distribution of aquatic macrophytes. This is evident from the presence of *Alternanthera sessilis, Eichhornia crassipes* and *Pistia stratiotes* at site 2, 3 and 4 and absence in Site 1. The presence of these macrophytes may be due to due to the accumulation of sewage containing more organic load.

Anthropogenic activities at Site 2, 3 and 4 has led to degradation of water quality as compared to Site 1 (control site). Thus, regular monitoring of the river water quality should be done so as to know the status of the river. Disposal of wastes into river must be checked. Awareness programme should be conducted to educate the people on the importance of proper management of the river water.

Appendix I

Correlation coefficient (r) between the water quality parameters for two successive years (October 2016- September 2018)

Parameters	Temp	EC	TDS	Turb	pH	DO	BOD	Chloride	TA	Acidity	TH	Phosphate	Nitrite
Temp	1												
EC	.862**	1											
TDS	.819**	.912**	1										
Turb	.789**	.836**	.750**	1									
pH	-0	0.236	0.2	.411*	1								
DO	-.879**	-.843**	-.717**	-.850**	-0.06	1							
BOD	.851**	.766**	.623**	.899**	0.16	-.919**	1						
Chloride	0.17	.408*	.436*	0.4	.407*	-0.09	0	1					
TA	0.06	0.147	0.4	0.34	.678**	0.04	0	.545**	1				
Acidity	-0	-0.27	-0	-.473*	-.632**	0.12	-0	-.622**	-0.35	1			
TH	0.16	0.357	.414*	.456*	.522**	-0.1	0	.849**	.714**	-.551**	1		
Phosphate	.755**	.765**	.666**	.961**	.427*	-.864**	.922**	0.19	0.29	-0.37	0.274	1	
Nitrite	.786**	.853**	.694**	.962**	0.33	-.899**	.934**	0.28	0.14	-.410*	0.322	.949**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)

Appendix II

Correlation coefficient (r) between the water quality parameters at Site 1 for two successive years (October 2016- September 2018)

Parameters	Temp	EC	TDS	Turb	pH	DO	BOD	Cl	TA	Acidity	TH	Phosphate	Nitrite
Temp	1												
EC	.714*	1											
TDS	0.785	0.678	1										
Turb	.896*	0.591	0.72	1									
pH	-0.099	0.191	-0.578	-0.176	1								
DO	-0.705	-0.717	-.825*	-0.603	0.287	1							
BOD	.990**	0.781	0.784	.942**	-0.09	-0.711	1						
Cl	-0.554	-0.463	-0.6	-0.213	0.334	0.673	-0.457	1					
TA	-0.417	-0.55	-0.782	-0.241	0.503	.872*	-0.392	0.74	1				
Acidity	0.109	-0.134	0.276	-0.106	-0.551	-0.364	0.019	-0.807	-0.534	1			
TH	-0.674	-0.582	-0.725	-0.405	0.335	.851*	-0.609	.958**	.826*	-0.716	1		
Phosphate	.980**	.836*	0.745	.812*	-0.008	-0.757	.957**	-0.648	-0.482	0.181	-0.758	1	
Nitrite	.932**	.901*	0.806	0.751	-0.044	-.868*	.915*	-0.681	-0.647	0.194	-.813*	.972**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)

Appendix III
Correlation coefficient (r) between the water quality parameters at Site 2 for two successive years (October 2016- September 2018)

Parameters	Temp	EC	TDS	Turb	pH	DO	BOD	Cl	TA	Acidity	TH	Phosphate	Nitrite
Temp	1												
EC	.939**	1											
TDS	.884*	.894*	1										
Turb	0.779	0.729	0.498	1									
pH	-0.41	-0.229	-0.634	0.253	1								
DO	-.927**	-.846*	-0.724	-.948**	0.049	1							
BOD	.857*	0.754	0.596	.965**	0.086	-.982**	1						
Cl	-0.1	0.058	-0.039	0	0.135	0.12	-0.221	1					
TA	-0.505	-0.785	-0.789	-0.243	0.407	0.424	-0.32	0.135	1				
Acidity	0.041	-0.154	0.227	-0.492	-0.77	0.223	-0.251	-0.639	-0.195	1			
TH	-0.333	-0.418	-0.449	-0.178	0.23	0.331	-0.35	0.754	0.718	-0.456	1		
Phosphate	0.674	0.599	0.354	.956**	0.356	-.889*	.955**	-0.245	-0.175	-0.405	-0.32	1	
Nitrite	0.746	0.809	0.539	.971**	0.268	-.935**	.946**	-0.034	-0.379	-0.473	-0.27	.932**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed)

Appendix IV

Correlation coefficient (r) between the water quality parameters at Site 3 for two successive years (October 2016- September 2018)

Parameters	Temp	EC	TDS	Turb	pH	DO	BOD	Cl	TA	Acidity	TH	Phosphate	Nitrite
Temp	1												
EC	.936**	1											
TDS	.895*	.896*	1										
Turb	0.603	0.692	0.41	1									
pH	-0.63	-0.46	-0.8	0	1								
DO	-.855*	-.885*	-0.79	-1	0.4	1							
BOD	.833*	.869*	0.71	.917*	-0	-.949**	1						
Cl	-0.12	0.214	0.02	0	0.2	0.2	0.03	1					
TA	-0.61	-0.74	-0.8	-0	0.7	0.7	-0.5	0.26	1				
Acidity	0.131	-0.21	0.18	-1	-1	0	-0.3	-0.7	-0.3	1			
TH	-0.27	-0.14	-0.3	0	0.5	0.4	-0.1	.848*	0.7	-0.65	1		
Phosphate	0.601	0.576	0.33	.956**	0.2	-1	.889*	-0.1	-0.2	-0.41	-0.1	1	
Nitrite	0.669	0.798	0.53	.973**	0.1	-.862*	.966**	0.16	-0.3	-0.48	0	.922**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)

Appendix V
Correlation coefficient (r) between the water quality parameters at Site 4 for two successive years (October 2016- September 2018)

Parameters	Temp	EC	TDS	Turb	pH	DO	BOD	Cl	TA	Acidity	TH	Phosphate	Nitrite
Temp	1												
EC	.938**	1											
TDS	.899*	.892*	1										
Turb	0.699	0.747	0.49										
pH	-0.71	-0.51	-.840*	-0	1								
DO	-.864*	-0.81	-0.67	-.919**	0.3	1							
BOD	0.76	0.616	0.46	.914*	-0	-.957**	1						
Cl	-0.2	-0.04	-0.13	0	0.2	0.3	-0.3	1					
TA	-0.59	-0.79	-0.77	-0	0.6	0.6	-0.3	0.4	1				
Acidity	0.084	-0.2	0.18	-1	-1	0.2	-0.3	-0.6	-0.1	1			
TH	-0.11	0.136	-0.08	0	0.4	0.1	-0.1	.876*	0.37	-0.72	1		
Phosphate	0.624	0.597	0.35	.927**	0.1	-.926**	.969**	-0.3	-0.4	-0.4	-0	1	
Nitrite	0.696	0.811	0.54	.972**	-0	-.935**	.895*	-0.1	-0.5	-0.47	0.2	.929**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed)

REFERENCES

Abbas, A. A. A. and Hassan, F. M. (2017). Water quality assessment of Euphrates river in Qadisiyah province (Diwaniyah river), Iraq. TIJAS, Vol.48, No.6, (in press.).

Abdo, M.H. (2005). Physico-chemical characteristics of Abuza ‘Baal Ponds’, Egypt. *Eqyptian Journal of Aquatic Research*, 31(2): 1-15.

Abdul Hameed M., Jawad, A., Haider, S.A. and Bahram, K.M. (2010). Application of Water Quality Index for assessment of Dokan Lake ecosystem, Kurdistan Region. *Journal of Water Resource and Protection*, 2:792-798.

Abdul, H.M., Jawad A., Haider S.A., Bahram, K.M. (2010). Application of water quality index for assessment of Dokan Lake Ecosystem, Kurdistan region, Iraq. *J Water Resour Prot.* 2:792–798.

Abdulwahid, S.J. (2013). Water quality index of delizhiyan springs and Shawrawa River within Soran district, Erbil, Kursistan region of Iraq. *J. Appl. Environ. Biol. Sci*., 3(1): 40-48.

Abed, S.A. and Jazie, A.A. (2014). Assessment of somephysico-chemical properties for water in Ganga River at Varanasi, India. *Al-Qadisiya Journal for Engineering Sciences*, 7(2):148-164.

Abel-Satar and Amaal, M. (2005). Water quality assessment of River Nile from IDFO to Cairo, Egypt. J. Aqua. Res. 31(2): 200-223.

Adekunle, A. S. and Eniola, I. T. K. (2008). Impact Of Industrial Effluents On Quality Of Segment Of Asa River Within An Industrial Estate In Ilorin, Nigeria. *New York Science Journal*, 1(1): 17-21.

Adimalla, N. and Qian, H. (2019). Groundwater quality evaluation using water quality index (WQI) for drinking purposes and human health risk (HHR) assessment in an agricultural region of Nanganur, south India. *Ecotoxicology and Environmental Safety*, 176:153–161.

Agarwal, A. and Saxena, M. (2011 a). Assessment of Pollution by Physicochemical Water Parameters Using Regression Analysis: A Case Study of Gagan River at Moradabad- India. *Advances in Applied Science Research*, 2(2):185–189.

Agarwal, A., Saxena, M. and Agarwal, M. (2011 b). Correlation Between Physicochemical Water Parameters Using Regression Analysis: A Case Study of River Ram Ganga at Moradabad, India. *Asian Journal of Water, Environment and Pollution*, 8(4):97–100.

Agarwal, A.K. and Rozgar, G.R. (2010). PhysicoChemical and Microbiological Study of Tehri Dam Reservoir, Garhwal Himalaya, India. *Jour. Env. Res.*, 2(4):329-337.

Agarwal, D.K., Gaur, S.D., Tiwari, I.C., Narayan Sawmi, N. and Magwah, S.M. 1976. Physico-chemical characteristics of Ganges water at Varanasi. *Ind. J. Env. Hlth.*, 18: 201-206.

Agarwal, M. and Agarwal, A. (2013). Linear Regression and Correlation Analysis of Water Quality Parameters: A Case Study of River Kosi at District Rampur, India. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(12): 7273-7279.

Agrahari M. and Kushwaha V.B. (2012). Effect of domestic sewage on the physico-chemical quality of river Rapti at Gorakhpur. *Bioscan*, 7(1), 135-138.

Ahipathi, M.V. and Puttaiah, E.T. (2006). Ecological characteristics of Vrishabhavathi river in Bangalore (India). *Environmental Geology*, 49: 1217-1222.

Ahmad, U., Parveen, S., Hasan, T. and Bilal Nabi Bhat , B.N. (2015). Diversity of Aquatic macrophytes of Aligarh, U.P. India. *Int.J.Curr.Microbiol.App.Sci*., 4(4): 494-505.

Ahmed, M. J., Ahsan, A., Haque, M.R., Siraj, S., Bhuiyan, M.H.R., Bhattacharjee S.C., and Islam, S. (2010). Physicochemical Assessment of Surface and Groundwater Quality of the Greater Chittagong Region of Bangladesh. *Pakistan Journal of Analytical & Environmental Chemistry*, 11(2):1-11.

Akkaraboyina, M. and Raju, B. (2012). A comparative study of water quality indices of river Godavari. *Int. J. Eng. Res. Dev*., 2(3): 29-34.

Akomolafe, G.F. and Nkwocha, O. P. (2017). Assessment of the distribution of aquatic macrophytes in Lafia andDoma Metropolis, Nasarawa State, Nigeria. *Journal of Research in Forestry, Wildlife & Environment*, Vol. 9(4): 56-65.

Alam, W. and Laishram, R. J. (2017). Spatial and Temporal Assessment of Water Quality of Nambul River within Imphal City, Manipur. International Conference on Natural Resources Management and Technology Trends, at Manipur University, Imphal. pp.108-109.

Ali, M., Salam, A., Ahmed, N., Khan, B. and Khokhar, M. Y. (2004). Monthly variation in physicochemical characteristics and metal contents of Indus river at Ghazi Ghat, Muzaffargarh, Pakistan. *Pakistan Journal of Zoology*, 36(4): 295-300.

Al-Janabi, Z. Z., Al-Kubaisi, A.-R., & Al-Obaidy, A.-H. M. J. (2018). Assessment of Water Quality of Tigris River by using Water Quality Index (CCME WQI). *Al-Nahrain Journal of Science*, *15*(1), 119-126.

