STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM

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STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM

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CERTIFICATE

This is to certify that the Ph.D. Thesis entitled "**STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM**" submitted by **Sabrina Lalhmangaihzuali** for the award of the degree of Doctor of Philosophy in the Department of Environmental Science, Mizoram University, is a record of original investigation carried out by her under my supervision. The authenticity and content of the thesis are the original work of the Research Scholar. It is further certified that no portion(s) or part(s) of the content of the thesis has been submitted for any degree in Mizoram University or other University or Institute. She has been duly registered and the thesis presented is worthy of being considered for the award of the Doctor of Philosophy in Environmental Science.

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I **Sabrina Lalhmangaihzuali,** hereby declare that the subject matter of this thesis entitled **"STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM"** is the record of work done by me, that the content of the thesis does not form basis of the award of any previous degree to me or to do 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.

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CONTENTS

		Page No.
Certificate		i
Declaration		ii
Acknowledgements		iii-iv
Contents		v
List of Tables		vi
List of Figures		vii-ix
List of Maps		x
List of Photo plates		xi-xiv
Body of the thesis		1-205
CHAPTERS		**Page No.**
CHAPTER 1	INTRODUCTION	1-10
CHAPTER 2	REVIEW OF LITERATURE	11-18
CHAPTER 3	METHODOLOGY	19-34
CHAPTER 4	RESULTS	35-109
CHAPTER 5	DISCUSSION	110-142
CHAPTER 6	SUMMARY AND CONCLUSIONS	143-152
References		153-170
Appendices		171-210
Bio-Data		
Particulars		

LIST OF TABLES

Table No.	TABLE TITLE	Page No.
3.1	Location of sampling sites.	25
4.1	List of water resources found in the north zone.	34-35
4.2	List of water resources found in the east zone.	36
4.3	List of water resources found in the west zone.	37-38
4.4	List of water resources found in the south zone.	39
5.1	One-way Anova for water temperature variations.	72
5.2	One-way Anova for water turbidity variations.	74
5.3	One-way Anova for water turbidity variations.	76
5.4	One-way Anova for water ORP variations.	78
5.5	One-way Anova for water acidity variations.	80
5.6	One-way Anova for water acidity variations.	82
5.7	One-way Anova for water chloride variations.	84
5.8	One-way Anova for water total hardness variations .	86
5.9	One-way Anova for water DO variations.	88
5.10	One-way Anova for water BOD variations.	90
5.11	One-way Anova for water nitrite variations.	92
5.12	One-way Anova for water phosphate variations.	94
5.13	One-way Anova for water sulphate variations.	96
5.14	One-way Anova for water total coliform variations.	98
5.15	One-way Anova for water faecal coliform variations.	100

LIST OF FIGURES

Fig. No.	FIGURE TITLE	Page No.
4.1	Seasonal variation in temperature of water at selected study sites during 2016-2017.	40
4.2	Seasonal variation in temperature of water at selected study sites during 2017-2018	40
4.3	Seasonal variation in turbidity of water at selected study sites during 2016-2017	42
4.4	Seasonal variation in turbidity of water at selected study sites during 2017-2018	42
4.5	Seasonal variation in pH of water at selected study sites during 2016-2017	44
4.6	Seasonal variation in pH of water at selected study sites during 2017-2018	44
4.7	Seasonal variation in oxidation reduction potential of water at selected study sites during 2016-2017	46
4.8	Seasonal variation in oxidation reduction potential in water at selected study sites during 2017-2018	46
4.9	Seasonal variation in acidity of water at selected study sites during 2016-2017	48
4.10	Seasonal variation in acidity of water at selected	

study sites during 2017-20 18 48

4.11 Seasonal variation in alkalinity of water at selected study sites during 2016-2017 50

4.12 Seasonal variation in alkalinity of water at selected study sites during 2017-2018 50

4.13 Seasonal variation in chloride of water at selected study sites during 2016-2017 52

4.14 Seasonal variation in chloride of water at selected study sites during 2017-2018 52

4.15 Seasonal variation in total hardness of water at selected study sites during 2016-2017 54

4.16 Seasonal variation in total hardness of water at selected study sites during 2017-2018 54

4.17 Seasonal variation in dissolved oxygen of water at selected study sites during 2016-2017 56

4.18 Seasonal variation in dissolved oxygen of water at selected study sites during 2017-2018 56

4.19 Seasonal variation in biological oxygen demand of water at selected study sites during 2016-2017 58

4.20 Seasonal variation in biological oxygen demand of water at selected study sites during 2017-2018 58

4.21	Seasonal variation in nitrite of water at selected study sites during 2016-2017	60
4.22	Seasonal variation in nitrite of water at selected study sites during 2017-2018	60
4.23	Seasonal variation in phosphate of water at selected study sites during 2016-2017	62
4.24	Seasonal variation in phosphate of water at selected study sites during 2017-2018	62
4.25	Seasonal variation in sulphate of water at selected study sites during 2016-2017	64
4.26	Seasonal variation in sulphate of water at selected study sites during 2017-2018	64
4.27	Seasonal variation in total coliform of water at selected study sites during 2016-2017	66
4.28	Seasonal variation in total coliform of water at selected study sites during 2017-2018	66
4.29	Seasonal variation in faecal coliform of water at selected study sites during 2016-2017	68
4.30	Seasonal variation in faecal coliform of water at selected study sites during 2017-2018	68

LIST OF MAPS

Map No.	MAP TITLE	Page No.
3.1	Location map of study area	23
3.2	Location map of survey area	24
3.3	Location map of sampling sites	26

LIST OF PHOTO PLATES

Photo plate No.	PHOTO PLATE TITLE	Page No.
1	Sampling Sites	24
2	Nephalometer/ Turbidity meter- 135	32
3	pH meter	32
4	Total coliform incubator	32
5	Fecal coliform incubator	32
6	Coliform tube containing EC broth with samples for presumptive test.	33
7	BOD incubator	33
8	UV VIS Double beam Spectrophotmeter- 2205	33
9	Coliform tube	33
10	Autoclave	34
11	Zemabawk (Near Highland motor workshop)	43
12	Tuirial river approach road	43
13	Turial River,during winter season	44
14	Tuikual River during winter season	44
15	Zemabawk,Turial Road	45
16	Roadside seasonal spring water at ThuampuiVeng	45
17	Zuangtui near NIELIT	46
18	Zuangtui near TNT	46
19	Roadside spring at Zuangtui	47
20	Pu Sawma tuikhur at Zuangtui near Presbyterian Church	47
21	Roadside spring at Zuangtui,Muthi Road	48
22	Conserved seasonal spring water collection point at Muthi Road	48
23	Muthi Road seasonal spring collected site	49
24	Perennial spring collection site at Muthi road, near	

	Durtlang approach road	49
25	Underground water collection point at Thuampui	50
26	Underground water pumping site near Ramhlun 'N' Bazar	50
27	Underground water pumping site at Ramhlun 'N'	51
28	Underground water pumping site at Ramhlun 'S' near Baptist church	51
29	Perennial spring near Zonuamkawn	52
30	Perennial sprig water near Lalkhawchhana point, Zonuam	52
31	Spring collected site near Active Gym, Zonuam	53
32	Seasonal spring water near Zonuam kawn	53
33	Perennial spring near LuangmualVengthlang Baptist church	54
34	Spring collected site near Vaivakawn, Zopuii Gas Agency	54
35	Perennial spring water near Ruaipuii Building	55
36	Conserved spring collection site near Vaivakawn Taxi Stand	55
37	Abandoned groundwater pumping facilities near Animal home, Dinthar	56
38	A man using groundwater for wasginf and cleaning	56
39	Seasonal spring water collection site constructed by AMC, near Rollick distributor	57
40	A woman collecting water for household purpose, near Pine Mount School	57
41	Spring collection site Near MRF tyre work, Temple	58
42	A man cleaning spring collection site, Tuikual	58
43	Spring collected in between houses at Upper Khatla	59
44	Roadside spring collection site being protected by a concrete wall	60

45 Chawnpui roadside perennial spring collection point 60
46 Underground water pumping point, near Pachuau Motor Service, Tlangnuam 61
47 Underground water pumping point, at Chhangurkawn 61
48 Underground water pumping point, at Tlangnuam, Dam veng 62
49 Roadside perennial spring water collected with tap for the collection tank, at Tlangnuam, Dam veng 62
50 Roadside perennial spring water used for washing hair at ITI Veng 63
51 Spring water near Viroga Spa &Steambath, Republic 63
52 Spring water used for washing clothes and collecting for household purposes at Republic Veng 64
53 Seasonal spring near College Veng 65
54 Roadside spring collection point near College Veng 65
55 Underground water pumping point Near Republic Presbyterian Church 66
56 Underground water pumping point and spring water collection point in one place at Bethlehem Veng. 66
57 Spring water collection point at Bethlehem Veng kawn 67
58 Underground water pumping point and spring water collection point in one place at Bethlehem Veng. 67
59 Perennial Underground water being pumped out during winter at Bethlehem Veng. 68
60 Perennial Underground water at Armed Veng. 69
61 Perennial at AizawlVenglai, Near Vanglaini 69
62 Underground water at Dinthar, Near Salvation Army Church 70
63 Spring collection point at Dinthar(New Capital Complex approach road) 70
64 Roadside spring collection point at Dinthar(New Capital Complex approach road) 71

65	Spring collection point at Govt. Complex	71
66	Spring collection point near New Capital Complex gate No. 2	72
67	Spring collection point at Govt. Complex road	72
68	Perennial spring water collection point and has been collecting the water through pipes in the nearby houses at ZonuamNearANganwadi.	73
69	Perennial spring water Near Zonuam Presbyterian Church	73
70	Perennial spring water at Govt. Complex approach road from Chhangurkawn	74
71	Underground water pumping point located at Chaltlang	74
72	Underground water pumping point located at stone crushing area, LuangmualVengthlang	75
73	Underground water pumping point located Govt. Complex road, near Pine Mount School hostel	75
74	Underground water pumping point located Govt. Complex road	76
75	Spring water at Ramthar	76
76	Spring water at Zonuam ,Chawnpui road	77
77	BawngkawnThuampui Road	77
78	Car Wash, Tuirial Road	78

CHAPTER- 1

INTRODUCTION

1.1 Water Resources

A transparent fluid or molecules which forms the world's streams, lakes, oceans and rain is known as water. From the total area of the earth's surface 71% is covered by water. Water on earth moves repeatedly through the series of evaporation and transpiration, condensation, precipitation and runoff. On earth water is finite. The amount of water is fixed which means it neither decreases nor increases. Due to water cycle or hydrological cycle fresh water is a renewable resource. The main source of freshwater is rainfall from human perspective. For the growth of vegetation, such as natural vegetation, pasture, rain-fed maize etc. most of the rainfall is used directly. Transpiration is the process which is highly productive and the bulk of food crops are producing in Southern Africa (Hughes *et.al.*, 1998). Only some amount of the rainfall flows into rivers as surface water and recharges groundwater. This is the water that is used for the distribution of domestic uses, industrial production, irrigated agriculture etc. And this water has a tendency to harness through infrastructure development (like dams, wells) and that we tend to pollute. There are a large number of types of water use. Among these are rain fed agriculture, irrigation, domestic use in urban centers and in rural areas, livestock, industrial and commercial use, Institutions (example are schools, hospitals, government buildings, sports facilities etc.), waste and wastewater disposal, cooling (for thermal power generation), hydropower, recreation, fisheries, the environment (wildlife, nature conservation etc.). The various uses of water within the different sectors of an economy add value to those sectors. Few sectors may use little amount of water but has an important contribution to the gross national product (GNP) of an economy. The importance of the water quality in regard to both human health and the production of food supply has become widely recognized in recent years, and has become widely recognized in recent years, and to some extent, the importance of water quality in the maintenance of healthy and desirable aquatic population has also joined appreciation (Zaag, 2003). Water is the most precious commodity to the human life, if it is properly managed it can serve the society in number of ways.

Depending upon the circumstances it can be both priceless and worthless, blessing or a curse (Geeta *et al.*2013). Other sectors may use a tons of water but contribute relatively little there to that economy.

Water is essential for life on earth. Because of its importance, the pattern of human settlement throughout history has often been determined by its availability (Mahmoud *et al.* 2001). Next to oxygen, water is the most important substance for human existence (White, 1969).

Water has a minimum of three important physical attributes with an impact on management:

a. Fresh water is *vital* to sustain life, for which there is no substitute. This means that water features a (high) *value* to its users.
b. Although water is a renewable resource, it is practically speaking *finite*. The use of water is therefore *subtractible*, meaning that the utilization by somebody may preclude the utilization by somebody else.
c. Water is a *fugitive* resource. It is therefore difficult to assess the (variations in) *stock* and *flow* of the resource, and to define the *boundaries* of the resource, which complicate the design and monitoring of withdrawals also because the *exclusion* of non-members. Engineering, economic, social, ecological and legal aspects got to be considered, also as quantitative and qualitative aspects, and provide and demand. Moreover, also the 'management cycle' (planning, monitoring, operation & maintenance, etc.) must be consistent. An important purpose of water management is to match or balance the demand for water with its availability, through suitable water allocation arrangements (Rogers, 1998).