Al-Obadiy, A. H. M.J; Awad, E.S; Kadhem, A. J and Al-Mashhady, A. A. (2015). Evaluating water quality of Mahrut River, Diyala, Iraq for Irrigation. *Engineering and Technology Journal*, 33(4) :830- 837.

Alphayo, S. and Sharma, M. (2018). Water Quality Assessment of Ruvu River in Tanzania Using NSFWQI. *Journal of Scientific Research and Reports*, 20(3): 1-9.

Alphayo, Stephano & Sharma, Mahendra. (2018). Water Quality Assessment of Ruvu River in Tanzania Using NSFWQI. Journal of Scientific Research and Reports. 20(3): 1-9.

Al-Shujairi, S. H. (2013). Develop and apply water quality index to evaluate water quality of Tigris and Euphrates Rivers in Iraq. *International Journal Modern Engineering Research*, 3(4): 2119- 2126.

Ambasht, R.S. and Srivastava, A. K. (1997). Distribution, density, dominance and diversity of aquatic macrophytes in relation to pollution of Ganga river at Varanasi, India. *Ecoprint and Int. J. of Ecol*., 4(1):1-8.

Anushka and Deswal, S. (2017). Assessing the Impact of a few Anthropogenic Activities on Water Quality of River Ganga. *International Journal on Emerging Technologies,* 8(1): 251-255.

APHA. (2005). Standard methods for the examination of water and waste water; 21st edition as prescribed by American Public Health Association, American Water Works Association and Water Environment Federation, Washington, D.C.

Aris, A. Z., Lim, W. Y., Praveena, S. M., Yusoff, M. K., Ramli, M. F. and Juahir. H. (2014). Water quality status of selected rivers in Kota Marudu, Sabah, Malaysia and its suitability for usage. *Sains Malaysiana* , 43(3): 377-388.

Arts, G.H.P. (2002). Deterioration of Atlantic soft water macrophyte communities by acidification, eutrophication and alkalization. *Aquat. Bot*., 73: 373-393.

Asadi, S.S., Vuppala, P., and Anji, R.M. (2007). Remote sensing and GIS techniques for evaluation of groundwater quality in Municipal Corporation of Hyderabad (Zone-V). *India. Int. J. Environ. Res. Public Health,* 4(1): 45-52.

Asha, P.S. and R. Diwakar. (2007). Hydrobiology of the inshore waters off Tuticorin in the Gulf. *J. Mar. Biol. Ass. India*, 49:7-11.

Asrari, E., Madadi, M. and Masoud, M. (2008) Study of Water Quality in Kor River, West Southern of Iran. *Nature Environment and Pollution Technology*. 7(3):501-504.

Atta, I., Ismael, B. and Razzak, A. (2008). Chemical and physical analysis of some ground water sample in Al-Quti wells Hodiedah, Yemen. *J. Iran. Chem. Res*., 1:141-144.

Avvannavar, S.M., Shrihari, S. (2008). Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India. *Environ Monit Assess,* 143:279–290.

Ayoade, A.A., Agarwal, N.K. and Chandola-Saklani, A. (2009). Changes in physicochemical features and plankton of two regulated high alititude rivers Garhwal Himalaya, India. *Euro. J. Scienti. Res*. 27(1):77-92.

Baattrup-Pedersen, A., Szoszkiewicz, K., Nijboer, R., O'Hare, M. and Ferreira, T. (2006). Macrophyte communities in unimpacted European streams: variability in assemblage patterns, abundance and diversity. *Hydrobiologia*, 566:179–196.

Bailung, B. and Biswas, S.P. (2018). Assessment of physico-chemical parameters of Dihing River-Tributary of Almighty Brahmaputra, Assam, NE India. Indian *Journal of Environmental Sciences*, 22(1):16-20.

Balan, I.N., Shivakumar, M. and Kumar P.D.M. (2012). An assessment of groundwater quality using water quality index in Chennai Tamil Nadu India. *Chron Young Sci.,* 3(2):146–150.

Barai, S. R. and Kumar, S. (2013). Evaluation of the physio-chemical characterestics of river Varuna at Varanasi, India. *Journal of Environmental Biology*, 34: 259–265.

Barooah, C. and Mahanta, P. K. (2006). Aquatic Angiosperms of Biswanath Chariali. *Indian Journal of Forestry*. 29(3): 307-318.

Baruah, P.P. and Baruah, C.K. (2000). Study of the hydrophytic flora of kaziranga National Park, Assam, India. *Annals of Forestry*, 8(2): 170-178.

Bathusa, M.I. and Safetharan, M.K. (2007). Physico-chemical characteristics and correlation and regression study on ground water of Coimbatore north zone (TN). *J. Environ. Sci. Egg*., 49:215-224.

Bhalla, R. and Sekhon, B. (2010). Seasonal physico-chemical characteristics assessment and primary production in the planktonic community of Godavari river, water, Nashik (Maharashtra). *Envi. Cons. J.*, 11(1and 2):41-45.

Bhandari, N.S. and Nayal K. (2008). Correlation study on the physico-chemical parameters and quality assessment of Kosi river water, Uttarakhand. *Electronic Journal of Chemistry*, 592: 342-346.

Bhanja, K.M. and Patra, A. (2000). Studies on the water quality index of River Sanamachhakandana at Keonjhar garh, Orissa (India). *Poll. Res.,* 19(3): 377-385.

Bharali, Jasmine, Baruah, B.K., and Sarma, H.P. (2008). Studies on physic-chemical characteristics of water of the Wetlands in Kaziranga National Park, Assam. *Poll. Res.,* 27(3): 591-597.

Bhatnagar, A. and Devi, P. (2012). Applications of correlation and regression analysis in assessing lentic water quality: a case study at Brahmasarovar Kurukshethra, India. *International Journal of Environmental Sciences*, 3(2):813-820.

Bhatt, L.R., Lacoul, P., Lekhak, H.D. and Jha, P.K. (1999). Physicochemical characteristics and phytoplankton of Taudaha lake, Kathmandu. *Poll. Res*. 18(14): 353-358.

Bhowmik, B.K. and Datta, S. (2011). Diversity of Aquatic and Marshland Plants of Tripura, India: In Recent Studies in Biodiversity and Traditional Knowledge in India. Recent Studies in Biodiversity and Traditional Knowledge in India. Pp. 117-130.

Bhutekar, D. and Aher, S.B. and Babare, M. (2018). Spatial and seasonal variation in physic-chemical properties of Godavari river at Ambid Region, Maharashtra. *J. Env. Bio-Sci*., 32 (1): 15-23.

Bianchini Jr., I., Cunha-Santino, M.B. and Pert, A.M. (2008). Oxygen demand during mineralization of aquatic macrophytes from an oxbow lake. *Brazilian Journal of Biology*, 68(1):61-67.

Billore, D.K. and Vyas, I.N. (1981). Distribution and production of macrophytes in Pichhola Lake, Udaipur. *International Journal of Ecological Science*, 7: 45-54.

Bini, L.M., Thomaz, S.M., Murphy, K.J. and Camargo, A.F.M. (1999). Aquatic macrophytes distribution in relation to water and sediment conditions in the Itaipu reservoir, Brazil. *Hydrobiologia*, 415: 147-154.

BIS. (2003). Indian standard specifications for drinking water. IS 10500. Indian Institute, New Delhi, India.

Biswas, K. and Calder, C.C. (1937). Hand-book of common water and marsh plants of India and Burma. Health Bulletin. 24. Govt. Press, Calcutta.

Borchardt, J.A. and Walton, G. (1971). Water Quality. In: *Water Quality and Treatment*, 3rd Edition, American Water Works Association, McGraw-Hill, New York.

Bordalo A., Teixeira, R. and Wiebe, W. J. (2006). A Water Quality Index Applied to an International Shared River Basin: The Case of Douro river. *Environmental Management*, 38(6): 910-920.

Bordoloi, R. (2014). A comparative study of aquatic macrophytes and its primary Productivity in the closed and open type wetlands of upper Reaches of the Brahmaputra river basin. *J.Bio.Innov*, 3 (2): 103-116.

Boyd, C.E. (2015) Water quality: An introduction. Springer International Publishing. 2nd edition. Pp-22.

Boyd, C.E. and Tucker, C.S. (1998). Pond aquaculture and water quality management. Kluwer Academic Pub., London. Pp-44–8.

Bozniak, E.G. and Kennedy, L.L. (1968). Periodicity and the ecology of the plankton in an oligotrophic and eutrophic lake, *Canadian Journal of Botany,* 46 (10):1259-1271.

Brahmaputra Board. (2000). Water Vision: North East 2050. Report of the Brahmaputra Board, Ministry of Water Resources, Government of India.

Brinson, M.M., Lugo, A.E. and Brown, S. (1981). Primary productivity, decomposition and consumer activity in freshwater wetlands. *Ann. Rev. Ecol. Syst*., 12: 123--161.

Brown, R.M., McClelland, N.I., Deininger, R.A. and O’Connor, M.F. (1972). Water Quality Index-Crashing the Physicological Barrier, Proc. 6th Annual Conference. *Advances in Water Pollution Research,* 6: 787-794.

Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G. (1970). Water quality indexdo we dare?. *Water sewage works*, 117(10): 339-343.

Buchanan, S., and Triantafilis, J. (2009). Mapping water table depth using geophysical and environmental variables. *Groundwater*, 47(1): 80- 96.

Burlakoti, C. and Karmacharya, S.B. (2004). Quantitative analysis of macrophytes of Beeshazar Tal, Chitwan, Nepal. *Him J Sci*., 2(3): 37-41.

Camargo, A.F.M. and Esteves, F.A. (1995). Biomass and Productivity of Aquatic Macrophytes in Brazilian Lacustrine Ecosystems. In: Tundisi, J. G., Bicudo, C. E. M. and Matsumura, T. T. (eds.), Limnology in Brazil, ABD/SBL, Rio de Janeiro. Pp-137-149.

Carpenter, S.R. and Lodge, D.M. (1986). Effects of submerged macrophytes on ecosystem processes. *Aquatic Botany*, 26: 341-370.

Census. (2011). Ministry of Home Affairs, Government of India.

Chadetrik R., Arun, L. and Prakash D.R. (2015). Assessment of Physico-chemical Characteristics of River Yamuna at Agra Region of Uttar Pradesh, India. *Int. Res. J. Environ.Sci.*, 4(9):25-32.

Chambers, P.A., Lacoul, P., Murphy, K.J. and Thomaz, S.M. (2008). Global diversity of aquatic macrophytes in freshwater. *Hydrobiologia*, 595(1): 9-26.

Chandio, T. A., Khan, M. N., and Sarwar, A. (2015). Fluoride estimation and its correlation with other physicochemical parameters in drinking water of some areas of Balochistan, Pakistan. *Environmental Monitoring and Assessment*, 187(8):531.

Chandra, S., Singh, A. and Tomar, P.K. (2011). Evaluation of Physicochemical Characteristics of Various River Water in India. *E-Journal of Chemistry*, 8(4), 1546-1555.

Chaphekar, S.B. (1991). An overview on bioindicators. *J. Env. Biol.*, 12:163-168.

Chaubey, S. and Patil, M. K. (2015). Correlation Study and Regression Analysis of Water Quality Assessment of Nagpur City, India. *International Journal of Scientific and Research Publications*, 5(11):753–757.

Chauhan, B.S. and Sagar, S.K. (2013). Impact of Pollutants on Water Quality of River Sutlej in Nangal Area of Punjab, India. *Biological Forum – An International Journal*, 5(1): 113-123.

Chaurasia, M. and Pandey, G.C. (2007). Study of physicochemical characteristic of some water pond of Ayodhya –Faizabad. *Indian J. of Environmental protection*, 27(11):1019-1023.

Chavan, A. R. and Sabnis, S. D. (1961). A study of the hydrophytes of Baroda and Environs. *J. Indian Bot. Soc.*, XL (1): 121-130.

Chetana Suvarna, A. and Somashekar, R. K. (1997). Evaluation of water quality index of the river Cauvery and its tributaries. *Current science (Current Science Association and Indian Academy of Science, Bangalore)*, 72(9):640–646.

Chhetry, D.T. and Pal, J. (2012). Physico-chemical properties of seepage stream at Shripur area, Eastern Nepal, *Nepalese Journal of Bioscience*, 2: 46-54.

Chitmanat, C and Traichaiyaporn, S., (2010). Spatial and temporal variations of physical chemical water quality and some heavy metals in water, sediments and fish of the Mae Kuang River, Northern Thailand. *International Journal of Agriculture and Biology*, 12(6): 816-820.

Chung, I.H. and Jeng, S.S. (1974). Heavy metal pollution of Ta-Tu River. Bulletin of the Institutes of Zoology, Academy of Science, 13: 69-73.

Clayton, J. and Edwards, T. (2006). Aquatic plants as environmental indicators of ecological condition in New Zealand lakes. *Hydrobiologia*, 570:147–151.

Cook, C.D.K. (1996). Aquatic and Wetland Plants of India: A Reference Book and Identification Manual for the Vascular Plants found in permanent or seasonal fresh water in the Subcontinent of India South of the Himalayas. Oxford University Press. Pp-280-385.

Cowx, I.G. and Welcomme, R.L. (1998). Rehabilitation of Rivers for Fish. Fishing News Books, Oxford, UK. Pp-260.

Cronk, J.K. and Fennessy, M.S. (2001). Wetland Plants: Biology and Ecology. Lewis publishers, Boca Raton London, New York, Washington, D.C. Pp- 482.

Daniel, M.H.B., Montebelo, A.A., Bernardes, M.C., Ometto, J.P.H.B., DeCamargo, P.B., Krusche, A.V., Ballester, M.V., Victoria, R.L. and Martinelli, L.A. (2002). Effects of urban sewage on dissolved oxygen, dissolved inorganic and organic carbon and electrical conductivity of small streams along a gradient of urbanization in the Piracicaba River basin. *Water, Air and Soil Pollution*, 136: 189-206.

Daraigan, S.G., Wahdain, A.S., Ba-Mosa, A.S., and Obid, M.H. (2011). Linear correlation analysis study of drinking water quality data for AlMukalla City, Hadhramout, Yemen. *International Journal of Environmental Sciences*, 1(7):1692-170.

Das, B.K., Borua, P. and Kar, D. (2014). Study of Seasonal Variation of Water Quality of River Siang in Arunachal Pradesh, India. *Journal of Environmental Science, Toxicology and Food Technology,* 8 (2):11-20.

Das, J. and Acharya, B.C. (2003). Hydrology and assessment of lotic water quality in Cuttack city, India. *Water, Air, Soil Pollut.*, 150: 163-175.

Das, K.R., Bhoominathan, S.D., Kanagaraj, S. and Govindaraju, M. (2017). Development of a water quality index (WQI) for the Loktak Lake in India. *Appl Water Sci.*, 7:2907–2918.

Das, N.K. and Sinha, R.K. (1993). Assessment of water quality of Ganga River, Patna, *India Environ Ecol*., Vol 11(4):829-832.

Datar, M.O. and Vashistha, R.P. (1992). Physico-chemical aspects of pollution in river Betwa, Indian J Environ Protect., 12:577-580.

Davie, T. (2003). Fundamentals of Hydrology, Routledge, New York, Pp-169.

Deb, D.B. (1976). A study on the aquatic vascular plants of India. *Bulletin of the Botanical Society of Bengal*, 29:155-230.

Debels, P., Figueroa, R., Urrutla, R., Barra, R., and Niell, X. (2005). Evaluation of water quality in the Chillan river (Central Chile) using physicochemical parameters and modified water quality index. *Environmental Monitoring and Assessment*, 110: 301–322.

Deka, S.J., Sarma, G.C., Baishya R. and Deka, S.P. (2010). Phenological study of Macrophytes of some selected wetlands of Goalpara distric Assam, India. *Plant Archives*, 10(1):165-170.

Deka, U. and Sarma, S.K. (2014). Present status of aquatic macrophytes of the wetlands of Nalbari district of Assam, India. *Asian Journal of Plant Science and Research*, 4(3): 67- 75.

Devlin, R.M. .(1967). Plant Physiology. Reinhold, New York, Pp-564.

Dey, S.C. and Kar, D. (1989). Aquatic macrophytes of Lake Sone in Assam. *Environ Ecol.*, 7:253–254.

Dhar, N., Goswami, M.M. and Kar, D. (2004). Aquatic macrophytes in Baskandi Lake, an oxbow lake of Barak Basin, Assam. *Environment and Ecology*, 22(Spl-4): 606-608.

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.

Drusilla, R., Kumerasan, A. and Narayanan, N. (2005). Studies on the Water Quality of Lotie Systems in and around Courtallam, Tamilnadu, Part II. *Poll. Res.*, 1:177-185.

Dulo, S.O. (2008). Determination of some physico-chemical parameters of the Nairobi River, Kenya. *J. Appl. Sci. Environ. Manage*., 12(1): 57-62.

Dutta, B. and Sarma, B. (2018). Correlation Study and Regression Analysis of Ground Water Quality Assessment of Nagaon Town of Assam, India. *IJERT*, 7(6):320-331.

Dutta, D. and Sarma, H.P. (2013). Flouride hydrochemistry of Dikrong river basin, Arunachal Pradesh, India. *International Journal of Scientific and Engineering Researc*h, 4(4): 1640- 1643.

Dutta, S., Naik-Desai, A., Almeida, S.M. and Das, A.P. (2002). Aquatic macrophytes of Apalchand Reservein the Jalpaiguri Districtof West Bengal. In Perspectives of Plant Biodiversity. Ed. A.P. Das, Bishen Singh and Mahendrapal Singh, Dehradun. Pp-53 – 65.

Dutta, T., Deka, U. and Rabha, P.K. (2014). Diversity of aquatic macrophytes of Kapla beel (wetland) of Barpeta district, Assam, India. Annals of Biological Research, 5(12): 41-45.

Dwivedi, S. and Dwivedi, A.K. (2010). River pollution and solution. New Central Book Agency (P) Ltd., New Delhi. Pp:19-20

Dwivedi, S.L. and Pathak, V. (2007). A preliminary assignment of water quality index to Mandakini River, Chitrakoot. *Indian Journal of Environmental Protection*, 27(11): 1036-1038.

Efe, S. T. (2002). Urban Warming in Nigerian cities.The case of Warri metropolis. *African Journal of Environmental Studies*, 2(2): 160-168.

El-Korashey, R. (2009). Using regression analysis to estimate water quality constituents in Bahr El Baqar drain. *Jr. of Appl. Sc. Res*., 5(8): 1067-1076.

El-Sherbini, A. and El-Moattassem, M. (1994). River Nile Water Quality Index during High and Low Flow Conditions. National Conference on the River Nile, Assiut Center for Environmental Studies.

Erondu, E. S. and Chindah, A.C. (1991). Physicochemical and phytoplankton changes in tidal fresh water station of the new calabar river, south Eastern Nigeria. *Environmental and Ecology*. 9(3):5561-5570.

Eyarin Jehamalar, E., Golda, D.B. and Das, S.M. (2010). Water quality index and its seasonal variation on Thamiraparani river at Kanyakumari district, Tamil Nadu, India. *Journal of Basic and Applied Science,* 4 (3): 110-116.

Ezzat, S., Hesham, M., Mervate, A., Essam, S. and Mostafa, E. (2012). Water Quality Assessment of River Nile at Rosetta Branch: Impact of Drains Discharge. Middle East Journal of Scientific Research. 12. 413-423.

Fadiran A.O., Mamba S.M. (2005). Analysis of nitrates and nitrites in some water and factory effluent samples from cities in Swaziland. *Bull. Chem. Soc. Ethiopia*, 19 (1): 35- 44.

Fafioye O. O., Olurin K. B., and Sowunmi A. A. (2005). Studies on the physico-chemical parameters of Omi water body of Ago-Iwoye, Nigeria, African Journal of Biotechnology, 4 (9):1022-1024.

Fakayode, S.O. (2005). Impact assessment of industrial effluent on water quality of the receiving Alaro river in Ibandan, Nigeria. *Ajeam-Ragee,* 10: 1-13.

Falkenmark, M. (1993). Water Scarcity: Time for realism. *Populi*., 20(6):11-12.

Fatema, K., Wan Maznah, W. O., and Isa, M. M. (2014). Spatial and Temporal Variation of Physico-chemical Parameters in the Merbok Estuary, Kedah, Malaysia. *Tropical life sciences research*, *25*(2):1–19.

Fathi, E., Zamani-Ahmadmahmoodi, R. and Zare-Bidaki, R. (2018). Water quality evaluation using water quality index and multivariate methods, Beheshtabad River, Iran. *Appl Water Sci*., 8**:**210.

Fella, H.C, Mohamed, B.E., Fatouma, B. and Mohand, S.H. (2013). Preliminary study on physico-chemical parameters and phytoplankton of Chiffa River. *Journal of Ecosystems*, 9: 1-9.

Firozia, N.J. and Sanal Kumar, M.G. (2013). Water Quality Assessment of Pamba River of Kerala, India in Relation to Pilgrimage Season. *Int. J. Res. Chem. Environ.*, 3(1) :341-347.

Forest Survey of India. (2019). Indian State of Forest Report. Ministry of Forest, Environment and Climate Change, Government of India.

Forstner, U and Whittman, G.T.W. (1979). Metal pollution in the aquatic environment. Springer-Verlag, Berlin, Heidelberg, New York, Pp- 486.

Fulazzaky, M. A., Seong, T., and Masirin, M. (2010). Assessment of water quality status for the Selangor River in Malaysia. *Water, Air, and Soil Pollution*, 205: 63–77.

Fytianos, K., Siumka, A., Zachariadis, G. A., and Beltsios, S. (2002). Assessment of the quality characteristics of Pinios Rtiver, Greece. *Water, Air, and Soil Pollution, 136:317–329.*

Galal, T.M. and Farahat, E.A. (2015). The invasive macrophyte P. stratiotes L. as a bioindicator for water pollution in Lake Mariut, Egypt. *Environmental Monitoring and Assessment*, 187: 701-712.

Gandotra, R., Sharma, J.P., and Andotra, P. (2008). Evaluation of water quality of river Tawi with reference to Physico-chemical parameters of district Jammu (J&K), India. *Curr. World Environ*., 3(1):55-66

Gangwar, R.K., Khare P., Singh J. and Singh A.P. (2012). Assessment of physico-chemical properties of water river Ramganga at Bareilly, U.P. *Journal of Chemical and Pharmaceutical Research*, 4(9): 4231- 4234.

Garg, D.K., Goyal, R.K. and Agarwal, V.P. (1990). Correlation among water quality parameters of groundwater of Roorkee city. *Indian Journal of Environmental Protection*, 10(5): 355-359.

Gasim MB, Ismail BS, Toriman E, Mir SI, Chek TC (2007). A physico- chemical assessment of the Bebar River, Pahang, Malaysia. *Global J. Environ. Res*., 1(1): 7-11.

Ghimire, N.P. (2016). Physico-chemical characteristics and macrophytes of Pravas Lake in Palpa, Nepal. International *Journal of Advancement in Earth and Environmental Sciences*. 4(1): 14-18.

Gleick, P. (1993). An introduction to global freshwater issues: Gleick, P. ed. Water in crisis. New York, Oxford University Press, Pp.3-12.

Gleick, P.H. (1996). Basic Water Requirements for Human Activities: Meeting Basic Needs. Water International, 21(2): 83-92.

Gourkar A. R., Rewatkar S. B. and Siddique, M.I.M. (2016). Study of Physico-Chemical Parameters and Correlationship among Different Parameters in Water of Kathani River, Gadchiroli, Maharashtra. IJSR, 5(7):2174-2180

Gunasekar, A. and S. Suthakar, Isaac (2015). Assessment of Physico Chemical Characteristics of River Sone at Bihar, India. *Int. J. Curr. Res. Biosci. Plant Biol.*, 2(8):50-58.

Gupta, H. P. (2001). Some aspect of limnologic studies on two ecologically different water bodies in Santhal Pargna with special reference to sewage Pollution. Ph.D. Thesis, S.K. Universuty, Dumka, Jharkhand.

Gupta, N., Yadav, K.K., Kumar, V. and Singh, D. (2013). Assessment of Physicochemical Properties of Yamuna River in Agra City. *Int. J. ChemTech. Res.*, 5(1): 528-53.

Hacioglu, N. and Dulger, B. (2009). Monthly variation of some physico-chemical and microbiological parameters in Biga Stream (Biga, Canakkale, Turkey). African Journal of Biotechnology, 8 (9):1929-1937.

Hafizurrahman, A.A., Khan, M. and ZulfiqarAli. (2016). Evaluation of Physicochemical Characteristics of Gomti River Water at Uttar Pradesh, India. *Int. J. Adv. Res*., 4(12):1408-1414.

Hasanzadeh, H.H. (2008). Water quality, physico-chemical and biological characteristics of Tajan river. *J. Ind. Poll Control*, 24(2): 169-176.

Henry-Silva, G.G., Pezzato, M.M., Benessi, R.F. and Camargo, A.F.M. (2001). Chemical composition of five species of aquatic macrophytes from lotic ecosystems of the southern coast of the state of São Paulo (Brazil). *Acta Limnol. Bras*., 13:11- 17.