The concept of water resources is not unidimensional. There is no limitations to its physical measure (hydrological and hydrogeological), the 'flows and stocks', but other are encompasses more in qualitative, environmental and socio-economic dimensions. Fresh water (both surface and ground water) is the central of three dimensions of sustainable development – social, economic and environmental. Clean water and healthy water ecosystems provide the essential goods and services upon which many livelihoods depend, from irrigation water to making fertile floodplains for grazing. According to UN agriculture report on water and livelihoods, about 75%

of the world's poorest people live in rural areas across the world and for them, water access can literally mean the difference between life and death (Sullivan *et al.*,2008). Spring is a point where water flows out of the ground or any natural situation where water flows from an aquifer to the earth's surface. It is a component of the hydrosphere. A spring may flow throughout the year or seasonally. This depends on the water getting into the ground all of the time. Karst topography has resulting the spring water where surface water has infiltrated the Earth's surface, becoming part of the area groundwater. The groundwater eventually emerges from below the surface. The forcing of the spring to the surface are often the result of a confined aquifer during which the recharge area of the spring water water level rests at a higher elevation than that of the outlet. Spring water forced to the surface by elevated sources are artesian wells and non – artesian springs may simply flow from a higher elevation through the earth to a lower elevation and exit in the form of a spring, using the ground like a drainage pipe(LaMoreaux,2001).

Human existence mainly depends on fresh water supply which is less than 1% of the water available on earth (Reagen& Fisher 1997). Ground and spring water represents an important source of drinking water and its quality is currently threatened by a combination of over- abstraction and microbiological and chemical contamination (Anguloet *al.* 1997).

1.2 Groundwater

Groundwater is fresh water thatis found in the subsurface minute opening space of soil and rocks. The groundwater also flows within aquifers beneath the water table. That makes it useful to make the difference between groundwater that is closely related with surface water and deep groundwater in an aquifer. Leaching of surface water is the natural input of groundwater. Seepage to the ocean and springs are the natural output of groundwater(Gleeson*et al.*,2012.).Safe drinking water is essential to humans and other lifeforms even though it provides no calories or organic nutrients. (United States Geological Survey,2009). The quality of life is linked with the quality of environment, hence the biological components of fresh water depend solely on letters physico-chemical conditions. Therefore to determine the characteristics of physico-chemical parameters of water is essential, as it has

great importance on the explanation of functions and metabolism of the aquatic ecosystem. The planktons are the indicators of ecological conditions and reveals past history of take, and the chemical nature shows its recent conditions. Of the environmental conditions are altered than the change in population is inheritable which is replaced by species to species. Water quality is dynamic and its changing parameters require the water technologist to be in constant touch with the chemist, the bacteriologist, the biologist and the toxicologist.

1.3 Spring water

Springs a replace in the soil or rock where underground water emerges naturally.. Springs water that do not get dry on the basis of seasons and flows throughout the year are known as perennial springs water. One that keeps full or flowing throughout the year for all or most years, but in practice there are degrees and kind of difference and this is the unsophisticated way of a perennial water body. When there is cut in the water table to the surface of the earth, then only spring water can occur(depression spring), when one water bearing layer meets a layer like hard rock or clay that does not allow water to permeate (contact spring), when there are fractures in hard rock (fractures spring), cavities in limestone (karst spring) or along faults in the rock structure (fault spring). A combination of these kind of springs sometimes occurred naturally. There may be a drastic differences comparing between periods of drought and deep water in their internal ecology. The serial of cycle based on its season in some cases is ecologically important, although there is a rare exceptional water level that can be taken routinely into account. Also there may be efficiently lasting changes; even large rivers have lost their perennial condition regularly increasing due to constantly rising of human demand for fresh water for various purposes like domestic, agriculture, industry, urbanization and different developmental works (Sam 2011).

As reported in the European legislation (2009/54/EC Directive) from an aquifer or underground basin natural mineral waters are originated, spring from one or more natural or bore sources and have different hygienic features and eventually in properties of health" (in Italy, D. Leg.N.176 of 2011). Springs are different from

drinking water because of their purity and conservation, for their constant minerals level (trace elements or other constituents) and, where suitable, they can be determined for certain effects (Quattrini *et al.*, 2016).

1.4 Water pollution

According to water (Prevention and Control of Pollution) Act, 1974 water pollution is define as " such contamination of water and such changes in the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or any other liquid, gaseous or solid substance into water (whether directly or indirectly) or is likely to create a nuisance or render such water harmful or injurious to the public health or safety or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms".

The term water pollution refers to anything causing change in the diversity of aquatic life due to declining in water quality. And with the increasing living standards and wide sphere of other human activities clean water is becoming more and more precious. Today water pollution is a problem being faced by human. Water which is clean for consumption or used with low risk of instant or long term harm is known as drinking water. In many developed countries water distributed for domestic use, commercial and industry is all of drinking water standard although only a very small proportion is actually consumed in food preparations (Anon., 2009).

One of the most serious problems that we faced today is water pollution. It become more difficult to prevent pollution to ground water, surface water rivers, sea, lakes, ponds, etc.. The toxins can penetrate through soil and rock into the groundwater resources, resulting in physical and substance changes and in changes in water quality (Pepper *et al.*, 1996*).*For example, around 70% of the water in India has been turned out to be contaminated because of the release of household sewage and mechanical effluents into regular water sources (Singh, 2014).

Water must not contain microbiological contaminations that are pathogenic to humans (Nzunga,2019). Microbiological contamination of drinking water causes numerous irresistible ailments, such as cholera, enteric fever, hepatitis and looseness of the bowels (Berkman*et al*.,2002; Fewtrell*et al*. 2005*)*. Water quality is indicated by various physical parameters such as pH, total solids, dissolved oxygen, hardness, chlorine content, and sodium content. Nitrate contamination results from human and animal wastes, soil nitrogen content, plant debris, industrial effluents and chemicals, and seepage and silage through drainage system (Aryal*et al*., 2012;Spalding, 1993). The turbidity in the groundwater is an indication of pollution of water resulting from deterioration of organic matter and the improper disposal of domestic and industrial solid wastes and wastewater (Prakash, 2006). High level of water hardness led to heart diseases and kidney stone formation (Krishnan *et al*., 2007). Spring is unique ecosystems; however, in many cases, they are severely threatened and thus require an urgent need for better management and conversation (Rossi *et al*., 2015). Identifying the chemical, physical and microbiological characteristics of water is a key step in the management of the springs. They are important parameters in directing the efforts to remove potential area to select and design water purification units (Daghrah, 2009). Microbial parameters include total and fecal coliforms. The contamination of water is not indicated by the presence of total coliforms in the water. However, the fecal coliforms found in the groundwater are an indication of contamination from human or animal sewage (Gama Program, 2016; Gafny*et al*., 2017; Health Canada, 2007)

There are five millions of springs across India, which are extended from the Nilgiris in the Himalayas, springs are a safe source drinking water for rural and urban communities. For many people, spring is the sole source of water. In India springs continue to dry up in many of the mountain states. Regardless of the significant role they play, springs are in catastrophe. With an increasing demand there is an increase in pumping of groundwater that lead to declining in discharging of springs. A survey in Sikkim found that in half of all spring water production has declined in the state and this is a dangerous sign that aquifers are depleting in a state, and almost entirely dependent on springs for drinking water. Similar effects are being observed in nearly

all mountainous regions in India. When perennial springs are becoming seasonal in Western Ghats, the communities in the area struggle to meet their demand. Temples built on perennial are now dry as upstream wells compete for drinking and irrigation water. To make the problem worse, water quality is also worsening due to changing land use and no proper sanitation in handling and treatment. Springs traditionally used as a village drinking water source are being abandoned due to the close proximity and contamination from latrines (India water portal).

1.4.1 Sources of water pollution:

Various sources of water pollution are i)Sewage and Domestics Wastes, (ii)Industrial Effluents, (iii)Agricultural Discharges, (iv)Pesticides and Fertilizers, (v)Soap and Detergents, (vi)Thermal Pollution etc.

i)Sewage and Domestic Wastes

Sewage and domestic wastes are the main sources of water pollution and they contribute about 75% of the sources of water pollution. If domestic waste and sewage handling are not properly and carefully done after they are produced and are directly discharged into water bodies, the water gets contaminated or polluted. Domestic sewage contains decomposable organic matter which exerts on oxygen demand and sewage contains oxidisable and fermentable matter which causes depletion of Dissolved Oxygen (DO) level in the water bodies.

ii) Industrial Effluents

Industrial effluents are discharged into water bodies containing toxic chemicals, phenols, aldehydes, ketones, cyanides, metallic wastes, plasticizers, toxic acids, oil and grease, dyes, suspended solids, radioactive wastes etc. The principal types of industries which contribute to water pollution are chemical and pharmaceutical industries, steel plants, coal, soap and detergents, paper and pulp, distilleries, tanneries, foods processing plants etc. Biological purification mechanism of sewage treatment was poisoned when all the mentions wastes are discharged through sewage and then pose several pollution problems.

iii) Agricultural Discharge

It was reported that nutrients of plants, pesticides, insecticides, herbicides and fertilizers plants and animal debris cause a heavy pollution to water sources. Now a day fertilizers containing phosphates and nitrites are added to soil, some of these are washed off through rain fall, irrigation and drainage into water body thereby severely disturbing aquatic system. Organic wastes increase the Biological Oxygen Demand (BOD) of the receiving water body. During monsoon the rainfall has carried some pesticides which are non- biodegradable, when sprayed remain in the soil for longer time into the water bodies.

iv) Soap and Detergents

Soap when contact with water they formed oleic acid and fatty acid,. Thus acidity of water increases which perturb the aquatic life. The water bodies were severely affected by using detergents as the cleaning agents contain several pollutants and thus create water pollution. They contain surface activity agents and contribute to phosphates of sodium, silicates, sulphate and several other salt builders in water. When waste water gets contaminated with detergents it carries a huge cap of foam, which is anesthetic for all purposes. When detergent become in contact water the complex phosphates that composed detergents, the concentration of phosphates increases in water that makes the water poisonous and caused eutrophication problems.

v) Thermal pollution

The aquatic environment was adversely affected by discharging the pollutants with unused heat from the nuclear and thermal power plant.Many industries with cooling system, contribute thermal loading of water bodies except from the electric power plant. These pollutants increase the temperature of water and decrease the DO value thus making condition unsuitable for aquatic life (Singh, 2016).

In addition to the various sources of water pollutants and desertification, pollution is also reducing the volume of safe drinking water. Since water is the vital

concern for mankind and essential for man, animal and aquatic, to know and learn more about water pollution and its related effect in the various quality is much crucial. People living around the study area are also seeking the spring water as household and domestic purposes. Considering this situation a good knowledge of the qualities of spring water is necessary to guide its suitability for use. APH (1998) also stated that physicochemical characteristics are vital water quality monitoring parameters and affect the quality of a water resource. Therefore, to determine the physic-chemical and bacteriological quality of the spring water which justifies the quality of a drinking water, the present study was formulated.

1.5. Scope of the research

Water is a part of nature and essential to life itself. There is an occurrence of different types of minerals that are different from their source as the spring water comes from the earth. It can be dedicated that mountain spring water provide the most pure natural source of water. People have always been concern about their health and so not tap water that preserves us from various illness but the naturally occurring and full of earth energy was hope to function for this concern. But spring water in various places could get contaminated or polluted from run off and the contaminants that moves through the rock or soil. In Mizoram spring water is one of the major sources of drinking water, washing and homestead garden as well as irrigation purposes. However, total water consumption was rising steadily which are driven by increasing population and economic growth. Water competition and threats to environmental quality have become increasingly critical. Some of the spring water sources are located at a considerable distance in villages and some are located on the roadsides. In a crowded city like Aizawl, some spring-water holes are located in close proximities of dwellings so as to warranty contamination from domestic activities. The research work will provide whether the water resources are potable for domestic utilization. Since public water supply is inadequate in Aizawl city and lack of water storage system, many households cannot but rely on private water supply drawn from seasonal and perennial water resources in and around Aizawl city. An investigation in spring water quality, although taken by some researchers in an intermittent seasons could not provide adequate results, so for the present research investigation will provide whether the water resources are potable for domestic utilization.

1.6. Objectives

1.6.1 To survey and describe water resources in and around Aizawl city.

1.6.2 To analyze the physical and chemical characteristics of selected perennial spring water.

1.6.3 Strategies for better management options and utility

CHAPTER - 2

REVIEW OF LITERATURE

A perennial water resource is water that has continuous presence in its bed all year round during years of normal rainfall. Liquid mainly fresh water, as opposed to intermittent or seasonal water is referred to as perennial water body. There occurred variation in fullness in most of the water body which may be due to heaviness of precipitation, changing in seasons and other factors in any given year. In such water bodies the water level does not dry out, though it may drop so drastically with great reduction in their surface area. The water bodies come apart and are separated with dry land between, either arid or covered with vegetation. Such water may differ drastically between periods of drought and deep water in their internal ecology. Periodic or seasonal cycle is ecologically important, although the occurrences of exceptional water levels are too rare to be taken routinely into account. There may be an occurrence of permanent changes effectively; ever more regularly even large rivers have lost their status of being perennial in nature due to an increase in demand of the human demand for fresh water for various purposes like agriculture, industry or the needs of the populations of large cities or domestic purposes(Lake,2011).