Heydari, M.M., Abasi, A., Rohani, S.M. and Hosseini, S.M.A. (2013). Correlation Study and Regression Analysis of Drinking Water Quality in Kashan City, Iran. *Middle-East Journal of Scientific Research*, 13 (9): 1238-1244.

Hoque M. M., Roy, S., Hoque, M. N. and Islam, M. Z. (2012). Assessment of Some Water Quality Parameters of Bansi River in Monsoon and Winter Seasons. *Environ. Sci. & Natural Resources*, 5(2): 53 -57.

Horton, R. R. (1965). An index number system for rating water quality. *J. Wat. Pollut. Control. Fed*., 37: 300-306.

Hrivnak, R., Otahelova, H. and Jarolimek, I. (2006). Diversity of aquatic macrophytes in relation to environmental factors in the Slatina River (Slovakia). *Biologia Bratislava*,

Hrivnak, R., Otahelova, H. and Milan, V. (2007). The Relationship Between Macrophyte Vegetation and Habitat Factors Along A Middle-size European River. *Pol. J. Ecol*., 55(4): 717-729.

Hutchinson, G.E. (1975). A treatise on limnology, Limnological botany. John Wiley and Sons, NewYork, London, Sydney and Toronto. 3: Pp-660.

ICMR. (1996). *Guideline for Drinking Water Manual*. New Delhi: Indian Council of medical Research.

Igwe, O. and Idris, I.G. (2019). Evaluation and characterization of groundwater of the Maastrichtian Lafia formation, Central Benue trough, Nigeria. *J Earth Syst Sci.*, 128 (6):168.

Ikhuoriah, S. and Oronsaye, C.G. (2016). Assessment of Physicochemical Characteristics and some Heavy Metals of Ossiomo River, Ologbo – A Tributary of Benin River, Southern Nigeria. *J. Appl. Sci. Environ. Manage*, 20(2):472 – 481.

Imtiyaz, T., Zahoor, P. Shailendra, S., Mudgal, L.K. and Anis, S. (2012). Physicochemical properties of water of river Narmada at Madhya Pradesh, India. *Res*., 4(6): 5-9.

Indu, S.A. and Chandra, R. (2015). A Study on Physico-chemical Parameters and Correlation Analysis of Surface Water of Nawabganj Lake. *International Journal of Current Research*, 7(8):19548–19554.

Iqbal, F., Ali, M., Salam, A., Khan, B.A., Ahmad, S., Oamar, M. and Umer, K. (2004). Seasonal variations of physico-chemical characteristics of River Soan water at Dhoak Pathan Bridge (Chakwal), Pakistan. *International Journal of Agriculture and Biology*, 6(1): 89-92.

Ishaku, J.M., Ahmed, A.S. and Abubakar, M. A. (2012). Assessment of groundwater quality using water quality index and GIS in Jada, northeastern Nigeria. *Int. Res. J. Geol. Min.*, 2(3):54–61.

Islam, M. (1999). A study on the certain aquatic macrophytes of lentic habitat of Dibrugarh district. *Assam.Adv. Plant Sci*., 12: 35-40.

Jain, A., Roshnibala, S., Kanjilal, P.B., Singh, R.S. and Singh, H.B. (2007). Aquatic/semi-aquatic plants used in herbal remedies in the wetlands of Manipur, Northeastern India. *Indian Journal of Traditional Knowledge*, 6(2): 346-351.

Jain, C. K. and Sharma, M. K. (2000). Regression analysis of groundwater quality data of Sagar District Madhya Pradesh. *Indian Journal of Environmental Health*, 42(4):159--168.

Jalal, K.C.A., Noor F.H.N., Kamaruzzaman, B.Y., Shahbudin, S., Alam, M.Z.and Irwandi, J. (2009). Studies on physico-chemical characteristics and sediment environment along the coastal waters in Pulau Tuba, Langkawi, Malaysia. *Aquat Ecosyst Health*, 12:350–357.

Jehangir, A., Tanveer, A., Yousuf, A. R., Masood, A., and Naqash, A. H., (2011). Geochemistry and Irrigation Quality of Groundwater along River Jhelum in South Kashmir, India. *Recent Research in Science and Technology,* 3(6): 57-63.

Joarder, M. A., Raihan, F., Alam, J. B. and Hasanuzzaman, S. (2008). Regression analysis of Groundwater quality data of Sunamjang District, Bangladesh. *International Journal of Environmental Research*, 2(3): 291--296.

Jonnalagadda, S. and Mhere, G. (2001). Water quality of the odzi river in the eastern highlands of zimbabwe. *Water Research*, 35(10), 2371–2376.

Joshi, B.D., Pathak, J.K., Singh, Y.N., Bisht, R.C.S. and Joshi, P.C. (1993). On the physico- chemical characteristics of river Bhagirathi: In the uplands of Garhwal Himalaya. *Him. J. Env. Zool*., 7: 64-75.

Joshi, D.M., Kumar, A. and Agarwal, N. (2009). Studies on physicochemical parameters to assess the water quality of river Ganga for drinking purposes in Haridwar district, Rasayan. *J. Chem.*, 2(1): 195-203.

Jothivenkatachalam, K., Nithya, K. and Mohan, S.C. (2010). Correlation analysis of drinking water quality in and around Perur block of Coimbatore District, Tamil Nadu, India. *Rasayan J. Chem.,* 3:649-54.

Jung, S.Y. and Kim, I.K. (2017). Analysis of Water Qiality factor and correlation between Water Quaity ang Chl-a in Middle and Downstream Weir Section of Nakdong River.

Kalavathy, S., Sharma, T.R. and Sureshkumar, P. (2011). Water quality index of river Cauvery in Tiruchirappalli district, Tamil Nadu. *Arch. Environ. Sci.,* 5: 55-61.

Kalra, N., Kumar, R., Yadav, S. S., and Singh, R. T. (2012). Physico-chemical analysis of ground water taken from five blocks (Udwantnagar, Tarari, Charpokhar, Piro, Sahar) of southern Bhojpur (Bihar). *Journal of Chemical and Pharmaceutical Research*, 4(3): 1827-1832.

Kamal, D., Khan, A.N., Rahman, M.A. and Ahamed, F. (2007). Study on the Physico Chemical Properties of Water if Mouri River, Khulna, Bangladesh. *Pakistan Journal of Biological Sciences, 10: 710-717.*

Kannel P. R., Lee, S., Lee, Y., Kanel, S. R. and Khan, S. P. (2007). Application of Water Quality Indices and Dissolved Oxygen as Indicators for River Water Classification and Urban Impact Assessment. *Environmental Monitoring and Assessment*, 132(1-3): 93-110.

Kapoor, S. (2004). Biodiversity, productivity and stability of sloping lands around railway tracks. Ph. D. Thesis, V.B.S. Purvanchal University, Jaunpur.

Kar, P.K., Pani, K.R., Pattanayak, S.K. and Sahu, S.K. (2010). Applicability of Regression analysis in estimation of water quality parameters of Mahanadi River in and around Hirakud, Orissa (India). *The Esocscan*, 4(4):291-296.

Karmakar, P. and Biswas, S. P. (2016). Water Quality of Meleng River in Jorhat District, Assam. *IRJET*, 3(8):861-865.

Kataria, H.C. (1995). Turbidity measurement in groundwater of Bhopal city. *Journal of Natzwre Conservators*, 7(1): 79-82.

Kataria, H.C., Quereshi, H.A., Iqbal, S.A. and Shandilya, A.K. (1996). Assessment of water quality of Kolar reservoir in Bhopal, MP. *Poll. Res.,* 15: 191-193.

Keddy, P.A. (2000). Wetland ecology: Principles and conservation. Cambridge University Press. Pp-614.

Ketata Mouna, R., Gueddari, M., and Bouhlila, R. (2011). Use of Geographical Information System and Water Quality Index to Assess Groundwater Quality in El Khairat Deep Aquifer (Enfidha, Tunisian Sahel). *Iranica Journal of Energy & Environment*, 2 (2): 133-144.

Khatoon, N., Khan, A.H., Rehman, M. and Pathak, V. (2013). Correlation Study for the Assessment of Water Quality and its Parameters of Ganga River, Kanpur, Uttar Pradesh, India. *IOSR Journal of Applied Chemistry,* 5(3): 80-90.

Kiran, B.R., Patel, A.N., Kumar Vijaya and Puttaiah, E.T. (2006). Aquatic macrophytes in fish culture ponds at Bhadra fish farm, Karnataka. *Journal of Aquatic Biology*, 21(2):27- 30.

Kosha, A.S. and Geeta, S.J. (2015). Evaluation of water quality index for River Sabarmati, Gujarat, India. *Appl Water Sci*., 7(3):1349-1358.

Koshy M. and Nayar, T.V. (1999). Water quality aspect of river Pamba. *Poll. Res*., 18(4):501-510.

Koshy M. and Nayar, T.V. (2000). Water quality of River Pamba at Kozencherry. *Pollution Research,* 19: 665-668.

Krishna kumar, S., Logeshkumaran, A., Magesh, N.S., Prince, S.G, and Chandrasekar, N. (2015). Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. *Appl Water Sci.,* 5:335–343)

Krishnaram, H., Mohan, M., Ramchandra and Vishalkashi, Y. (2007). Limnological studies on Kolaramma lake Kolar, Karnataka. *Environmental Ecology,* 52(2): 364-367.

Kshirsagar, A. D. and Gunale, V. R. (2013). Diversity of aquatic macrophytes from River Mula Pune City, MS, India. *Science Research Reporter*. 3(1):9-14.

Kulshrestha, H. and Sharma, S. (2006). Impact of mass bathing during Ardhkumbh on water quality status of river Ganga. *J. Environ Biol*., 27:437-440.

Kumar Pramod, Panday Anupama and Upadhyay Hem Chandra. (2014). Seasonal variation in physico-chemical properties of Kali River in Pithoragarh district of Uttarakhand, India. *J. environ. Res. Develop.,* 8(3A): 600- 606.

Kumar, A., Bisht, B. S., Joshi, V. D., Singh, A. K., and Talwar, A. (2010). Physical, chemical and bacteriological study of water from rivers of Uttarakhand. *Journal of Human Ecology, 32*:169–173.

Kumar, N. and Sinha, D.K. (2010). Drinking water quality management through correlation studies among various physicochemical parameters: a case study. *Int. J. Environ Sci.,* 1: 253-259.

Kumar, R. (1991). Net primary production and conservation studies of a riparian ecosystem in Renukoot-Obra-region.Ph.D. Thesis, B.H.U., Varanasi, India.

Kumari, V. and Chaurasia, G.L. (2015). Study of Water Quality Status of Sai River in Uttar-Pradesh With Reference to Water Quality Index Assessment. *Jour. Innovative Res. Sci., Engg. Tech*.,.4(1)18614-18623.

Lalchhingpuii, Lalparmawii, S., Lalramnghinglova, H. and Mishra, B.P. (2011a). Assessment of the water quality of Tlawng river in Aizawl, Mizoram. *Science Vision,* 11(2): 72-76.

Lalchhingpuii, Lalramnghinglova, H. and Mishra, B.P. (2011b). Sulphate, Phosphate-P and nitrate-N contents in Tlawng river in vicinity of Aizawl city, Mizoram. *Science Vision*, 11(4), 19-202.

Lalparmawii S. and Mishra B.P. (2012). Seasonal variation in water quality of Tuirial River in vicinity of the hydel project in Mizoram, India. *Sci Vision*., 12(4), 159-163.

Lalparmawii, S. (2012). Analysis of Water Quality and Biomonitoring of Tuirial river in the Vicinity of the Hydel Project in Mizoram, India. Unpublished Ph.D Thesis, Mizoram University, India.

Lalzahawmi Chenkual and B.P. Mishra. (2016). Assessment of seasonal variation in chemical characteristics of Tamdil lake, Mizoram, Northeast India. *IJSEAS*, 2(7):157-164.

Lalzahawmi Chenkual, Laltanpuia, B.P. Mishra. (2016). Seasonal Variation in Physical Characteristics of Tamdil lake, Mizoram, Northeast India. *IJMSET*, 3(6): 24-29.

Lamare, R. E. and Singh, O. P. (2014). Degradation in water quality due to limestone mining in East Jaintia Hills, Meghalaya, India. International Research Journal of Environmental Science, 3 (5), 13-20.

Lamare, R. E. and Singh, O. P. (2015). Localised effect of artisanal and small scale mining of limestone mining on water quality in Meghalaya, India. Pollution Research, 34 (2), 321-329.

Lamare, R.E. and Singh, O.P. (2016). Seasonal variation in water quality of Lukha River, Meghalaya, India. Current World Environment, 11(1): 101-113.

Lavania, G.S., Paliwal, S.C. and Gopal, B. (1990). Aquatic vegetation of the Indian subcontinent; In E. Gopal (ed.). Ecology and management of the Aquatic Vegetation of the Indian Subcontinent. Dordrecht: Kluwer Academy Publishers. Pp-29-78.

Lim B.J., Han S.R., Choi I.C., Yoon J.H., Lee J.J., Cheon S.U., and Cho, K. (2017). Evaluation of physico-chemical parameters regulating zooplankton community structure in the Geum River, Korea. *Iranian Journal of Fisheries Sciences*, 19(1):352-371

Liu, Z., Sun, G., Huang, S., Sun, W., Guo, J., and Xu, M. (2012). Water Quality Index as a Simple Indicator of Drinking Water Source in the Dongjiang River, China. *Internationnal Journal of Environmental Protection*, 2:16-21.

Lohani, B.N. and Todino, M. (1984). Water quality index for Chao Phraya river. *J. Environmental Enginnnering Division (ASCE)*, 110: 1163–1175.

Madhulekha, S., Arya, S. and Agarwal, S. (2017). Study of Correlation Coefficient for Physico-chemical parameter to assess the water quality of river Ganga at Kanpur, India. *International Journal of Innovative Research in Science*, 6(8): 17164-17170.

Maiti, S.K. (2001). Handbook of methods in environment studies, water and wastewater analysis, Vol 1, Oxford. Pp- 138-141.

Maliya, S.D. and Singh, S.M. (2004). Diversity of aquatic & wetland macrophytes vegetation of Uttar Pradesh (India). *Journal of Economic & Taxonomic Botany*, 28(4) 935-975.

Mallik, B.K. (2014). Correlation and regression study on physico- chemical parameters of ground water nearby Tlawng River at Bairabi, Kolasib, Mizoram, India. International Journal of Geology, Earth and Environmental Sciences, 4 (1): 220-223.

Mandal, H.S. and Das, A. (2011). Assessment of seasonal variation in physico-chemical characteristics and quality of Torsha river water for irrigation used in Cooch Behar and Jalpaiguri Districts of West Bengal. *India. J. Chem. Pharm. Res.*, 3(6): 265- 270.

Manikannan, R., Asokan, S. and Ali, A.H.M.S. (2011). Seasonal variations of physico- chemical properties of the Great Vedaranyam Swamp, Point Calimere Wildlife Sanctuary, South-East coast of India. *African Journal of Environment Science and Technology*, 5(9): 673 -681.

Martin P, Haniffa M.A. (2003). Water quality profile in the South Indian River Tamiraparani. *IJEP*, 23:286-292.

Massoud, M.A. (2012). Assessment of water quality along a recreational section of the Damour River in Lebanon using the water quality index. *Environ. Monit. Assess*, 184:4151–4160.

Mathuthu A. S., Zaranyika F. M. and Jonnalagadda S. B. (1993) Monitoring of water quality in upper Mukuvisi river in Harare, Zimbabwe. *Environ. Int.*, 19:51–61.

Matta, G. (2014). A study on physico-chemical Characteristics to assess the pollution status of river Ganga in Uttarakhand. Journal of Chemical and Pharmaceutical Sciences. 7. 210-217.

Matta, Gagan. (2014). A study on physico-chemical Characteristics to assess the pollution status of river Ganga in Uttarakhand. *Journal of Chemical and Pharmaceutical Sciences*, 7:210-217.

Mbalassa, M., Bagalwa,J.J.M, Nshombo, M. and Kateyo, M.E. (2014). Assessment of physicochemical parameters in relation with fish ecology in Ishasha River and Lake Edward, Albertine Rift Valley. *Int.J.Curr.Microbiol.App.Sci.*, 3(6): 230-244.

Medhi, K.K., Borkataki, S. and Choudhury, M.P. (2015). An assessment of physico-chemical water quality of kolong river, Nagaon District (ASSAM), North East India. *Plant Archives*, 15(2):1093-1096.

Melzer, A. (1999). Aquatic macrophytes as tool for lake management. In: Harper, D.M., Brierley, B., Ferguson, A.J.D. and Phillips, G. (Eds.), The Ecological bases for Lake and Reservoir Management. *Hydrobiologia*, 395(396): 181-190.

Metcalf, E. and Eddy, H. (2003). Wastewater engineering: treatment and reuse, 4th edn. Tata McGraw-Hill Publ. Co. Limited, New Delhi, Pp-1819.

Milovanovic, M. (2007). Water quality assessment and determination of pollution sources along the Axios/Vardar River, Southeastern Europe. *Desalination, 213*, 159–173.

Misaghi, F., Delgosha, F., Razzaghmanesh, M. and Myers, B. (2017). Introducing a water quality index for assessing water for irrigation purposes: a case study of the Ghezel Ozan River. *Sci Total Environ*., 589:107–116.

Mishra, A., Mukherjee, A. and Tripathi, B.D. (2009). Seasonal and Temporal Variation in Physico- Chemical and Bacteriological Characteristics of River Ganga in Varansi. *Int. J. Environ. Res.*, 3(3): 395-402.

Mishra, B P. and Premeshowri, G. (2014). Impact of sandstone quarry on water quality of Tlawng river in Aizawl district, Mizoram, North east India. In: Management of Natural Resources for Sustainable Development: Challenges and Opportunities.

Mishra, B.P. (2008). Water pollution and food contamination in relation to health hazards: Food safety as a global challenge. *Pollution Research*, 27(3): 395-400.

Mishra, B.P. (2009). Status of the quality of spring water, the major source of drinking water in Mizoram, India, *Ecology, Environment & Conservation*, 15(1):159-165.

Mishra, B.P. and Lalhruaizeli. (2009). Status of quality of spring water in western part of Aizawl city, Mizoram. *Ecol Environ Conserv*., 15:159–165.

Mishra, B.P. and Tripathi, B.D. (2004). Distribution of macrophytes and phytosociology of H. verticillata, Casp. And L. minor Linn. in lotic and lentic aquatic ecosystems. *Ecology, Environment & Conservation*, 8(1): 37-41.

Mishra, B.P. and Tripathi, B.D. (2000). Sewage quality analysis: Pollutants removal efficiency of a sewage treatment plant. *J.Ind. Pollut. Contr*., 16(2): 239-251.

Mishra, B.P. and Tripathi, B.D. (2001). Impact of city sewage discharge in physico-chemical characteristics of river Ganga water. *Asian J. Micro, Biotech and Env. Sc.*, 3(4): 333- 338.

Mishra, B.P. and Tripathi, B.D. (2003). Seasonal variation in physico-chemical characteristics of Ganga River as influenced by sewage discharge. *Indian J. Ecol.*, 30: 27-32.

Mithani Imran, Dahegaonakar, N.R., Shinde J.S., and Tummawar, S.D. (2012). Priliminary studies on physico- chemical parameters of River Wardha, District chandrapur. Maharashtra. *Journal of Research in Ecology***,** 1(1):14-18**.**

Mitsch, J. and Gosselink, J.G. (2000). The values of wetlands: landscapes and institutional perspectives. The value of wetlands: importance of scale and landscape setting. *Ecological Economics*, 35(200): 25-33.

Mohanta, B.K. and Patra, A.K. (2000). Studies on the water quality index of river Sanmachhakandana at Keonjhar Garh, Orissa. *Poll. Res*., 19(3): 377-385.

Mormul, R.P., Ferreira, F.A., Michelan, T.S., Carvalho, P., Silveira, M.J. and Thomaz, S.M. (2010). Aquatic macrophytes in the large, sub-tropical Itaipu Reservoir, Brazil. *Int. J. Trop. Biol*., 58(4): 1437-1452.

Moyel, M. S. and Hussain, N. (2015). Water quality assessment of the Shatt Al-Arab River, Southern Iraq. *J. of Coastal Life Medicine*, 3(6):459-465.

Moyo, N.A.G. and Rapatsa, M.M. (2016). Impact of urbanization on the ecology of Mukuvisi River, Harare, Zimbabwe. *Physics and Chemistry of the Earth*, 92: 14-19.

Mrazovac, S., and Vojinović-Miloradov, M. (2011). Correlation of main physicochemical parameters of some groundwater in northern Serbia. *Journal of Geochemical Exploration*, 108(3):176–182.

Muduli, S.D., Swain, G.D., Bhuyan, N.K. and Dhal, N.K. (2006). Physico-chemical characteristic assessment of Brahmani river Orrisa, India. *Pollut. Res.*, 25, 763-766.

Mulla, J.G., Farooqui, M. and Zaheer, A. (2007). A correlation and regression equations among water quality parameters. *Int J Chem Sci*., 5: 943-952.

Munshi, J.S.D. and Singh, D.K. (1991). Physico-chemical profile of river Ganga, Kahalgann, Bihar, India, *Aquatic Science in India,* Gopal, B. and Asthana, V. (Ed.), Indian Association of Limnological Oceanography, Pp. 83-92.

Mustapha, A., Aris, A.Z., Juahir, H., Ramli, M.F. and Kura, N.U. (2013). River water quality assessment using environmentric techniques: case study of Jakara River Basin. *Environ Sci Pollut Res*., 20:5630–5644.

Muthulingam, U., Narayanasamy, D., Kankashanthi, K. and Thangavel, S. (2010). A floristic study in a perennial lake of Thiruvallur district, South India. *Web Med Central Ecology*, 1(10): 1-8.

Nair, G.A., Abdullah, I.M. and Fadiel, M.M. (2005). Physiochemical parameters and correlation coefficients of ground water of North East Libya. *Pollut. Res.*, 24:1-6.

Namrata S. (2010). Physico-chemical properties of polluted water of river Ganga at Varanasi. *International Journal of Energy and Environment*, 1(5):823-832.

Niroula, B. and Singh, K.L.B. (2011). Seasonal variation in Importance Value Index (IVI), Diversity Indices and Biomass of aquatic macrophytes at Biratnagar and adjoining areas, eastern Nepal. *Nepalese Journal of Biosciences*, 1: 1-7.

Nongmaithem, N. and Basudha, Ch. (2017). Physico-Chemical Properties of Different Water Bodies of Manipur. *Journal of Scientific Research and Reports*, 16:1-6.

Nurcihan, H. and Basaran D. (2009). Monthly variation of some physico-chemical and microbiological parameters in Biga Stream (Biga, Canakkale, Turkey). *African Journal of Biotechnology*, 8 (9):1929-1937.

O'Hare, M. T., Baattrup-Pedersen, A., Baumgarte, I., Freeman, A., Gunn, I. D. M., Lázár, A. N., Bowes, M. J. (2018). Responses of aquatic plants to eutrophication in rivers: A revised conceptual model. *Frontiers in Plant Science*, 9: 451–451.

Okweye, P. S. (2013). Seasonal variation in physico-chemical parameters and heavy metals assessment in surface water of North Alabama. *Research Journal of Chemistry and Environment*, 17(7): 68-115.

Omonona, O.V., Onwuka, O.S. and Okogbue, C.O. (2014). Characterization of groundwater quality in three settlement areas of Enugu metropolis, southeastern Nigeria, using multivariate analysis. *Environ Monit Assess*, 186**:**651–664.

Otieno, A.A., Kitur, E.L. and Gathuru, G. (2017). Physico-chemical properties of river Kisat, Lake Victoria Catchment, Kisumu County, Kenya. Environ. Pollut. *Climate Change*, 1(4): 1-4.

Pachuau, R. (2009). Mizoram: A Study in Comprehensive Geography. Northern Bok Centre, New Delh, Pp- 24-53.

Padial, A.A., Bini, L.M. and Thomaz, S.M. (2008). The study of aquatic macrophytes in neotropics: a scientometrical view of the main trends and gaps. *Brazilian Journal of Biology*, 68:139- 147.

Padmaja, S. (2019). A Study on the Water Quality Assessment of Nallavagu River in Sangareddy. *Can J Biomed Res & Tech*, 1(2): 3.

Pandey, M., and Sundaram, S. M. (2002). Trend of water quality of river Ganga at Varanasi using WQI approach. *International Journal of Ecology and Environmental Science*, 28:139–142.

Pandey, U.E., Tiwari, G.L. and Pandey, D.C. (1989). Ecology of macrophytes of Mcpherson lake (Allahabad). *J. Indian Bot Soc*., 68: 277-282.

Patel, A. and Datar, M. (2014). Seasonal variations of physico-chemical characteristics of river Betwa in Vidisha District. *I J S E T*, 3 (6): 2205 – 2214.