2.1 International

Limnology as an instinct field of science has developed during the last 100 year or so beginnings of Knowledge Concerning fresh possibly before the days of Aristotle (384-322 B.C). However, there are no important scientific contributions of year after year the time of Aristotle other than the historical interest involved (Welch 1952).

The world water resources have been the subject of great concern in the various national and international debates, programmes and conference because they are indispensable to life in various ways (Tundisi, 2008).

In Palestine water shortage and water quality are imminent (Salaymeh*et al.*, 2011.). Water is viewed as standout amongst the most imperative and delicate issues

in the Middle East (World Health Organization, 2004). The surface water resources are rare and unnatural. Thus, the groundwater is the main supply for the Palestinian individuals (Palestinian Water Authority, 1994). The WHO has set the minimum per capita daily consumption of 100liters per day (World Health Organization, 2009). The mean value of the daily consumption in the west bank is 66liters per capita per day (Tselm, 2008; WHO, 2011). Such a clear deficiency of clean fresh water with the increasing demand for industrial, agriculture, and domestic uses is one of the main problems in Palestine (Khatib, 2003).

Due to high salt content Isinuka spring water is not fresh which mean that the water is not suitable for drinking without undergoing several treatments. The water having pH ranging between 6.87- 8.33 is moderately hard, salty and fairly neutral. One of the five study site continually emits a characteristics odor and the five spring sources were characterized by very high concentrations of TDS, turbidity, chloride and ammonium nitrate which exceed the maximum permissible limits recommended for drinking water. This may be because the locations of the spring has become a tourist center and is believed to be a mystery water sources. The springs are also the main sources of domestic water supply for the villagers, which pollute the water (Faniran*et al*. 2000). When the water becomes polluted it led to arising of waterborne diseases and the burden of waterborne diseases in low-income countries remains high. In 2005, a seven-country study involving nearly one million people in refugee camps indicated there were 132,000 cases of diarrhea and over 280,000 reported cases of malaria attributable to incomplete water and sanitation provision (Cronin *et al*. 2009). A review of trends of the estimates for the years 2005 to 2007 revealed that 1,400 deaths were directly attributable to incomplete water and sanitation alone in refugee camps in Ethiopia, Kenya and Tanzania (Cronin *et al*. 2009). Therefore, there is need to intensify efforts for improving safe water and sanitation provisions in emergency settings. One critical measure that has been recommended for attaining safe water supplies for people in emergencies is the use of the safe water chain approach (Ali *et al*.2015)The safe water chain encompasses all practices that aim at ensuring that water remains safe between the water source on 08 July 2020 and point of human consumption (Ssemugabo *et al.*2019).

According to Adeniji, 2012, the natural spring water in Ibadan residents needs urgent sanitary action in order to maintain the quality of the water for it could go a long way to combat water supply shortages in the city. Adequate chlorination and proper introduction of disinfectants to all underground tanks of these natural springs are to be done by Ministry of Environmental Health and should be done periodically. Regular bacteriological assessment of the spring after each disinfection process should also be adopted (Adeniji, 2012).

For human development, living organisms and natural habitat water is the most important resources. It is used for drinking, cleaning, agriculture, transportation, industry, recreation, and animal farming, producing electricity for domestic, industrial and commercial use. Due to its multiple benefits and therefore the problems created by its excesses, shortages and quality deterioration, water as a resource requires special attention. On a worldwide scale, total quantity of water available is about 1600 million cubic km. The water cycle moves enormous quantity of water round the globe. As 97.5% of all water on earth is saline water world's water has little potential for human use. Out of the remaining 2.5% freshwater, most of which lies deep and frozen in Antarctica and Greenland, only about 0.26% fish in rivers, lakes and within the soils and shallow aquifers which are readily usable for mankind. The hydrological cycle is being modified quantitatively and qualitatively in most of the river basins of our country as a results of the developmental activities like construction of dams and reservoirs, land use change, irrigation, etc. (Sharma, 2017).

The sensitivity of a water resource system to global climate change may be a function of several physical features and, importantly, societal characteristics. There are several indicators of water resource stress, including the quantity of water available per person and therefore the ratio of volume of water withdrawn to volume of water potentially available (Falkenmark and Lindh, 1974). It is difficult to draw quantitative conclusions about the impacts of global climate change, for several reasons. Different studies have used different methodologies and different scenarios, but, most vital, different systems respond very differently to global climate change. It is possible, however, to form some qualitative generalizations:

a) In systems with large reservoir capacity, changes in resource reliability could also be proportionately smaller than changes in river flows.
b) The potential impacts of global climate change must be considered within the context of other changes that affect

water management. Few studies have explicitly compared global climate change within the context of other pressures, but as for many environments is likely that over a time horizon of but 20 years, climate change impacts will be very small relative to other pressures. This will depend on the system.

c) The implications of climate change are likely to be greatest in systems that currently are highly stressed.

In terms of resources per inhabitant in each continent, America has 24 000 m^3/year, Europe 9 300 m^3/year, Africa 5 000 m^3/year and Asia 3 400.1 m^3/year. In computing water resources on a country basis, a distinction is to be made between renewable and non-renewable water resources.

- Renewable water resources are computed on the basis of the water cycle. In this report, they represent the long-term average annual flow of rivers (surface water) and groundwater.
- Non-renewable water resources are groundwater bodies (deep aquifers) that have a negligible rate of recharge on the human time-scale and thus can be considered non-renewable (Aaron,2001).

Surface water and groundwater base flow in Morocco: The total groundwater resource equivalent to the aquifer recharge is estimated at 10 km^3/year, of which 3 km^3/year corresponds to the base flow of rivers. Recharge of aquifer by floods in the Islamic Republic of Iran: The contribution of surface water (floods) to aquifer recharge is estimated at 12.7 km^3/year, out of the total IRWR of 128.75 km^3/year (Anon.2003).

National :

India receives on an average about 4000 billion cubic metre (bcm) of precipitation every year. Almost 50 per cent of this water is lost to evaporation, percolation, sub-surface flows to oceans and only 1953 bcm is accounted for. Because of spatial and temporal variation in the availability of water, only 1086 bcm is utilizable (Phansalker and Verma, 2005). More than half of this quantity is lost to the atmosphere or through deep percolation and only about 1869 bcm flow in the rivers as surface flow. This is estimated to be the water resources potential of the country. Nearly 60 per cent of the potential lies in the Ganga–Brahmaputra– Meghna system in the North. Another 11 per cent in the high rainfall region of the Western Ghats flows through the small west-bound rivers draining into the Arabian Sea (IWRS 1996).

According to Chauhan *et al*. (2020) presence of coliform in the water samples indicate a high bacteriological contamination due to which a major fraction of the people depending on the water resource suffered from dysentery, diarrhea and typhoid. And if proper disinfection of the bacteria is carried out, the water of the natural resources is best for the drinking purposes. But if the treatment of the bacteria is not conducted, it will cause several waterborne diseases like diarrhea, typhoid and dysentery as observed in their survey. The changes in qualitative and quantitative status of water due to anthropogenic pressure led to vanish of human beings. Moreover, quality of water depends on the source of water, storage technique and the treatment opted (Lim *et al*.2012; Kumpel and Nelson2013; Wright *et al.* 2014).

Many large towns and mega cities, particularly those situated in water deficit river basins, are already facing shortages in domestic and industrial water supply. In 1901, the urban population was about 26 million which was less than 11 percent of the total population. By 2001, the urban population increased to 285 millions (28 per cent of the total population) with 35 urban agglomerations/cities having a population of more than one million. It has been projected that by the year 2050, urban population in India of 820 million would constitute nearly 50 per cent of the total population. As the economic condition of the people improves, the per capita water

demand will also grow. Meeting the water requirement of large cities will be a challenging task (Anon., 2003). In India inland water bodies have attracted attention of various workers leading to the studies on seasonal variations in abiotic and biotic factors. But few have tries to explore the diurnal variations in physio-chemical and plankton factors (Michael, 1964).

The Constitution of India lays down the legislative and functional jurisdiction of the Union, State and local Governments regarding 'water'. Under the scheme of the constitution, '*Water is basically a State subject and the Union comes in only in the case of inter – state rivers waters'* (Anon.2020).

Regional:

The main water resource in Mizoram is the numerous perennial springs and the rivers. The groundwater resource is also utilized wherever possible. As per the census of India 2001, only 5% of the rural households enjoy water supply within their premises and about 75% of the households get water from their near premises. For majority of the households 47% the main source of water is spring water. In the state the gravity-based schemes are successful and sustainable. The hand pumps are not working properly and there are instances of excess iron from the hand pump (Upadhyay and Lalroneiha 2014).

Hydro-geological, the entire area of Aizawl district is occupied by semi-consolidated formations of denude structural hills belonging to Surma Formation of Miocene age. The low linear ridges are characterized by low permeability and infiltration capacity. It acts as run off zone. The moderate linear ridges, which occupy the major portion of the district, comprise hard and compact sandstone, shale, siltstones and alternations of Surma Group of rocks. This unit is also characterized by very low permeability and infiltration capacity that acts as run off zone. Ground water potential is low.

The major water resources consumed or supply to the people in Aizawl, Mizoram is from Tlawng river, however the river do not provide enough water supply for daily purposes. Thus depend on the spring water collecting in the nearby localities in various areas of within the city (Lalchhingpuii*et al*., 2011). We can state that from the study conducted by Mishra 2009, there is an ample need of proper

treatment of spring water in Mizoram before its use, as it serve as a major source of drinking water in the state because most of the parameters of the water analyzed it has been found that the value of various parameters were high during warm and rainy season, while the concentration of various parameters were low during cold and dry seasons (Mishra, 2009).

From the study conducted by Lalramnghinglova in 2006, some of the springs were slightly acidic in nature. The chemical properties of water samples were satisfactory as the chemical level were low giving no cause for concern. But the presence of fecal coliform, is the seepage of sewage water into the water resources because of poor sanitation conditions and unhealthy poultry- pig rearing habits near inhabitants prevailing in the city (Lalramnghinglova, 2006).

The linear rolling valleys with limited aerial extend are underlain by shale, sandstone and siltstone alternations. No ground water abstraction structures are noticed in the valley. However, during earlier field investigation by CGWB, occurrences of small pond like structures with very shallow water level (2.0 m) had been reported. As such, shallow ground water structures may be feasible in suitable locations of the valley portions. In general, the terrain is tectonically young and immature. The entire district is covered by hills of semi-consolidated rocks of tertiary age. The rock types are comprised of mostly siltstone, clay stone and compact sandstone. In spite of good rainfall of more than 2,000 mm in the district, there is acute shortage of water during summer, because most of the rain water flows out as surface run off. The scope for ground water storage is limited mostly to secondary porosities controlled by structures. These aquifers are the main source of springs. Ground water emanating in the form of springs are being developed for use as a source for water supply.

Ground water is used mainly for drinking purpose as there is no major industry in the district. Ground water utilization for irrigation may be considered as negligible. Due to hilly terrain, spatial variation of rainfall, nature of soil, non-availability of irrigation facilities, people practice jhum cultivation.

Hydro geological investigations carried out by the Central Ground Water Board during 1984-85 & 1985-86 in the entire state revealed the occurrence of a good number of perennial springs in different altitudes. The discharges of the springs

progressively increase in the lower altitudes. These springs can be developed scientifically for providing safe drinking water to the rural people. Rain water harvesting which is well known to the people of the district can also be developed for solving scarcity of potable water.