Patela, J.Y. and Vaghanib, M.V. (2015). Correlation Study for Assessment of Water Quality and Its Parameters of Par River Valsad, Gujarat, India. *International Journal of Innovative and Emerging Research in Engineering*, 2(2):150-156.

Pathak, K.C. (1990). A detailed study on the hydrophytic flora of Guwahati and its vicinity. Ph. D. Thesis. Guwahati University.

Patil, S. S. and Ghorade, I. B. (2013). Assessment of physicochemical characteristics of Godavari river water at Trimbakeshwar and Kopargaon, Maharashtra (India). *Environment*, 3(3): 149-152.

Pawar, R.M. and Shendge, N.M. (2016). Analysis of physico-chemical properties of water from different sources in and around Pune city. *Asain J. of Multidisciplinary Studies*, 4(3): 110-115.

Pesce, S. F., and Wunderlin, D. A. (2000). Use of water quality indices to verify the impact of Cordoba City (Argentina) on Suquýa River. *Water Research*, 34(11):2915–2926.

Pompeo, M.L.M. and Moschini-Carlos, V. (1996). Seasonal variation of the density of the macrophyte Scirpus cubensis (Poepp and Kunth) (CYPERACEAE) in the Lagoa do Inferno, State of Sao Paulo, Brazil. *Limnetica*, 12:17–23.

Ponsadailakshmi, S., Sankari, S. G., Prasanna, S. M. and Madhurambal, G. (2018). Evaluation of water quality suitability for drinking using drinking water quality index in Nagapattinam district, Tamil Nadu in Southern India. *Groundwater for Sustainable Development*, 6:43–49.

Prabu, V.A, Rajkumar, M. and Perumal, P. (2008). Seasonal variations in physico-chemical characteristics of Pichavaram mangroves, southeast coast of India. *J. Environ. Biol.*, 29:945-950.

Prasad, K.H., Anjali, C. and Reddy, M.S. (2016). Study of physico-chemical characteristics of Penna River at Chennur, Cuddapah basin, India. *Indian Journal of Advances in Chemical Science*, 4(1): 20-24.

Prasanna, M.B. and Ranjan, P.C. (2010). Physico chemical properties of water collected from Dhamra estuary. *International Journal of environmental sciences*, 1(3).

Prasannakumari, A A, Devi, T.G. and Sukeskumar, C.P. (2003). Surface water quality of river Neyyar - Thiruvananthapuram, Kerala, India. *Pollution Research,* 22:515-525.

Prati, L., Pavanello, R. and Pesarin, F. (1971). Assessment of surface water quality by a single index of pollution. *Water Research*, 5:741-751.

Raja, P., Muhindhar A.A., Elangovan, R. and Palanivel, M. (2008). Evaluation of physical and chemical parameters of river Kaveri, Tiruchirappalli, Tamil Nadu, India. *Journal of Environmental Biology*, 29(5):765-768.

Rajasegar, M. (2003). Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. *J. Environ. Biol*., 24:95-101.

Rajendran, R., Rajan, A., Raja, A.S., Prathipa, V. and Dheenadayalan, M. (2015). Assessment of Physico–Chemical Parameters of River Cauvery In and Around Nerur. *JESPR*, 1(1): 17-19.

Rajiv, R., Hasna, A.S., Kamaraj, M., Rajeshwari, S. and Sankar, A. (2012). Physico Chemical and Microbial Analysis of Different River Waters in Western Tamil Nadu, India. *International Research Journal of Environmental Sciences*. 1:2-6.

Ram, R. S. and Anandh, H. (1996). Water quality index of some Indian rivers. *Indian Journal of Environmental Health, NEERI, Nagpur, 38*(1): 21–34.

Ramakrishnaiah C. R., Sadashivaiah, C. and Ranganna, G. (2009). Assessment of Water Quality Index for the Ground Water in Tumkur Taluk. *E-Journal of Chemistry,* 6(2): 523-530.

Rao, C.F., Tiwari, R.P., Rao, A.R., Hassan, S.T., Someshwari, K. and Shymala, V. (1994). Soil erosion and land degradation prolems in Mizoram. Sponsored by Govt. of Mizoram. *IRDAS,* Hyderabad. Pp- 109.

Ravinder, K. and Pandit, A.K. (2006). Species composition and distribution of rooted floating-leaf vegetation in Hokarsar wetland of Kashmir Himalaya. *J. Res. Dev.,* 6: 43-50.

Rawson, D.S. (1937). Biological examination of the Kananskis Lakes, Alberta. Prep. for Alta. Ltd. Mines, *Fish. Serv*. Edmonton.

Reddy, C.S., Rangaswami, M., Pattanaik, C. and Jha, C.S. (2009). Invasion of alien species in wetlands of Samaspur Bird Santuary, Uttar Pradesh, India. Asian *Journal of Water, Environment and Pollution*, 6: 43-50.

Rich, P. H., Wetzel, R. G. and Van Thuy, N. (1971). Distribution, production and role of aquatic macrophytes in a Southern Michigan marl lake. *Freshwater Biology*, 1: 3-21.

Rios-Villamizar, E.A., Piedade, M.T.F., Junk, W.J. and Waichman, A.V. (2017). Surface water quality and deforestation of the Purus river basin, Brazilian Amazon. *Int. Aquat. Res*., 9:81-88.

Rout, S., Behera, A.K. and Patnaik, A. (2016). Water Quality Analysis of River Mahanadi in Sambalpur City. *IJSRP*, 6(2):266-279.

RRC. (2019). Action Plan for Conservation of Nine Rivers in Mizoram.

Sabrina Lalhmangaihzuali, Lalramnghinglova, H. and Mishra, B.P. (2019). Detail Assessment of Physico-Chemical Properties of Perennial Spring Water within Aizawl City, Mizoram. *RRIJM*, 4(10): 51-56.

Sah, S.K., J.P. Sah and V.A. Lance. (2000). Industrial Effluents and their Use in Agriculture along the Narayani River, Nawalparasi, Nepal. In: *Environment and Agriculture: At the Crossroad of the New Millennium (eds.)* Jha , P.K., S.B. Karmacharya, S.R. Baral and P. Lacoul. Ecological Society (ECOS), Nepal, Pp-456-466.

Said, A., Stevens, D. K. and Sehike, G. (2004). An innovative index for evaluating water quality in streams. *Environmental Management*, 34(3), 406-414.

Saikia, M. M. and Sarma, H. P. (2011). Fluoride geochemistry of Kollong river basin, Assam, India. *Archives of Applied Science Research*, 3(3):367–372.

Saikia, R. and Das, A. (2018). Studies on the Physico-Chemical Parameters of Kapili River, Rani in Kamrup District of Assam (India). *IJRAR*, 5(3):35-43.

Samantray, P., Mishra, B.K., Panda, C.R. and Rout, S.P. (2009). Assessment of water quality index in Mahanadi and Atharabanki River and Taldanda Canal in Paradip Area, India. *J Hum Ecol.*, 26:153-161.

Saravanakumar, K. and Kumar, R.R. (2011). Analysis of water quality parameters of groundwater near Ambattur industrial area, Tamilnadu, India. *Ind. J. Sci. Technol.*, 4(5): 560-562.

Sargaonkar, A. and Deshpande, V. (2003). Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environmental Monitoring and Assessment,* 89: 43-67.

Sarma, G.C. and Devi, N. (1999). Survey of Aquatic Flora of Goalpara District. In: Y.P.S. Pundir, Prashant Gahlot and Mohit Gahlot, (Eds,) Advances in Plant Science Rearch in India, International Book Distributors, (Editor), Advances in Plant Science Research in India, Dehradun. 19: 97-104.

Sarwade, A. and Kamble, N. (2015). Evaluation of physicochemical parameters of river Krishna, Sangli Maharashtra. *Octa Journal of Environmental Research*, 2:329-337.

Sawyer, C.H. (1960). Chemistry for sanitary engineers. Mc Graw Hill Book Co., New York.

Schaeperclaus, W., Kulow, H. and Schreckenbach, K. (1990). *Fischkrankheiten,* Berlin: Akademie-Verlag.

Sculthorpe, C.D. (1985). The biology of aquatic vascular plants. Konigstein-West Germany, Koeltz Scientific Books. Pp-597.

Seanego, K. G. and Moyo, N. A. G. (2013). The effect of sewage effluent on the physico-chemical and biological characteristics of the Sand River, Limpopo, South Africa. *Physics and Chemistry of the Earth, 66:75–82.*

Selakoti, B. and Rao, S.N. (2015). A study on seasonal fluctuations in physico-chemical variables in spring fed Kosi River at Almora province from central Himalaya, India. *Int.J.Curr.Microbiol.App.Sci*., 4(4): 418-425.

Senthilmanickam, J., Sabaridasan, A. and Soranam, R. (2016). A Study on Physico-Chemical Properties of Water Samples from Cauvery River of Pallipalayam Town, Namakkal District of Tamil Nadu, India. *Int. J. Adv. Sci. Eng*., 2(4):193-199.

Shah, M. C., Shilpkar, P and Sharma, S. (2007). Correlation, Regression Study on Physico-chemical parameters and water quality assessment of ground water of Mansa Taluka in Gujarat. *Asian Journal of Chemistry*, 19(5):3449-3454.

Sharma, P., Meher, P.K., Kumar, A., Gautam, Y.P., and Mishra, K.P. (2014). Changes in water quality index of Ganges river at different locations in Allahabad. *Sustainability of Water Quality and Ecology,* 3(4):67–76.

Sharma, R.K., Agrawal, M. and Marshall, F.M. (2004). Effects of waste water irrigation on heavy metal accumulation in soil and plants. Paper presented at a National Seminar, Bangalore University, Bangalore, Abst. No. 7, Pp-8.

Shigut, D.A., Liknew, G., Irge, D.D. and Ahmad, T. (2017). Assessment of physico-chemical quality of borehole and spring water sources supplied to Robe Town, Oromia region, Ethiopia. *Appl Water Sci*., 7:155–164.

Shinde SE, Pathan TS, Raut KS, Sonawane DL. (2011). Studies on the physico-chemical parameters and correlation coefficient of Harsool-savangi Dam, District Aurangabad, India. *Middle-East J Sci Res*., 8:544-554.

Shukla, M., Arya, S. and Agarwal, S. (2017). Study of Correlation Coefficient for Physico-chemical parameter to assess the water quality of river Ganga at

Kanpur, India. *International Journal of Innovative Research in Science*, 6(8): 17164-17170.

Simoes, F. S., Moreira, A. B., Bisinoti, M. C., Gimenez, S. M. N. and Yabe, M. J. S. (2008). Water Quality Index as a Simple Indicator of Aquaculture Effects on Aquatic Bodies. *Ecological Indicators*, 8(5): 476-484.

Singh, E. and Singh, M.P. (2010). Phytosociological analysis of macrophytes around Municipal Drains in Jaunpur. *International Journal of Biological, Biomolecular, Agricultural, Food and Botechnological Enginee*ring, 4(1): 84-89.

Singh, J., Gangwara, R. K., Khare, P., and Singh, A. P. (2012). Assessment of physico-chemical properties of water: River Ramganga at Bareilly, U.P. *Journal of Chemical and Pharmaceutical Research*, *4*, 4231–4234.

Singh, M.K., Paul, R., Karmakar, B., Jamatia, A and Das, M.K. (2016). Water quality assessment of river Haora in Agartala stretch during Durga idol immersion. *International Journal of Geology, Earth and Environmental Sciences*, 6(2): 37-44.

Singh, M.R. and Gupta, A. (2010). Seasonal variation in certain physicochemical parameters of Imphal, Iril and Toubal rivers from Manipur river system, India. *Ecology, Environment and Conservation*, 16(2): 197-207.

Singh, M.R., Gupta, A. and Beeteswari, K.H. (2010). Physico-chemical properties of water samples from Manipur river system, India. *J. Appl. Sci. Environ. Manage*., 14(4): 85-89.

Singh, N. (2010). Physicochemical properties of polluted water of river Ganga at Varanasi. *IJEE*., 1(5): 823-832.

Singh, N. and Sharma, R.C. (2016). Assessment of Physico-chemical parameters of Mountain River Baldi, Garhwal Himalayas. *IJFAS*., 4(2): 88-93.

Singh, N.K., Dutta, G.R., Singh, M. and Kishore, K. (1989). Assessment of water quality of the river Subernarekha at Ghatsila with reference to heavy metal pollution. *Freshwater Bio.,* 1(2): 113-120.