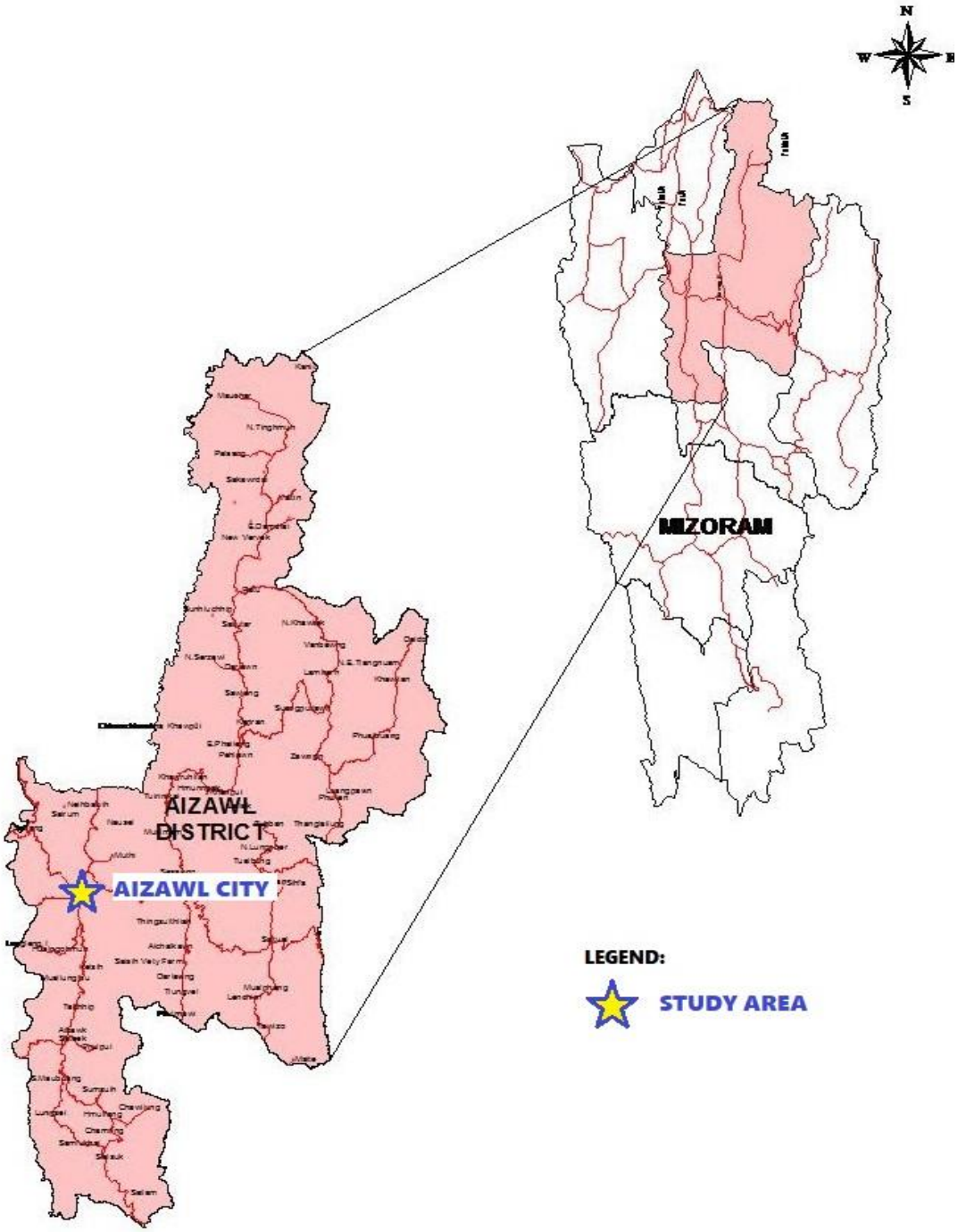
CHAPTER-3

METHODOLOGY

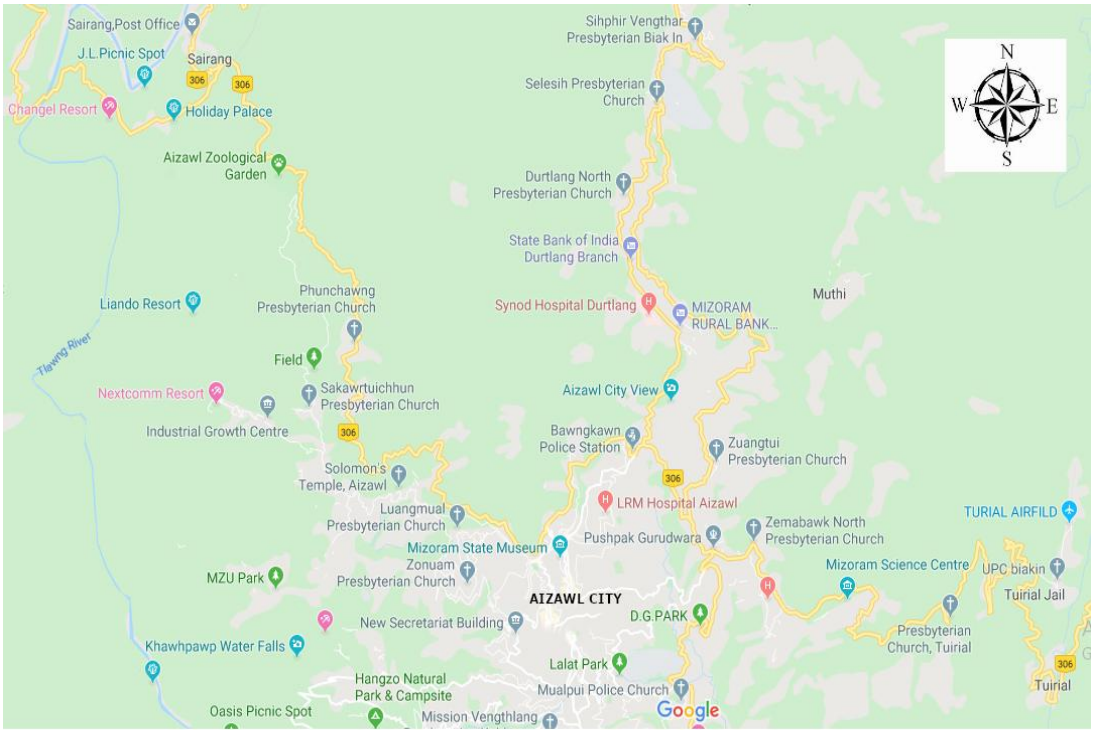
3.1 Study area:

Aizawl is the capital city of Mizoram. It is located in the northern part of Mizoram between 23°30'N latitude and 92°15'E longitude with an average altitude of 1,132metres above sea level, with Tlawng river valley to the west and Tuirial river to its east. It covers a total area of 3576 sq.km. It has mild, sub-tropical climate due to its location and elevation. The entire Aizawl district is under the direct influence of south – west monsoon, with an average rainfall of 3155.3 mm (MIRSAC, 2012). In summer, the temperature varies between 20 - 30°C, and in the winter 11 - 21°C (NIC, Mizoram). Aizawl is blessed with aesthetic scenery and serene surroundings with mild and pleasant weather throughout the year. It is an ideal hill station for tourists as it provides clean and fresh environment. Aizawl had a population of 293,416. Females constitute 50.61% of the population and males made up the remaining 49.39%. Mizo's from various tribes make up the majority of the population (Census, 2011).

The first written records of settlement in Aizawl can be traced back to 125 years ago during the British – Indian era. Aizawl city is surrounded on the east by Tuirial River which is at a distance of 10 km from the city and on the west by the Tlawng River which is at a distance of 5 km from the city. On the north, Aizawl is protected by the hills of Sihphir.



Map 3.1: Location map of study area



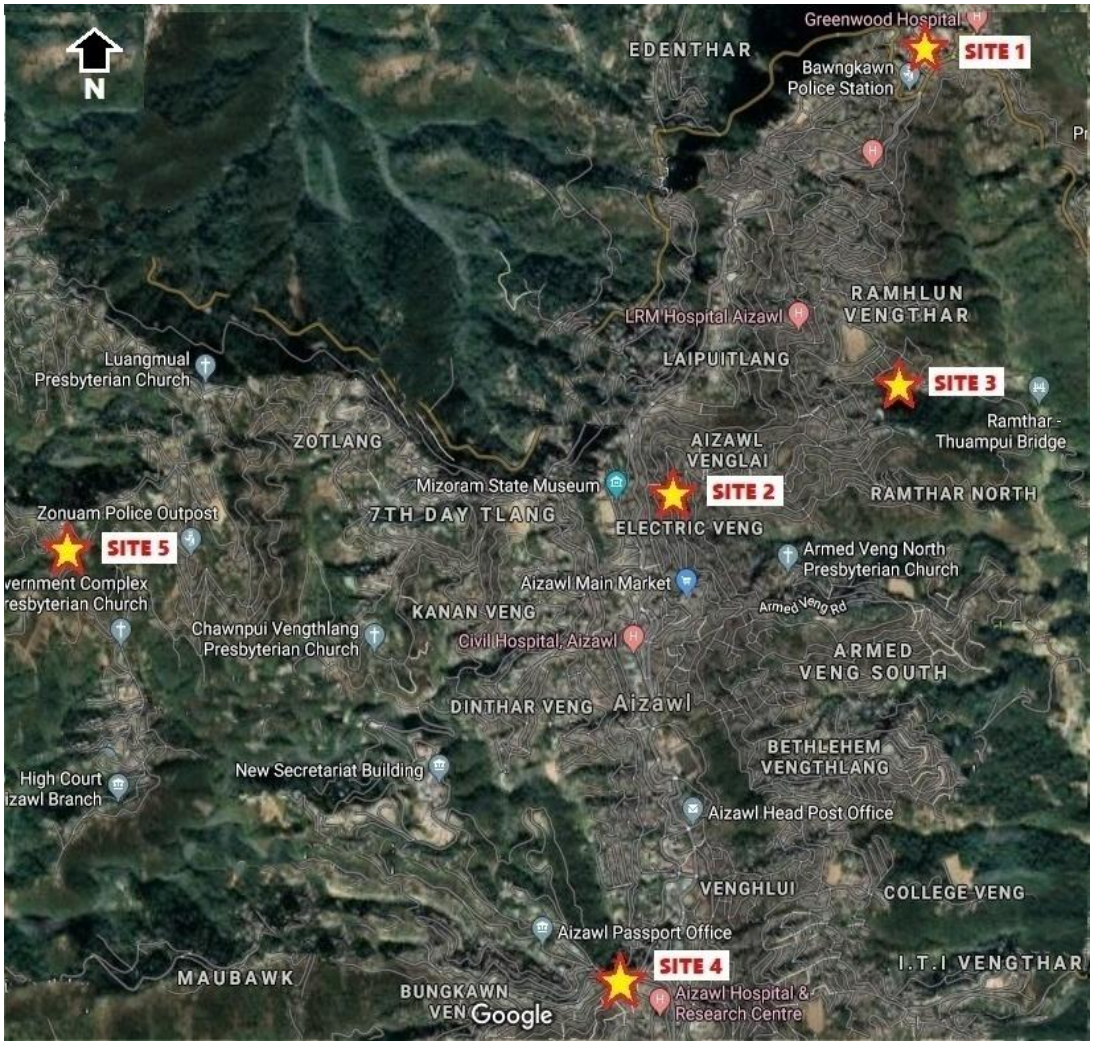
Map 3.2: Location map of survey area

3.2. Sampling Sites

For detailed investigation on water quality assessment, following 5 sampling sites have been selected in Aizawl city considering Central, North, South, East and West parts of city. **Table 3.1**.

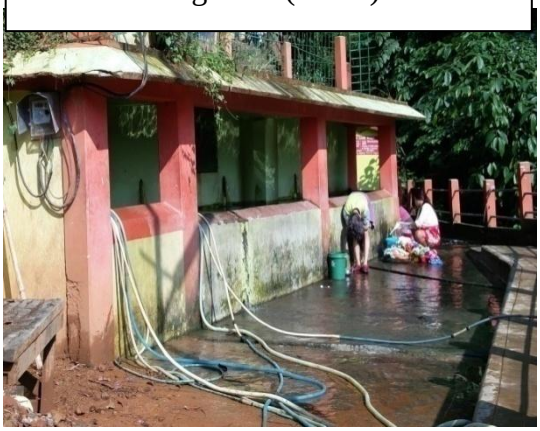
Table 3.1: Location of sampling sites.

Sampling Sites	Zone of sampling sites	Coordinates	Location
Site-1	North	N23˚45'16.7" E 092˚43'41.0"	BawngkawnTuikhur, Bawngkawn
Site-2	Central	N 23˚44'25.0" E092˚43'05.5"	Zotui, Electric Veng (Near ESRA Drug Store)
Site-3	East	N23˚44'16.0" E092˚43'14.6"	TheihaiTuikhur, Armed Veng
Site-4	South	N 23˚43'08.6" E092˚42'54.6"	SailoTui,MissionVeng
Site-5	West	N 23˚43'50.5" E092˚41'39.3"	Public Tuikhur, Govt. Complex

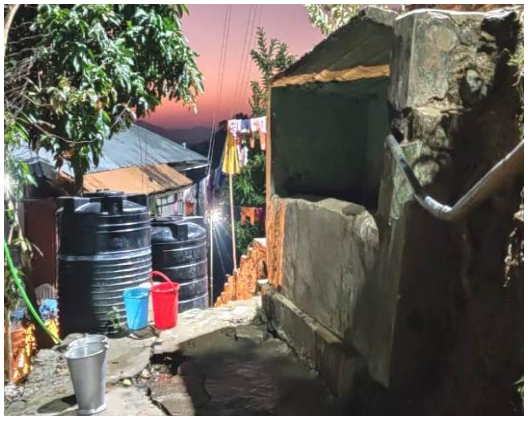


Map 3.3: Location map of sampling sites

Site 1: Bawngkawn (North)



Site 3: Armed Veng (East)



Site 5: Govt. Complex (West)

Site 4: Mission Veng (South)

Site 2: Electric Veng (Central)

Photo Plate 1: Sampling Sites

3.3 Analytical methods

3.3.1 Collection of samples

Data of water resources

Before selecting sites for the qualitative assessment of perennial spring water, survey method was employed to gather the number of water resources available from north, east, south, west and central zone of Aizawl city.