Singh, R.P. and Mathur, P. (2005). Investigation of variation in physicochemical characteristics of fresh water reservoir of Ajmer city, Rajasthan, India. *Journal of Environmental Science*, 9: 57-61.

Singh, T.G. and Gupta, A. (2015). A preliminary assessment of water quality in Nambul River, Manipur, India. *Indian Journal of Applied Research*, 5(7): 230-232.

Singh, Y.V. , Sharma, P.K., Meena, R., Kumar, M. and Verma, S.K. (2016). Physico-chemical analysis of river Ganga at Varanasi City in Uttar Pradesh, India. *Indian Journal of Agriculture and Allied Sciences,* 2(3):41-45.

Sirsath, D.B., Ambore, N.E., Pulle, J.S. and Thorat, D.H. (2006). Studies on the concentration of ion in freshwater pond at Dharampuri, Dist, Beed, India. *Poll. Res*. 25(3):507-509.

Sondergaard, M. and Sand-Jensen, K. (1979). Carbon uptake by leaves and roots of *Littorella uniflora* (L.) Aschers. *Aquat Bot.*, 6:1–12.

Srivastava, N., Harit, G. and Srivastava, R. (2009). A study of physico-chemical characteristics of lakes around Jaipur, India. *Journal of Environmental Biology,* 30(5): 889-894.

Srivastava, R.K., Sinha, A.K., Pandey, D.P., Singh, K.P. and Chandra, H. (1996) Water quality of the river Ganga at Phaphamau (Allahabad): Effect of mass bathing during MahaKumbh. *Environ.Toxicol. Water Qual*., 11(1):1-5.

Stambuck-Giljanovic, N. (1999). Water quality evaluation by index in Dalmatia. *Water Res.,* 33(16):3426–3440.

Stark, J.R., Hanson, P.E., Goldstein, R.M., Fallon, J.D., Fong, A.L., Lee, K.E., Kroening, S.E. and Andrews, W.J. (2001). *Water Quality in the Upper Mississippi River Basin, Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota, 1995–98*; United States Geological Survey: Reston, VA, USA.

Statistical Handbook, Mizoram. (2019). Directorate of Economics & Statistics, Government of Mizoram.

Stoner, J.D. (1978). Water Quality Indices for Specific Water Uses. USGS Circular No. 770, Department of the Interior, Arlington, VA. Pp-12.

Subramanyam, K. (1962). Aquatic Angiosperms: a systematic account of common Indian aquatic angiosperms. Botanical Monograph 3(1-6) 1-190. CSIR, New Delhi.

Sunar, S. and Mishra, B.P. (2018). Correlation and linear regression as a water quality monitoring tool for Serlui River in Kolasib district, Mizoram, India. *International Journal of Academic Research and Development*, 3(2): 676-680.

Sunar, Sangeeta and Mishra, B.P. (2016). Assessing the impact of Hydroelectric Power Project on the water quality of Serlui River in Kolasib district, Mizoram, North-East India. *Int. Res. J. Environment Sci*, 5(9):40-44.

Suresh, B., Manjappa, S. and Puttaiah, E.T. (2011) Phytoplankton dynamics and seasonal variation in Tungabhadra River, India. *Int. J. Water Res. Environ. Eng*., 3(14). 370-379.

Swer, S and Singh, O.P. (2004). Coal mining impacting water quality and aquatic biodiversity in Jaintia hills district of Meghalaya. *Envis Bulletin Himalayan Ecology*, 11(2): 29-36.

Swierk, D. and Krzyzaniak, M. (2019). Is There a Pattern for Occurrence of Macrophytes in Polish Ponds? *Water*, 11:1738

Tahera A., Fatema Tuz J., Fahmida A., Tridib Roy C., Sabuj Kanti M., Digbijoy D., Milan K. B, M D Akramul I., Mahfuzar R. (2016). Water quality index for measuring drinking water quality in rural Bangladesh: a crosssectional study. *Journal of Health, Population and Nutrition*, 35(4):1–12.

Tamire, G. and Mengistou, S. (2012). Macrophyte species composition, distribution and diversity in relation to some physicochemical factors in the littoral zone of Lake Ziway, Ethiopia. *African Journal of Ecology*, 51(1):66-77.

Tamire, G. and Mengistou, S. (2014). Biomass and net aboveground primary productivity of macrophytes in relation to physico-chemical factors in the littoral zone of Lake Ziway, Ethiopia. *Tropical Ecology*, 55:313-326.

Taran, M., Deb, S. and Roy, J. (2016). Physico-chemical characteristics, biodiversity assessment and economic valuation of Kalyanthakur para lake: a community based lake of Tripura, North-east India. *Lakes, reservoirs and ponds*, 10(2):96-109.

Tassaduqe, K., Ali, M., Salam, A., Latif, M. and Zahra, T., (2003). Study of the Seasonal Variations in the Physico Chemical and Biological Aspects of Indus River Pakistan. *Pakistan Journal of Biological Sciences*, 6 (21): 1795 – 1803, 2003.

Tawati, F., Risjani, Y., Djati, M.S., Yanuwiadi, B. and Leksono, A.S. (2018). The analysis of the physical and chemical properties of the water quality in the rainy season in the Sumber Maron River- Kepanjen, Malang-Indonesia. *Resources and Environment*, 8(1): 1-5.

Tchobanoglous G. and Schroeder E. D. (1987). Water Quality. Addison-Wesley, Reading, M.A.

Thasangzuala, Z.R. and Mishra, B.P. (2014). Physical characteristics of public drinking water in Aizawl city, Mizoram, India. *International Journal of Engineering & Technical Research*, 2(10): 56-60.

Thasangzuala, Z.R., Premeshowri, G. and Mishra, B.P. (2014). Chemical characteristics of public drinking water in Aizawl city, Mizoram, India. *International Journal of Green & Herbal Chemistry*, 4(1): 9-16.

Thengaonkar, V.P and Kulkarni, D.N. (1971). Relationship between alkalinity and flurides. *Indian Journal of Environmental Health*. 13(2): 144-153.

Thitame, S. N. and Pondhe, G. M. (2010). Assessment of seasonal variation in physico-chemical characteristics and quality of Pravara River water for irrigation use in Sangamner, Dist Ahmednagar, Maharashtra. J. Chem. Pharm. Res., 2(2): 316-320.

Tiwari, M. (2005). Assessment of physicochemical status of Khanpura Lake, Ajmer in relation to its impact on public health. *Eco. Env. And Cons*., 11(3-4): 491-493.

Tiwari, R.K, Rajak, G.P., Abhishek and Mondal, M.R. (2005). Water Quality Assessment of Ganga River in Bihar Region, India. *J. Env. Sci. & Engg*., 47:326-335.

Tiwari, T.N. and Mishra, M. (1985) A preliminary assignment of water quality index of major Indian rivers. *IJEP*, 5:276-279.

Tiwari, T.N., Das, S.C. and Bose, P.K. (1986). Water Quality Index for the River Jhelum in Kashmir and its Seasonal Variations. *Poll. Res*., 5:1-5.

Toufeek, M.A. and Korium, M.A. (2009). Physico-chemical characteristics of water quality in Lake Nasser water. *Global J. Environ. Res*., 3(3): 141-148.

Tripathi, A. K. (2002). Effect of municipal wastes on the riparian ecosystem along river bank at Jaunpur. Ph.D. Thesis, V.B.S.P.U. Jaunpur.

Tripathi, B.D. and Shukla, S.C. (1991). Biological treatment of wastewater by selected aquatic plants. *Environ. Poll*., 6: 69-78.

Tripathi, B.D., (1992). Utilization of aquatic plants for sewage treatment. Austrian NFP/UNEP Vienna, Autria. B/BD 3: 10-14.

Trivedi, P., Bajpai, A., and Thareja, S. (2009). Evaluation of Water Quality: Physico-Chemical Characteristics of Ganga River at Kanpur by using Correlation Study. *Nat and Sci*., 6:91-94.

Trivedy, R.K. (1988). Ecology and Pollution of Indian Rivers, Ashish

Udomsri, C., Premcharoen, S., Thawatphan, C., Vidthayanon, C. and Vajrodaya. S. (2005). Community structure of aquatic plant in Bung Khong Long, Nongkhai province, A Ramsar site of Thailand. *Kasetsart J. (Nat.Sci)*, 39 : 64-75.

Unni, K.S. (1971). Studies on the vegetation of ponds, swamps and riverbanks in Raipur, Madhya Pradesh. *Journal of Bombay Natural History Society*, 64(1): 95-102.

USPH. (1962). Drinking water standards. P.H.S. Pub. 956. U.S. *Department of Health, Education and Welfare*. Washington, D.C.

Van der Valk, A.G. and. Davis, C.B. (1976). Changes in the composition, structure and production of plant communities along a perturbed wetland coenocline. *Vegetatio*. 32: 87–96.

Varol M., Gokot B., Bekleyen A., and Sen, B. (2011). Water quality assessment and apportionment of pollution sources of Tigris River (Turkey) using multivariate statistical techniques: A case study. *River Res. Applic*, 28(9): 1429-1438.

Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Rajiv, G.R., Chidambaram, S., Anandhan, P., Manivannan, R. and Vasudevan, S. (2010). Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. *Environ Monit Assess*, 171:595–609.

Venkatesharaju K., Ravi Kumar, P., Somashekar, R.K. and Prakash, K.L. (2010). Physicochemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. *Journal of Science, Engineering and Technology*, 6: 50-59.

Venkatramanan, S., Chung, S.Y., Lee, S.Y. and Park, S. (2014). Assessment of river water quality via environmentric multivariate statistical tools and water quality index: a case study of Nakdong River Basin, Korea. *Carpathian J Earth Environ Sci.*, 9:125–132.

Vyas, L.N. (1964). A study of the hydrophytes and marsh plants of Alawar. *J. Indian bot. Soc*., 43: 17-30.

Wang, J. L., Fu, Z. S., Qiao, H. X. and Liu, F. X. (2019). Assessment of eutrophication and water quality in the estuarine area of Lake Wuli, Lake Taihu, China. *Science of the Total Environment*, 650:1392–1402.

Warren, C.E. (1971). Biology and Water Pollution Control. W.B. Saunder.

Watkar, A. M., and Barbate, M. P. (2015). Seasonal variations in Physico- chemical Properties of Chandrabhaga River in Dhapewada, Dist. Kalmeshwar Maharashtra, India. *Research Journal of Recent Sciences*, 4:1–4.

Westlake, D.F. (1965). Some basic data for investigations of the productivity of aquatic macrophytes. *Mem. Inst. Ital. Idrobiol*, 18:229-248.

WHO. (2008). *Guidelines for drinking water quality*, 3rd ed. World Health Organisation, Geneva.

Yadav, A.K., Khan, P. and Sharma, S.K. (2010). Water quality index assessment of groundwater in Todoraisingh tehsil of Rajasthan state, India-A greener approach. *E-Journal of Chemistry*, 7:S428-S432.

Yadav, R. C. and Srivastava, V.C. (2011). Physico-Chemical Properties of the Water of river Ganga at Gazipur. *Indian Journal of Science Research*, 2 (4): 41-44.

Yogendra, K. and Puttaiah, E.T. (2008). Determination of water Quality Index and Suitability of urban water body in Shimoga Town, Karnataka. The 12th world lake conference. Pp-342-346.

Zafar, A. and Sultana, N. (2008). Seasonal analysis in the water quality of river Ganga. *J. Curr. Sci*., 12(1): 217-220.

BIODATA

NAME: H. LALDINPUII
DEPARTMENT OF ENVIRONMENTAL SCIENCE
MIZORAM UNIVERSITY

CONTACT NO: +91 9774357603

EMAIL-ID: deehauhnar@gmail.com

TITLE OF THESIS: IMPACT OF POLLUTANTS ON WATER QUALITY AND DISTRIBUTION OF AQUATIC MACROPHYTES OF RIVER SERLUI-A, MIZORAM.

SUPERVISOR: Prof. B.P. MISHRA
DEPARTMENT OF ENVIRONMENTAL SCIENCE
MIZORAM UNIVERSITY

WORKSHOP/ SEMINAR

1. Attended the workshop on "Statistical and Computing Methods for Life-Science Data Analysis" held from 9th February to 16th February, 2015 organized by the Biological Anthropology Unit, Indian Statistical Institute, Kolkata.
2. Participated in "Two-day workshop on Current Trends of Biodiversity Research in Mizoram" held on 20th and 21st March, 2015 organized by Department of Environmental Science, Mizoram University and Department of Zoology, Pachhunga University College.
3. Participated in the "National Workshop on Statistical Analysis Using Excel Software" held on 13th-15th July, 2016 organized by Department of Statistics, Pachhunga University College.
4. Participated at the seminar on " Science and Technology for a Sustainable Future" organized by Mizoram Academy of Sciences, Mizoram Science, Technology & Innovation Council (Govt. of Mizoram) and Pachhunga University College held on 30th April, 2018.
5. Participated in the Mizoram Science Congress, 2018, a National Conference held at Pachhunga University College during 4th and 5th October, 2018.