Water for analysis

From the survey conducted five sites were selected for quality analysis. Water samples were collected between 6 a.m. to 10 a.m. and after that it was immediately transported to laboratory for the analysis. Wide mouth bottles painted in black to avoid penetration of light. Label for each samples for easy identification. And separately, BOD bottle was used to collect sample for analysis of dissolved oxygen and biological oxygen demand. And for coliform test, specially designed sterilized sample glass bottles were used and was placed immediately in a zip pouch fro prevention of any bacterial contamination.

3.3.2 Analysis of physical parameters

3.3.2.1 Temperature:

Temperature of water was measured by using a simple centigrade thermometer with a precision of 0.1 degree Celsius. Water sample was taken in a beaker and thermometer was dipped into it and the reading was noted. The value was expressed in ^{o}C.

3.3.2.2 Oxidation reduction potential of Water (µV):

The electrode of pH meter was dipped into the water samples after the probe was set to mV and then the reading was recorded. pH of water was measured using Digital pH meter. The values were expressed in µV.

3.3.2.3 Measurement of Turbidity in water (NTU):

Turbidity is the cloudiness or haziness of a water sample caused by a number of individual particles usually invisible to the naked eyes. It is the scattering of the beam of light on water surface, showing Tyndall phenomenon. The turbidity of the water samples was determined using Nephalometer which measures the intensity of light scattered at 90 degrees as a beam of light passes through the water sample. The higher the intensity of scattered light the higher is the turbidity. The values were expressed in NTU.

3.3.3. Chemical parameters:

3.3.3.1 Measurement of pH of water:

The pH value of any entity is defined as “the negative common logarithm of the entity”. The measurement of the pH of water is required to determine the corrosiveness of the water. pH of water was measured using Digital pH meter. It has no unit.

3.3.3.2 Acidity (mgL^{-1})

The total acidity of water sample was measured by using potentiometric titration method. Sodium hydroxide (0.02N) was used as a titrant. Acidity is mainly of two types namely: Methyl orange acidity or mineral acidity and Phenolphthalein acidity or CO2 acidity. Both mineral acidity and CO2 acidity can be measured by means of standard solutions of alkaline reagents. The values were expressed in mgL^{-1}.

Calculation:

$$\text{Acidity} = \frac{\text{Volume of titrant used X 1000}}{\text{Volume of sample taken}}$$

3.3.3.3 Total Alkalinity (mgL^{-1})

Total alkalinity is primarily defined as a measure of the acid neutralizing capacity of water. The total alkalinity of water samples was measured using potentiometric titration method. Standard sulphuric acid (0.02N) was used as a titrant to lower down the pH of sample at 8.3(phenolphthalein alkalinity) and to pH 3.7 (methyl orange alkalinity). Total alkalinity was calculated using the following formula, and values were expressed in mgL^{-1}.

Calculation :

$$\text{Total Alkalinity} = \frac{\text{Volume of titrant used x 1000}}{\text{Volume of sample taken}}$$

3.3.3.4 Estimation of chlorine as Chloride content of water(mg/L)

Chloride in the form of chloride ion (Cl-) is one of the major inorganic anions present in water and waste water. The chloride content of water was determined by using modified Mohr's Argentometric titration method. Silver Nitrate (0.041N) solution was used as a titrant. AgNO3 reacts with chloride to form slightly soluble silver salts in a weak acid solution which precipitate as AgCl. The brick red silver chromate is formed at the end point. Chloride content of water was calculated using the following formula, and result was expressed in mgL^{-1}.

Calculation:

$$\text{Chlorine (mg/L)} = \frac{\text{Volume of titrant x 0.041 x 36.46 x 1000}}{\text{Volume of the sample}}$$

3.3.3.5 Total Hardness as $CaCO_3$(mgL^{-1})

Total hardness of water is primarily the measure of the concentration of calcium and magnesium ions in water. Total Hardness is defined as the sum of calcium and magnesium hardness in mgL-1 as CaCO3. Total Hardness was measured using Ethylene-Diamine-TetraAcetic (EDTA) titration method. In alkaline condition, EDTA or its sodium salt (Na2EDTA) react with Ca++ and Mg++ to form a soluble complex. The Ca++ and Mg++ develop a wine red colour when small amount of dye such as Erichrome Black T is added under alkaline condition. When EDTA is used as a titrant, the Ca++ and Mg++ are complexed with EDTA, and resulting into a sharp change from wine red to blue colour which indicates the end point. The Total hardness was calculated by using the following formula, and values were expressed in mgl^{-1}.

Calculations :

Concentration of Total Hardness as $CaCO_3$ in mg/L

=Volume of EDTA consumed for sample x Molarity of EDTA x Mol.Wt. of CaCO3x1000/Vol. of sample taken for titration

$$= \frac{\text{Volume of EDTA x 0.01 x 100 x 1000}}{50}$$

3.3.3.6 Estimation of Dissolved Oxygen (mgL^{-1}) :

Dissolved oxygen content is the concentration of oxygen in dissolved form, and is essential for the sustenance and survival of oxygen-demanding aquatic organisms. It is an important parameter which determines the purity of water. The DO content of water samples was measured by following “Modified Winkler’s Azide Method”. This azide titrimetric procedure is based on the oxidizing property of oxygen dissolved in water. The DO content of water was calculated using the following formula, and result was expressed in mgL^{-1}.

Calculation :

$$1ml \text{ of } 0.025N\ Na_2S_2O_3 = 0.2mg \text{ of } O_2$$

$$DO\ (mg/L) = \frac{(0.2 \times 1000) \times V}{200}$$

Where,V = volume of titrant used.

3.3.3.7 Estimation of Biological Oxygen Demand (BOD):

Biological Oxygen Demand determines the amount of oxygen required by aerobic biological organisms (microorganisms) for decomposition of organic matter present in water. For estimation of BOD content of water, initial and final DO content of water samples were determined just after collection of sample and after 5 days incubation in BOD incubator at 20°C, respectively. Calculation of BOD content of water was done using the following formula and the result was expressed in mgL^{-1}.

Calculation :

The general equation for the determination of a BOD value is

$BOD = (D_1 - D_2)$,(in no dilution sample).

Where, D_1 = initial DO of the sample

D_2 = final DO of the sample

3.3.3.8 Nitrite-N :

Phenol Di – Sulphonic acid (PDA) method was employed for determining Nitrate-N content in water samples. The development of colour was observed in a Spectrophotometer and the value was expressed in mgL^{-1}.

Formula :

$$\text{Nitrate-N} = \frac{\text{Net mg Nitrate,N}}{\text{ml of Sample}}$$

$$NO_3 \text{ mg/l} = \text{Nitrate, N mg/l} \times 4.4$$

3.3.3.9 Phosphate-P

Stannous Chloride Method was used for determining Phosphate-P constant present in water sample.The absorbance of colour was observed using Spectrophotometer. The results was expressed in mgL^{-1}.

$$\text{Phosphate-P} = \frac{\text{mg of P (in approx. ml final volume)} \times 1000}{\text{Volume of water sample used}}$$

3.3.3.10 Sulphate

Ignition method was employed for detection of sulphate. As potassium and sodium ions are easily co- precipitated,the co- precipitation could be reduced by the presence of patric acid. The precipitation of calcium sulphate is prevented by the acidification of the solution.

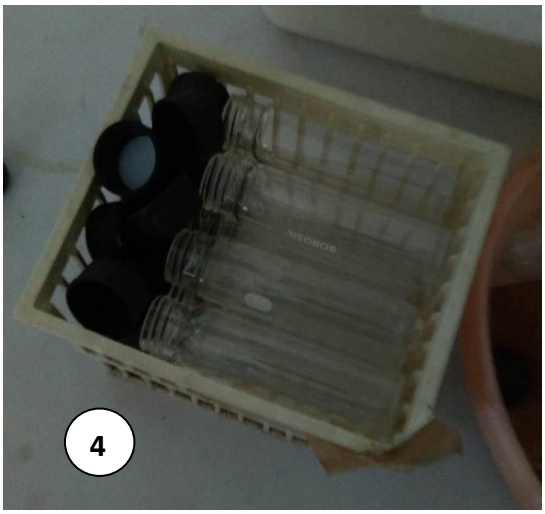
Formula

$$\text{Mg/L } SO_4 = \frac{W \times 411.5}{V}$$

3.5 Bacteriological Study – Total and fecal coliform test.

MPN method was employed for determining the presence of total and fecal coliform in the water sample. The results was expressed in MPN.

1) **Photo Plate 2:**Nephalometer/ Turbidity meter- 135
2) **Photo Plate 3:**pH meter
3) **Photo Plate 4:**Total coliform incubator
4) **Photo Plate 5:**Fecal coliform incubato



1) **Photo Plate 6:** Coliform tube containing EC broth with samples for presumptive test.
2) **Photo Plate 7:** BOD incubator
3) **Photo Plate 8:** UV VIS Double beam Spectrophotmeter- 2205
4) **Photo Plate 9:**Coliform tube

Photo Plate 10: Autoclave

CHAPTER- 4

RESULTS

Survey of Water Resources in Aizawl City:

From the survey conducted there are three types of water resources found within Aizawl city, they are rivers, spring water and ground water. The list of different water resources found in the north, east, west and south zone of Aizawl city are given in Table 4.1 to 4.4.

Table 4.1: List of water resources found in the north zone

AIZAWL NORTH				
Sl. No.	Source	Seasonality	Type	Coordinates
1	ChaltlangRuamVeng (Bawngkawn road)	Seasonal	Underground	N 23˚45'03.7" E 092˚43'22.7"
2	Bawngkawn (Brigade field approach road, below Greenwood Hospital)- I	Seasonal	Spring water	N 23˚45'21.3" E 092˚43'46.4"
3	Bawngkawn (Brigade field approach road, below Greenwood Hospital) - II	Seasonal	Spring water	N 23˚45'21.9" E 092˚43'50.4"
4	Bawngkawn (Near Bezelel Workshop)	Perennial	Spring water	N 23˚45'16.7" E 092˚43'41.0"
5	Halflong (Bawngkawn-Durtlang road)	Seasonal	Underground	N 23˚45'43.2" E 092˚43'59.7"
6	Durtlang (Near	Seasonal	Underground	N 23˚46'41.6"

	Presbyterian Church)			E 092˚43'40.8"
7	DurtlangVenglai (Zuangtui road, near New Haven Halfway Hostel)	Seasonal	Underground	N 23˚46'47.9" E 092˚43'44.8"
8	DurtlangLeitanRamthar (Zuangtui road)	Perennial	Spring water	N 23˚46'23.5" E 092˚44'14.9"
9	Zotuiluizau, DurtlangLeitanRamthar (Zuangtui road, Minor Irrigation Dept.)	Seasonal	Spring water	N 23˚46'19.2" E 092˚44'20.7"
10	Hunthar (Near Health Sub Centre)	Seasonal	Spring water	N 23˚44'32.0" E 092˚42'51.0"
11	Chaltlang-Sairang Road - I	Seasonal	Spring water	N 23˚41'15.3" E 092˚43'20.7"
12	Chaltlang-Sairang Road - II	Seasonal	Spring water	N 23˚45'17.5" E 092˚43'25.8"
13	Chaltlang-Sairang Road - III	Seasonal	Spring water	N 23˚45'17.9" E 092˚43'25.7"
14	Pa ThlanaTuikhur, Ramhlun North (Lower Road)	Seasonal	Spring water	N 23˚45'17.5" E 092˚43'25.8"
15	Ramhlun North (Near DONNA Embroidery)	Seasonal	Underground	N 23˚44'51.2" E 092˚43'23.3"
16	Ramhlun North (Near Zotei Building)	Seasonal	Underground	N 23˚44'45.3" E 092˚43'24.4"
17	A. BiakthuamaTuikhur, Ramhlun South	Seasonal	Spring water	N 23˚44'39.3" E 092˚43'22.9"
18	Ramhlun South (Near MHIP Hall)	Seasonal	Underground	N 23˚44'33.8" E 092˚43'23.5"
19	Ramhlun South (Near Presbyterian	Seasonal	Spring water	N 23˚44'32.5" E 092˚43'24.6"

	Church)			
20	AizawlVenglai	Seasonal	Spring water	N 23˚44'23.3" E 092˚43'11.9"
21	Zotui, Electric Veng (Near ESRA Drug Store)	Perennial	Spring water	N 23˚44'25.0" E 092˚43'05.5"
22	AizawlVenglai (Near Sanitation Point)	Seasonal	Spring water	N 23˚44'28.1" E 092˚43'04.1"
23	AizawlVenglai (Near YMA Diamond Jubilee Lungphun) - I	Perennial	Spring water	N 23˚44'25.7" E 092˚43'07.8"
24	AizawlVenglai (Near YMA Diamond Jubilee Lungphun)- II	Perennial	Underground	N 23˚44'25.7" E 092˚43'07.5"
25	AizawlVenglai (Along Concrete Road)	Seasonal	Spring water	N 23˚44'25.5" E 092˚43'16.8"
26	Private Water Supply - Hunthar Sinking Area	Perennial	Spring water	N 23˚44'25.8" E 092˚42'44.2"
27	Private Water Supply - Near Zarkawt Cemetery, Hunthar	Perennial	Spring water	N 23˚44'48.5" E 092˚42'55.6"

Table 4.2: List of water resources found in the east zone

AIZAWL EAST				
Sl. No.	Source	Seasonality	Type	Coordinates
1	MuannaVeng, Zuangtui	Seasonal	Spring water	N 23˚45'58.0" E 092˚44'52.7"
2	PuSawmaTuikhur, MuannaVeng, Zuangtui	Seasonal	Spring water	N 23˚45'34.2" E 092˚44'22.6"
3	PuDaraTuikhur, MuannaVeng, Zuangtui (Above Hauchhum Handloom)	Seasonal	Spring water	N 23˚45'32.5" E 092˚44'17.8"
4	Zemabawk (Near Bharat Petroleum Filling Station)	Seasonal	Spring water	N 23˚43'50.6" E 092˚45'29.8"
5	Tuirial Road	Seasonal	Spring water	N 23˚43'54.9" E 092˚46'48.9"
6	Tuirial River Bridge	Seasonal	River	N 23˚43'07.2" E 092˚47'59.1"
7	Private Water Supply - JK Tui, Zuangtui	Perennial	Spring water	N 23˚45'26.1" E 092˚44'30.7"
8	Chite River Bridge	Seasonal	River	N 23˚44'11.0" E 092˚44'05.3"
9	Tuirial, Near Tuirial River	Perennial	Spring water	N 23˚43'23.3" E 092˚47'51.9"
10	TuirialRoad,Near Bung Bangla	Perennial	Spring water	N 23˚73'18.02" E 092˚78'05.16"

Table 4.3: List of water resources found in the west zone

AIZAWL WEST				
Sl. No.	Source	Seasonality	Type	Coordinates
1	Tanhril AMC Tuikhur	Seasonal	Spring water	N 23˚44'35.0" E 092˚40'43.1"
2	Tanhril, near YMA Hall	Seasonal	Spring water	N 23˚44'22.7" E 092˚40'33.9"
3	Hrangbana Resort, Ramrikawn	Perennial	Spring water	N 23˚44'52.4" E 092˚40'34.6"
4	Tanhril, near Central Jail (Sakawrtuichhun Road)	Seasonal	Spring water	N 23˚45'04.3" E 092˚40'32.3"
5	Sakawrtuichhun, near Presbyterian Church	Seasonal	Spring water	N 23˚45'35.4" E 092˚40'27.0"
6	Tuivamit, MZU Road (Near Mandir)	Seasonal	Underground	N 23˚44'44.6" E 092˚40'59.0"
8	Luangmual, MZU Road (Above Road)	Seasonal	Spring water	N 23˚44'29.8" E 092˚41'60.9"
9	Luangmual, MZU Road (On Road side) - I	Seasonal	Spring water	N 23˚44'29.0" E 092˚41'49.6"
10	Luangmual, MZU Road (On Road side) - II	Seasonal	Spring water	N 23˚44'23.7" E 092˚41'47.4"
11	Luangmual, Near Zopuii Villa (MZU Road)	Seasonal	Underground	N 23˚44'21.3" E 092˚41'47.0"
12	Govt. Complex	Seasonal	Spring water	N 23˚44'29.8" E 092˚41'60.9"
13	Govt. Complex, Old Age Home Road	Seasonal	Spring water	N 23˚43'40.7" E 092˚41'41.9"
14	Govt. Complex	Seasonal	Spring water	N 23˚43'50.1" E 092˚41'40.0"

15	Govt. Complex	Seasonal	Spring water	N 23˚43'50.5" E 092˚41'39.3"
16	Zonuam, Chawnpui Road	Seasonal	Spring water	N 23˚43'46.2" E 092˚41'41.6"
17	New Capital Complex, near Bridge - I	Seasonal	Spring water	N 23˚43'58.7" E 092˚42'03.6"
18	New Capital Complex, near Bridge - II	Seasonal	Spring water	N 23˚43'48.4" E 092˚43'28.1"
19	BungkawnVengthar, near Vety Office	Seasonal	Spring water	N 23˚43'47.5" E 092˚42'28.4"
20	BungkawnVengthar, near Lai House	Seasonal	Spring water	N 23˚43'15.6" E 092˚43'40.9"
21	Tuikual, Temple - Vaivakawn Road	Seasonal	Spring water	N 23˚43'45.7" E 092˚43'00.5"
22	Vaivakawn - Tuikual Road (Near car wash) - I	Seasonal	Spring water	N 23˚44'14.2" E 092˚42'48.0"
23	Vaivakawn - Tuikual Road (Near car wash) - II	Seasonal	Spring water	N 23˚44'14.7" E 092˚42'47.8"
24	Zonuam, Near Lalkhawchhana Point - I	Seasonal	Spring water	N 23˚73'70.27" E 092˚70'04.06"
25	Zonuam, Near Lalkhawchhana Point - II	Seasonal	Spring water	N 23˚73'94.82" E 092˚70'87.94"
26	Zonuam, Near Lalkhawchhana Point - III	Seasonal	Spring water	N 23˚73'83.61" E 092˚69'98.30"
27	Zonuam, Near Active Gym- I	Seasonal	Groundwater	N 23˚74'17.44" E 092˚70'69.30"
28	Zonuam, Near Active Gym- II	Seasonal	Spring water	N 23˚74'17.44" E 092˚70'69.30"
29	LuangmualVengthlang, Near Baptist Church	Perennial	Spring water	N 23˚72'91.53" E 092˚70'44.44"

30	Chhangurkawn, Near Bus Stop	Seasonal	Groundwater	N 23˚74'24.79" E 092˚70'46.11"
31	Vaivakawn, Near Zopuii Gas Agency-I	Seasonal	Spring water	N 23˚74'00.53" E 092˚70'82.25"
32	Vaivakawn, Near Zopuii Gas Agency-II	Seasonal	Spring water	N 23˚74'00.53" E 092˚70'82.25"
33	Zonuam, Near Presbyterian church	Perennial	Spring water	
34	Zonuam, Near Anganwadi-2	Perennial	Spring water	

Table 4.4: List of water resources found in the south zone

AIZAWL SOUTH				
Sl. No.	Source	Seasonality	Type	Coordinates
1	Republic Near holy heart school.	Seasonal	Spring water	N 23˚44'35.0" E 092˚40'43.1"
2	Republic Near YMA hall	perennial	Spring water	N 23˚43'14.0" E 092˚43'18.57"
3	Republic Near College Veng	Seasonal	Spring Water	N 23˚72'27.82" E 092˚72'23.03"
4	Republic Near Presbyterian Church	Seasonal	Groundwater	N 23˚71'75.70" E 092˚72'93.06"
5	Republic near Vigora spa	seasonal	Spring water	N 23˚71'95.21" E 092˚72'18.95"
6	Upper Khatla, Pahlira Road	Seasonal	Spring water	N 23˚72'14.58" E 092˚71'76.01"
7	Kulikawn, Tlangnuam Road-I	Seasonal	Spring water	N 23˚70'85.89" E 092˚71'78.26"
8	Kulikawn, Tlangnuam Road-II	Seasonal	Groundwater	N 23˚70'66.03" E 092˚71'33.28"
9	Model veng, Tlangnuam Road	perennial	Spring water	N 23˚71'31.08" E 092˚71'40.13"
10	Tlangnuam, Dam veng	Seasonal	Groundwater	N 23˚70'69.03" E 092˚71'59.20"

Photo Plate 11: Zemabawk (Near Highland motor workshop)

Photo Plate 12: Tuirial river approach road

Photo Plate 13: TurialRiver,duringwinter season

Photo Plate 14: Tuikual River during winter season

Photo Plate 15: Zemabawk,Turial Road

Photo Plate 16: Roadside seasonal spring water at ThuampuiVeng

Photo Plate 17: Zuangtui near NIELIT

Photo Plate 18: Zuangtui near TNT

Photo Plate 19: Roadside spring at Zuangtui

Photo Plate 20: PuSawmatuikhur at Zuangtui nearPresbyterian Church

Photo Plate 21: Roadside spring at Zuangtui,Muthi Road

Photo Plate 22: Conserved seasonal spring water collection point at Muthi Road

Photo Plate 23: Muthi Road seasonal spring collected site

Photo Plate 24: Perennial spring collection site at Muthi road, near Durtlang approach road

Photo Plate 25: Underground water collection point at Thuampui

Photo Plate 26: Underground water pumping site near Ramhlun 'N' Bazar

Photo Plate 27: Underground water pumping site at Ramhlun 'N'

Photo Plate 28: Underground water pumping site at Ramhlun 'S' near Baptist church

Photo Plate 29: Perennial spring near Zonuamkawn

Photo Plate 30: Perennial spring water near Lalkhawchhana point, Zonuam

Photo Plate 31: Spring collected site near Active Gym, Zonuam

Photo Plate 32: Seasonal spring water near Zonuamkawn

Photo Plate 33: Perennial spring near LuangmualVengthlang Baptist church

Photo Plate 34: Spring collected site near Vaivakawn, Zopuii Gas Agency

Photo Plate 35: Perennial spring water near Ruaipuii Building

Photo Plate 36: Conserved spring collection site near Vaivakawn Taxi stand

Photo Plate 37: Abandoned groundwater pumping facilities near Animal home, Dinthar

Photo Plate 38: A man using groundwater for washing and cleaning

Photo Plate 39: Seasonal spring water collection site constructed by AMC, near Rollick distributor

Photo Plate 40:A woman collecting water for household purpose, near Pine Mount School

Photo Plate 41: Spring collection site Near MRF tyre work, Temple

Photo Plate 42: A man cleaning spring collection site, Tuikual

Photo Plate 43: Spring collected in between houses at Upper Khatla

Photo Plate 44: Roadside spring collection site being protected by a concrete wall

Photo Plate 45: Chawnpui roadside perennial spring collection point

Photo Plate 46: Underground water pumping point, near Pachuau Motor Service, Tlangnuam

Photo Plate 47: Underground water pumping point, at Chhangurkawn

Photo Plate 48:Underground water pumping point, at Tlangnuam, Dam veng

Photo Plate 49: Roadside perennial spring water collected with tap for the collection tank, at Tlangnuam, Dam veng

Photo Plate 50: Roadside perennial spring water used for washing hair at ITI Veng

Photo Plate 51: Spring water near Viroga Spa &Steambath, Republic

Photo Plate 52: Spring water used for washing clothes and collecting for household purposes at Republic Veng

Photo Plate 53: Seasonal spring near College Veng

Photo Plate 54: Roadside spring collection point near College Veng

Photo Plate 55: Underground water pumping point Near Republic Presbyterian Church

Photo Plate 56: Underground water pumping point and spring water collection point in one place at Bethlehem Veng.

Photo Plate 57: Spring water collection point at Bethlehem Vengkawn.

Photo Plate 58 : Underground water pumping point and spring water collection point in one place at Bethlehem Veng.

Photo Plate 59: Perennial Underground water being pumped out during winter at Bethlehem Veng.

Photo Plate 60: Perennial Underground water at Armed Veng.

Photo Plate 61: Perennial at AizawlVenglai, Near Vanglaini

Photo Plate 62: Underground water at Dinthar, Near Salvation Army Church

Photo Plate 63: Spring collection point at Dinthar(New Capital Complex approach road)

Photo Plate 64: Roadside spring collection point at Dinthar(New Capital Complex approach road)

Photo Plate 65: Spring collection point at Govt. Complex

Photo Plate 66: Spring collection point near New Capital Complex gate No. 2

Photo Plate 67: Spring collection point at Govt. Complex road

Photo Plate 68: Perennial spring water collection point and has been collecting the water through pipes in the nearby houses at ZonuamNearANganwadi.

Photo Plate 69: Perennial spring water Near Zonuam Presbyterian Church

Photo Plate 70: Perennial spring water at Govt. Complex approach road from Chhangurkawn

Photo Plate 71: Underground water pumping point located at Chaltlang

Photo Plate 72: Underground water pumping point located at stone crushing area, LuangmualVengthlang

Photo Plate 73: Underground water pumping point located Govt. Complex road, near Pine Mount School hostel

Photo Plate 74: Underground water pumping point located Govt. Complex road

Photo Plate 75: Spring water at Ramthar

Photo Plate 76: Spring water at Zonuam ,Chawnpui road

Photo Plate 77: BawngkawnThuampui Road

Photo Plate 78: Car Wash, Tuirial Road

Water Quality Assessment:

The findings on water quality attributes at selected study sites for two successive years (i.e., 2016-17 and 2017-180 can be summarized as follows.