6. Participated in "Regional Seminar on Climate Change: Impact, Adaptation & Response in the Eastern Himalayas" held from 1st -2nd, November, 2018 organized by the Department of Environmental Science, Mizoram University, Aizawl in collaboration with IHCAP- Indian Himalayas Climate Adaptation Programme.

7. Participated in the National Conference on Emerging Trends in Environmental Research held during 31st -2nd November, 2019, organized by the Department of Environmental Science, Pachhunga University College, Aizawl in collaboration with Environment, Forest and Climate Change Department, Government of Mizoram.

8. Participated at the International Conference on recent Advances in Animal Sciences (ICRAAS) from 6th-8th November, 2019 organized by Department of Zoology, Pachhunga University College, Aizawl along with Mizo Academy of Sciences, Mizoram University, Directorate of Fisheries (Govt. of Mizoram), Directorate of Agriculture (Research & Education, Govt. of Mizoram) and Environment, Forest and Climate Change Department (Govt. of India).

PAPER / POSTER PRESENTATION

1. Presented a poster entitled Environmental Implications of Developmental Activities on Water Quality of Serlui-A in Vicinity of Aizawl City, Mizoram" in the Regional Seminar on Climate Change: Impact, Adaptation & Response in the Eastern Himalayas held from 1st -2nd, November, 2018 organized by the Department of Environmental Science, Mizoram University, Aizawl in collaboration with IHCAP- Indian Himalayas Climate Adaptation Programme.

2. Presented a paper entitled "Assessment of Seasonal Variation in Physicochemical quality of Serlui-A River, Aizawl, Mizoram" in the National Conference on Emerging Trends in Environmental Research held during 31st - 2nd November, 2019, organized by the Department of Environmental Science, Pachhunga University College, Aizawl in collaboration with Environment, Forest and Climate Change Department, Government of Mizoram.

PAPER PUBLICATION

1. Laldinpuii, H. and Mishra, B.P. Assessment of the Chemical Characteristics of River Serlui-A in Aizawl, Mizoram, North East, India. *Environment and Ecology*, 37 (4):1141—1146.
2. Laldinpuii, H. and Mishra, B.P. 2020. Study of Physical Characteristics of Serlui-A River, Mizoram, Northeast India. *RRIJM*, 5(3):47-50.

PERSONAL DETAILS

Father's Name: Shri. Lalhmingthanga

Mother's Name: Smt. Margaret Zirsangliani Khiangte

Language: English, Mizo

Nationality: Indian

DECLARATION:

I hereby declare that the above information is correct to the best of my knowledge.

(H. LALDINPUII)

PARTICULARS OF THE CANDIDATE

NAME OF CANDIDATE: H. Laldinpuii

DEGREE: Ph.D.

DEPARTMENT: Environmental Science

TITLE OF THESIS: Impact of pollutants on water quality and distribution of aquatic macrophytes in river Serlui-A, Mizoram

DATE OF ADMISSION: 01.08.2015

APPROVAL OF RESEARCH PROPOSAL:

1. DRC: 31.03.2016
2. BOS: 7.04.2016
3. SCHOOL BOARD: 13.04.2016

MZU REGISTRATION NO.: 5923 of 2012

Ph.D. REGISTRATION NO. & DATE: MZU/Ph. D/903 0F 13.04.2016

Head
Department of Environmental Science

(ABSTRACT)

IMPACT OF POLLUTANTS ON WATER QUALITY AND DISTRIBUTION OF AQUATIC MACROPHYTES INRIVER SERLUI-A, MIZORAM

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

H. LALDINPUII

MZU REGISTRATION NO. 5923 0F 2012

PH.D REGISTRATION NO.: MZU/Ph. D/903 0F 13.04.2016

DEPARTMENT OF ENVIRONMENTAL SCIENCE
SCHOOL OF EARTH SCIENCE AND NATURAL RESOURCES MANAGEMENT

AUGUST, 2021

ABSTRACT

Water is one of the essential natural resource which is found around 75% in ocean comprises 97.4 % and the remaining in form of ice-caps and glacier, fresh water compartments of the hydrosphere. The water (rain, river, sea and ground water) is one of the major components of environmental resources that is under threat either from over exploitation or pollution, exacerbated by human activities on the earth's surface. Fresh water resources are used by humans for various purposes such as drinking, bathing and sanitation. In addition to these, people also depend on water resources for agriculture, commercial enterprises, mining, recreation, navigation and thermoelectric and hydroelectric power.

Water quality assessment is an essential process in the development of water resources and may be defined in terms of specific characteristics of water usually physical, chemical and biological (including bacteriological) that are important with regards to a certain servicesand human health is at risk if values exceed acceptable limits.

For detailed investigation, Serlui-A river has been selected which is approximately 7-8 kms long and it flows from Lungleng village towards Maubawk where it merges with river Tlawng. This river is being used for 1 MW Serlui- A hydroelectric power station.

The present study was taken up with the following objectives:

1. To study the water quality of Serlui-A river at selected sites.
2. To study distribution of aquatic macrophytes along Serlui-A river at selected sites.
3. To assess impact of pollutants on water quality and distribution of aquatic macrophytes in Serlui-A river.

For detailed study, four sampling sites of Serlui-A river were selected namely, Site 1 (situated near the source in Lungleng village, and considered as control/reference site to compare results from other sites selected towards downstream of river), Site 2 (situated just before hydroelectric power station), Site 3 (situated just after hydroelectric power station) and Site 4 (situated at the point where Serlui-A river merges with river Tlawng).

During the study period, water samples were collected on a monthly basis for two consecutive years (October 2016- September 2018). The water samples were then analysed for various physico-chemical characteristics namely, temperature, EC, turbidity, TDS, pH, DO, BOD, total alkalinity, acidity, total hardness, chloride, phosphate and nitrite. The methods as outlined in the 'Standard Methods for Examination of Water and Wastewater' (APHA, 2005) and 'Handbook of Methods in Environmental Studies, Water and Waste Water Analysis (Maiti, 2001) were followed. The observations were computed and expressed seasonally i.e., Post-monsoon (October-January), Pre-Monsoon (February-May) and Monsoon (June-September) seasons. To check the validity and significance of the observed data, analysis of variance (ANOVA) and correlation coefficient was carried out.

The findings of the present study can be summarized as follows:

1. The temperature ranged from 16.7^{0}C (Site 1, Post-Monsoon season) to 26.7^{0}C (Site 4, Monsoon season). The values were found to be high in Monsoon season and low during Post-monsoon season for both the years.
2. The electrical conductivity ranged from 23 μS (Site 1, Post-Monsoon Season) to 277.2 μS (Site 4, Monsoon season). The values found to be high in Monsoon season and low during Post-monsoon season for both the years
3. The total dissolved solids ranged from 14.7 mgL^{-1} (Site 1, Post-monsoon season)to 148.5 mgL^{-1} (Site 4, Monsoon season). The values were found to be low during Post-monsoon season and high during Monsoon season.

4. The turbidity as 2.3 NTU (Site 1, Post-monsoon season) to 6.7 NTU (Site 2 & 3, Monsoon season). The values were found to be lowest during Post-monsoon season and highest during Monsoon season.
5. The pH ranged from 6.1 (Site 1, Monsoon) to 7.9 (Site 3 & 4, Post-monsoon season). The values were found to be lower during monsoon season and higher during Post-monsoon season.
6. The DO ranged from 5 mgL^{-1}(Site 3, Monsoon season) to 7.9 mgL^{-1} (Site 1, Post-monsoon season). The values were found to be high in Post monsoon season and low during Monsoon season for both the years.
7. The BOD ranged from 1.1 mgL^{-1} (Site 1, Post- monsoon season) to 3.8 mgL^{-1} (Site 2, Monsoon season). The values were found to be high during Monsoon season and low during Post-monsoon season.
8. The chloride ranged from 1.33 $mgL\text{-}^{1}$ (Site 1, Monsoon season) to 44 mgL^{-1} (Site 3, Pre-monsoon season). The values were found to be lowest during monsoon season and highest during pre-monsoon season.
9. The total alkalinity ranged from 25.6 mg L^{-1} $CaCO_3$ (Site 1, Monsoon season) to 200 mg L^{-1} $CaCO_3$ (Site 2, Post-monsoon season). The values were found to be lowest during monsoon season and highest during the post-monsoon season.
10. The acidity ranged from 3.4 mgL^{-1} (Site 2, Pre-monsoon season) to 9 mgL^{-1} (Site 1, monsoon season). The values were found to be slightly higher during Monsoon season and lower during Pre-monsoon season.
11. The total hardness ranged from 18 mgL^{-1} $CaCO_3$ (Site 1, Monsoon season)to 141 mgL^{-1} $CaCO_3$ (Site 4, Pre-monsoon season). The values were found to be highest during pre-monsoon season as compared to post monsoon and monsoon season.
12. The phosphate-P ranged from 0.005 mgl^{-1} (Site 1, Post-monsoon season) to 0.246 mgl^{-1} (Site 4, Monsoon season). The values were found to be highest during monsoon season and lowest during pre-monsoon season.

13. The nitrite ranged from 0.008 mgl^{-1} (Site 1, Post-monsoon season) to 0.087 mgl^{-1} (Site 4, Monsoon season). The values were found to be highest during monsoon season and lowest during post-monsoon season.
14. The WQI at Site 1 (Control site) was found to be **35** and falls within Grade B (26-50) of the water quality classification based on weighted arithmetic WQI method.
15. The WQI at Site 2, Site 3 and Site 4 were found to be **131,132** and **134** respectively, and fall within Grade E (>100) of the water quality classification (polluted) based on weighted arithmetic WQI method.
16. The water quality attributes and WQI depict that the river water at Site 1 (Control/Reference Site) is clean, and intensity of pollutants is increased from upstream to downstream of river (Site 2 to 4).
17. Statistical analysis namely, ANOVA, correlation coefficient and linear regression and ANOVA were computed to check the significance and validity of data on water quality analysis.
18. A total of 17 macrophytes belonging to 12 families were reported from the study sites.
19. The study Site 1 was represented by 6 species namely *Ageratum conyzoides*, *Colocasia affinis, Commelina benghalensis, Juncus effuses, Murdannia nudiflora,* and *Polygonum barbatum.* It can be argued that there is no effect of pollutants on distribution of such species.
20. Site 2, 3 and 4 by 15 species each namely *Ageratum conyzoides, Alternanthera sessilis, Canna indica, Colocasia affinis, Cynodon dactylon, Cyperus scariosus, Dichrocephala integrifolia, Drymaria cordata, Echinochloa stagmina, Eichhornia crassipes, Murdannia nudiflora, Pistia stratoise Polygonum barbatum, Polygonum hydropiper and Pteridium aquilinum* These species are tolerant to pollution and growing well in polluted water.
21. Four species namely *Ageratum conyzoides*, *Colocasiaaffinis, Murdannianudiflora*and *Polygonumbarbatum* were found at all study Sites, indicating high ecological amplitude towards pollution.

22. The species present only at Site I (Control/Reference Site) are sensitive to pollutants and regarded as pollution indicator species, and used for biomonitoring of water bodies.

The overall findings show that there was a seasonal fluctuation in the values of various physico-chemical characteristics in the river. All the water quality parameters lie within the permissible limit as given by different scientific agencies except phosphate values for Site 2, Site 3 and Site 4 during all the seasons. High phosphorus value may be attributed to discharge of waste through run-off containing phosphorus. Proper treatment of water is of great importance as long term use may adversely affect both human and aquatic lives. The pollutants present in the river has some effect on the distribution of aquatic macrophytes. This is evident from the presence of *Alternantherasessilis,Eichhorniacrassipes* and *Pistia stratiotes* at site 2, 3 and 4 and absence in Site 1. The presence of these macrophytes may be due to due to the accumulation of sewage containing more organic load.

Anthropogenic activities at Site 2, 3 and 4 has led to degradation of water quality as compared to Site 1 (control site). Thus, regular monitoring of the river water quality should be done so as to know the status of the river. Disposal of wastes into river must be checked. Awareness programme should be conducted to educate the people on the importance of proper management of the river water.

(H. LALDINPUII)
Research Scholar

(Prof. B.P. MISHRA)
Supervisor
Department of Environmental Science
Mizoram University