4.1 Temperature:

During 2016-17, temperature varied from 20.32^{o}C (pre monsoon season) at Site 5 to 22.5^{o}C (monsoon season) at Site-1. The site-wise seasonal minimum and maximum values were recorded as 21.57^{o}C (post monsoon season) to 22.5^{o}C (monsoon season) at Site 1; 20.95^{o}C (pre monsoon season) to 21.5^{o}C (monsoon season) at site 2; 20.45^{o}C (pre monsoon season) to 22°C (monsoon season) at Site 3; 20.55^{o}C (pre monsoon and post monsoon season) to 22.12^{o}C (monsoon season) at Site 4;20.32^{o}C (pre monsoon season) to 21.62^{o}C (monsoon season) at Site 5.**Fig.4.1**

Similarly, during 2017-18, temperature varied from 20.2^{o}C (pre monsoon season) at Site-3 to 22.52^{o}C (post monsoon and monsoon season) at Site 1. The site-wise seasonal minimum and maximum values were recorded as 21.47^{o}C (pre monsoon season) to 22.52^{o}C (monsoon season) at Site 1 ; 20.77^{o}C (pre monsoon season) to 21.72^{o}C (pre monsoon and monsoon season) at Site 2; 20.2^{o}C (pre monsoon season) to 21.95 ^{o}C (monsoon season) at Site 3 ; 20.82^{o}C (pre monsoon season) to 21.95^{o}C (monsoon season) at Site 4; 20.45^{o}C (pre monsoon season) to 21.97^{o}C (monsoon season) at Site 5.**Fig.4.2**

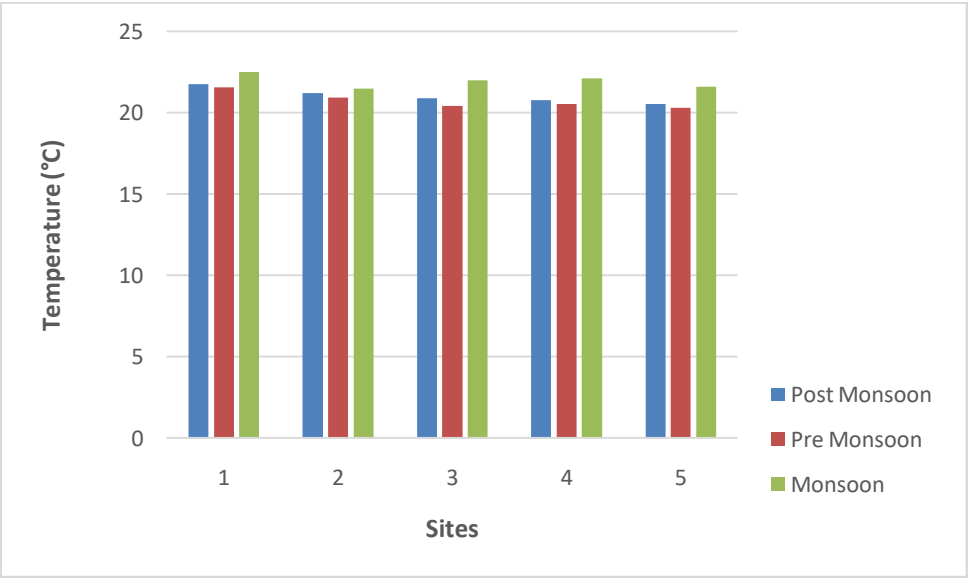


Fig. 4.1 Seasonal variation in temperature of water at selected study sites during 2016-2017.

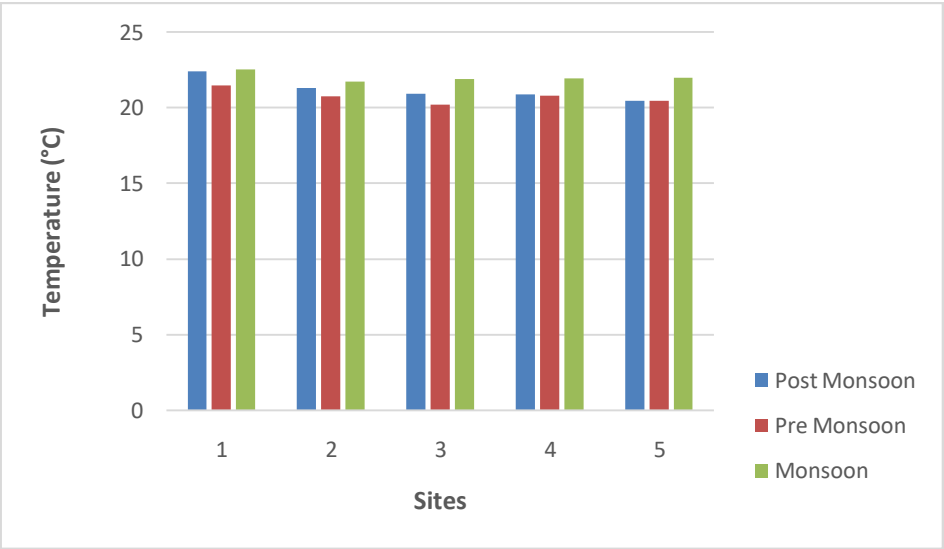


Fig. 4.2 Seasonal variation in temperature of water at selected study sites during 2017-2018

4.2 Turbidity:

During the year 2016 – 2017 the turbidity varied from 0.1 NTU (pre monsoon season) at Site3 to 1.15 NTU (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 0.42 NTU (pre monsoon season) to 1.15NTU (monsoon season) at Site 1; 0.15 (pre monsoon season) to 0.825 (monsoon season) at Site 2; 0.1 NTU (pre monsoon season) to 0.5 NTU (monsoon season) respectively at Site 3; 0.1 NTU (post monsoon season) to 0.97 NTU (monsoon season) at Site 4; 0.22 NTU (post monsoon season) to 0.52 NTU (monsoon season) at Site 5.**Fig. 4. 3**

Similarly, during the year 2017 – 2018turbidity varied from 0.12 NTU (pre monsoon season) at Site3 to 0.85 NTU (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 0.37 NTU (pre and post monsoon season) to 0.85 NTU (monsoon season) at Site 1; 0.2 NTU (pre and post monsoon season) to 0.4 NTU (monsoon season) at Site 2; 0.12 NTU (pre monsoon season) to 0.33 NTU (monsoon season) respectively at Site 3; 0.18 NTU (pre monsoon season) to 0.38 NTU (monsoon season) at Site 4; 0.12 NTU (pre and post monsoon season) to 0.27 NTU (monsoon season) at Site 5.**Fig. 4.4**

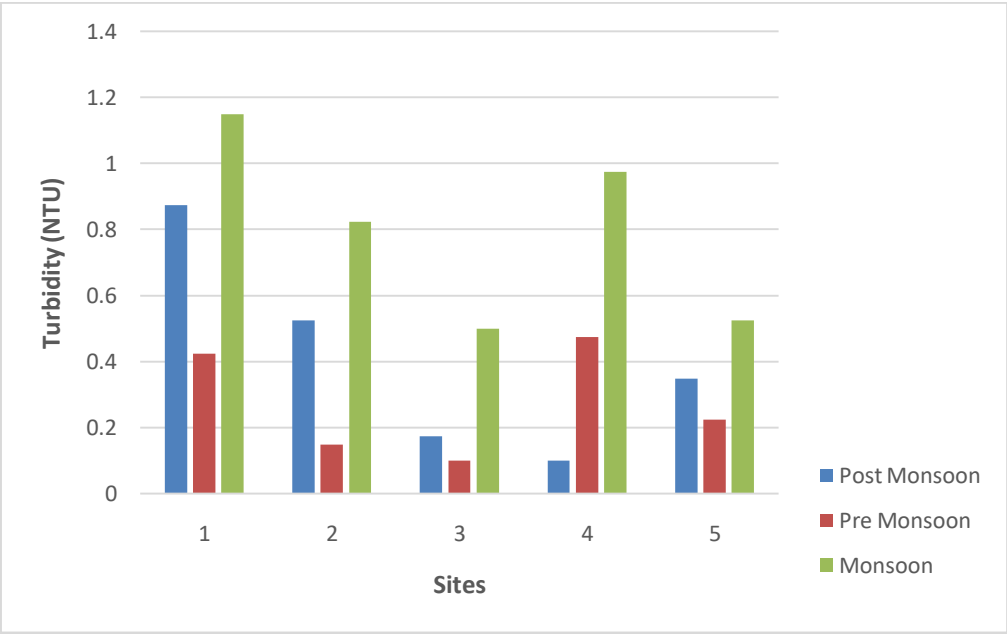


Fig. 4.3 Seasonal variation in turbidity of water at selected study sites during 2016-2017

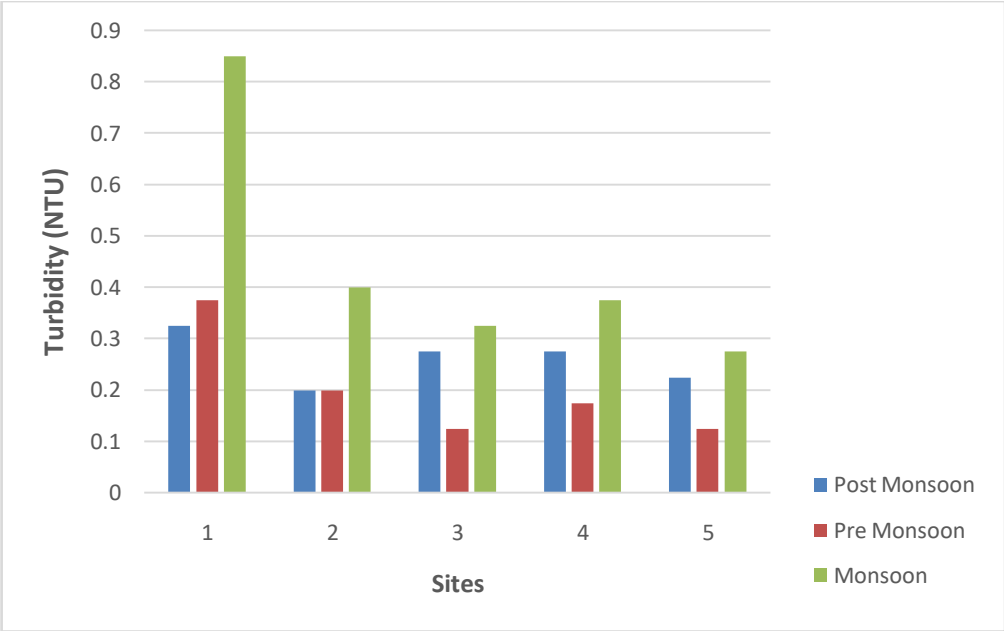


Fig. 4.4 Seasonal variation in turbidity of water at selected study sites during 2017-2018

4.3 pH:

During the year 2016 – 2017pH varied from 5.56 (post monsoon season) at Site3 to 6.69 (pre monsoon and monsoon season) at Site 2. The site wise minimum and maximum values were recorded as 5.89 (post monsoon season) to 6.07 (pre monsoon season) at Site 1; 5.95 (monsoon season) to 6.69 (pre monsoon season) at Site 2, 5.56 (monsoon season) to 5.75 (pre monsoon season) at Site 3; 5.72 (monsoon season) to 5.87 (premonsoon season) at Site 4; 5.75 (monsoon season) to 5.98 (pre monsoon season) at Site 5.**Fig. 4.5**

Similarly, during the year 2017 – 2018pH varied from 5.59 (monsoon season) at Site3 to 6.77 (pre monsoon) at Site 2. The site wise minimum and maximum values were recorded as 6.24 (monsoon season) to 6.48 (pre monsoon season) at Site 1; 6.03 (monsoon season) to 6.77 (pre monsoon season) at Site 2; 5.59 (monsoon season) to 6.06 (pre monsoon season) at Site 3 respectively; 5.93 (monsoon season) to 6.33 (pre monsoon season) at Site 4; 6.05 (post monsoon season) to 6.31(pre monsoon season) at Site 5.**Fig.4.6**

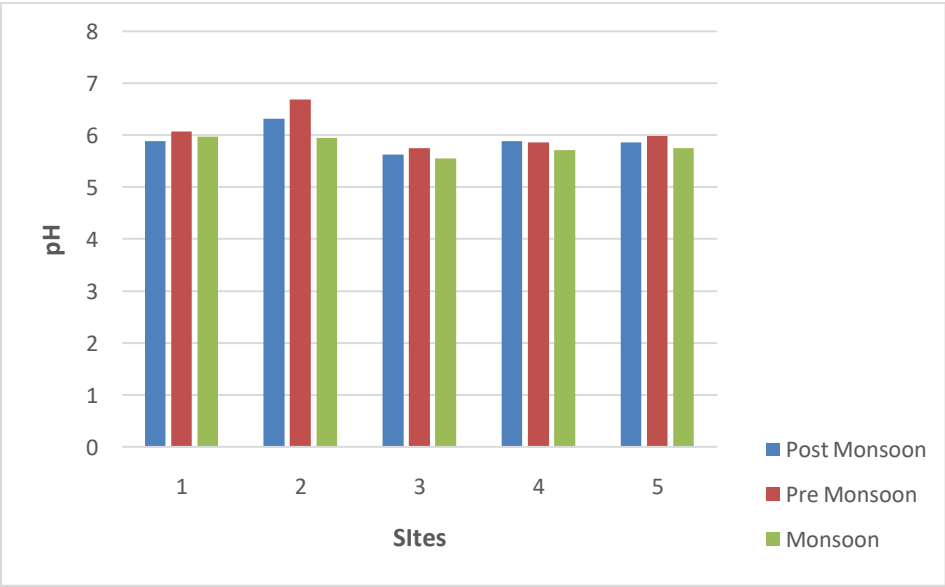


Fig. 4.5 Seasonal variation in pH of water at selected study sites during 2016-2017

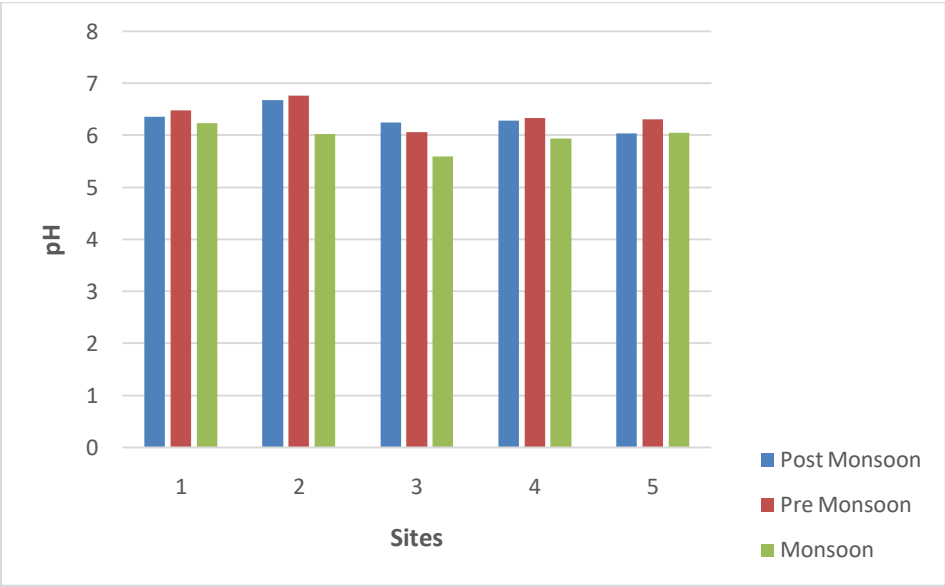


Fig. 4.6 Seasonal variation in pH of water at selected study sites during 2017-2018

4.4 Oxidation reduction potential:

During the year 2016 – 2017 oxidation reduction potential varied from 24.25 µV (post monsoon and monsoon season) at Site 2 to 81.65 µV (monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 56.6 µV (monsoon season) to 64.5 µV (pre monsoon season) at Site 1; 24.25 µV (pre monsoon) to 60.27 µV (monsoon season) at Site 2; 75 µV (post monsoon season) to 81.65 µV (monsoon season) at Site 3; 63.87 µV (post monsoon season) to 73.72 µV (monsoon season) at Site 4, and 59.85 µV (post monsoon season) to 68.42 µV (monsoon season) at Site 5. **Fig. 4.7**

Similarly, during the year 2017 – 2018 oxidation reduction potential varied from 27.25 µV (pre monsoon season) at Site 2 to 81.22 µV (monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 40.02 µV (post monsoon season) to 45.95 µV (monsoon season) at Site 1; 27.25 µV (pre monsoon season) to 57.67 µV (monsoon season) at Site 2; 55.65 µV (post monsoon season) to 81.22 µV (monsoon season) at Site 3, 39.5 µV (pre monsoon season) to 63.12 µV (monsoon season) at Site 4; 37.85 µV (pre monsoon season) to 55.35 µV (monsoon season) at Site 5.**Fig. 4.8**

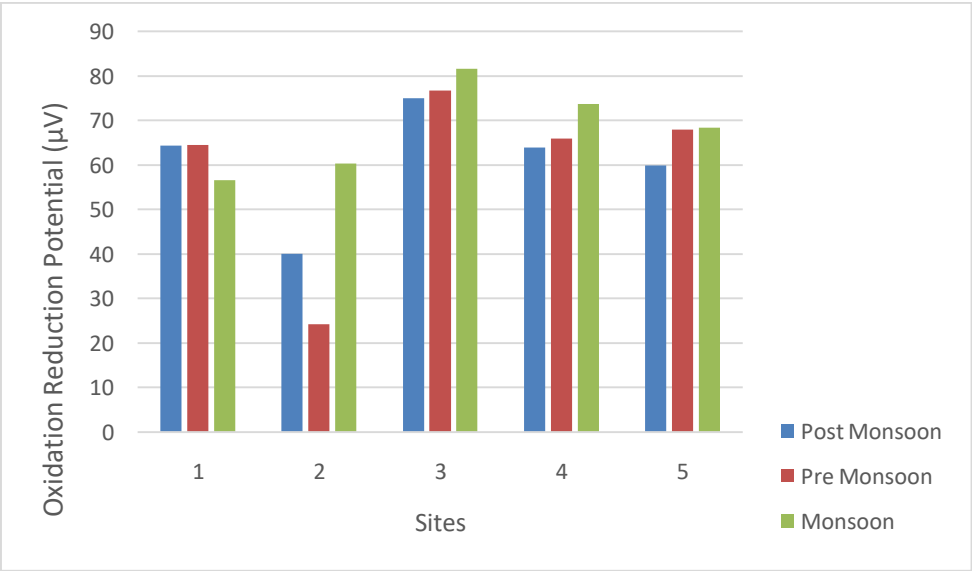


Fig. 4.7 Seasonal variation in oxidation reduction potential of water at selected study sites during 2016-2017

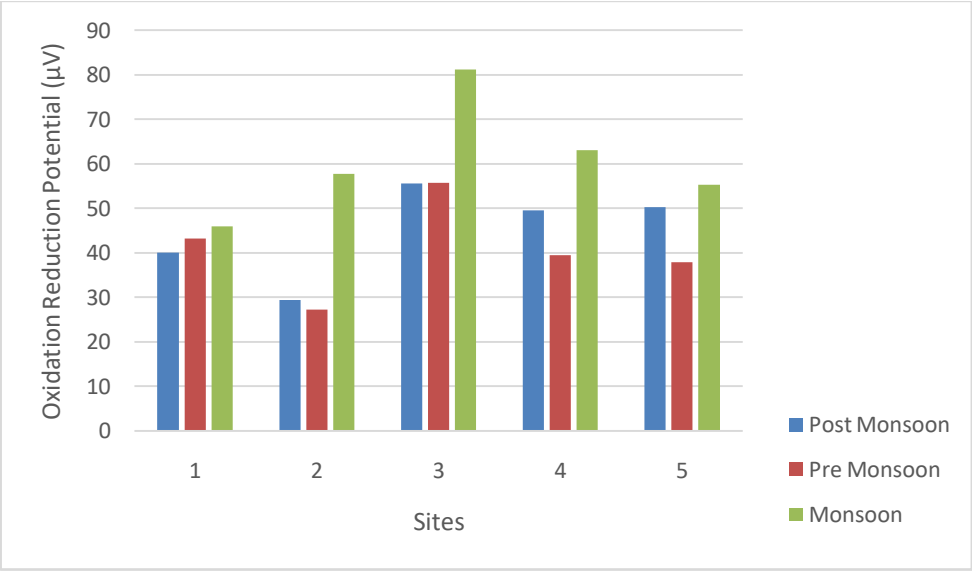


Fig. 4.8 Seasonal variation in oxidation reduction potential in water at selected study sites during 2017-2018

4.5 Acidity:

During the year 2016 – 2017acidity varied from 6 mgL^{-1} (pre monsoon season) at Site2 to 70.5 mgL^{-1} (post monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 51 mg/l (pre monsoon season) to 70.5 mgL^{-1} (post monsoon season) at Site 1; 6 mg/l (pre monsoon season) to 21.62 mgL^{-1} (monsoon season) at Site 2; 27 mgL^{-1} (pre monsoon season) to 48.75 mgL^{-1} (post monsoon season) at Site 3; 24.75 mgL^{-1} (pre monsoon season) to 45 mg/l (monsoon season) at Site 4; 24.75 mgL^{-1} (pre monsoon season) to 64.25 mgL^{-1} (post monsoon season) respectively at Site 5. **Fig. 4.9**

Similarly, during the year 2017 – 2018 acidity varied from 6 mgL^{-1} (pre monsoon season) at Site 2 to 93.5 mgL^{-1} (post monsoon season) at Site 5. The site wise minimum and maximum values were recorded as 42.75 mgL^{-1} (pre monsoon season) to 93.5 mgL^{-1} (post monsoon season) at Site 1; 6 mgL^{-1} (pre monsoon season) to 32.25 mgL^{-1} (post monsoon season) at Site 2;29 mgL^{-1} (pre monsoon season) to 64.75 mgL^{-1} (post monsoon season) at Site 3; 22.5 mgL^{-1} (pre monsoon season) to 63 mgL^{-1} (post monsoon season) at Site 4 and 40.5 mgL^{-1} (pre monsoon season) to 79 mgL^{-1} (post monsoon season) respectively at Site 5. **Fig. 4.10**

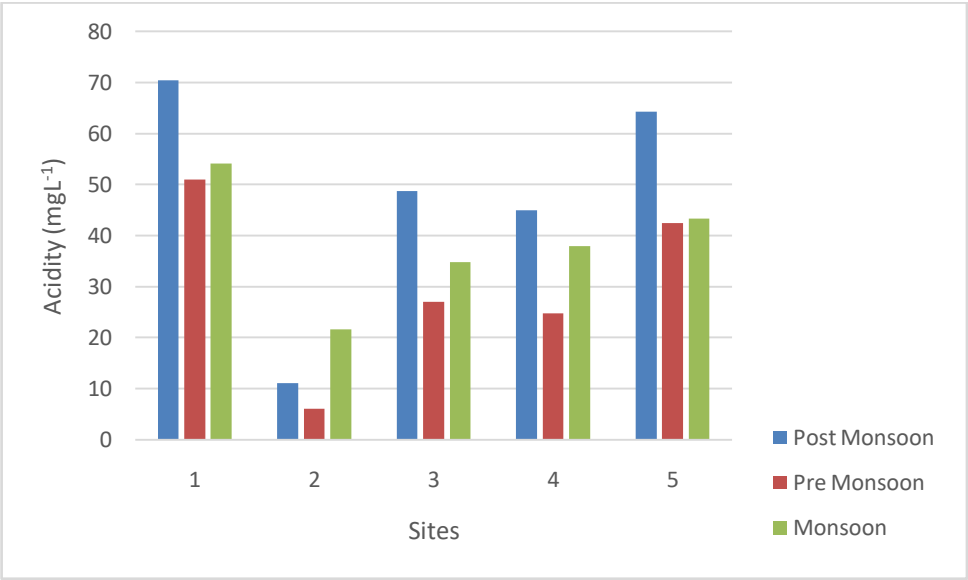


Fig. 4.9 Seasonal variation in acidity of water at selected study sites during 2016-2017

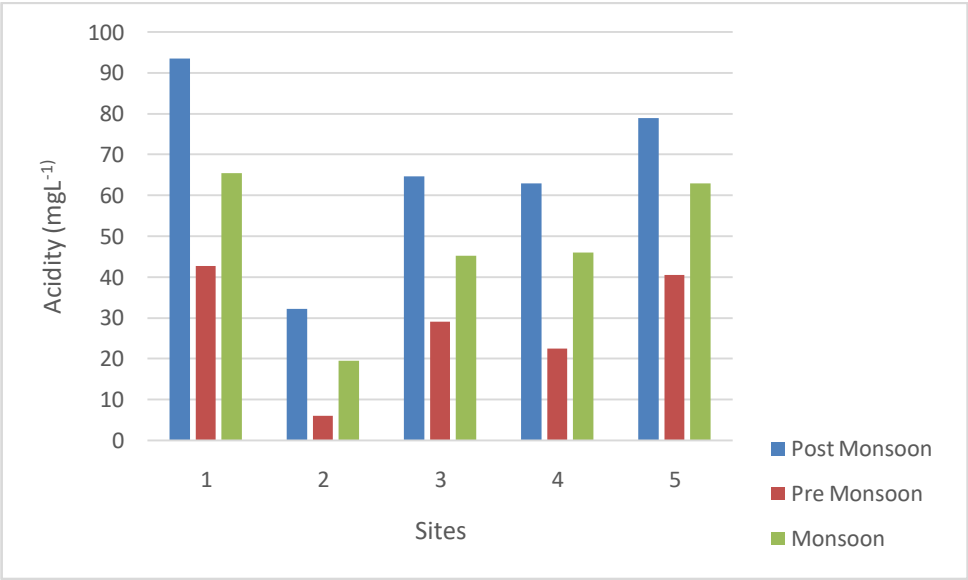


Fig. 4.10 Seasonal variation in acidity of water at selected study sites during 2017-20 18

4.6 Alkalinity:

During the year 2016 – 2017 alkalinity varied from 9.32 mgL^{-1} (monsoon season) at Site 3 to 68.5 mgL^{-1} (pre monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 22.65 mgL^{-1} (monsoon season) to 68.5 mgL^{-1} (pre monsoon season) at Site 1; 11.27 mgL^{-1} (monsoon season) to 21 mgL^{-1} (post monsoon season) at Site 2, 9.32 mgL^{-1} (monsoon season) to 27.5 mgL^{-1} (post monsoon season) at Site 3; 13.12 mgL^{-1} (monsoon season) to 33.25 mgL^{-1} (pre monsoon season) at Site 4; and 14.12 mgL^{-1} (monsoon season) to 51 mgL^{-1} (pre monsoon season) at Site 5. **Fig. 4.11**

Similarly during the year 2017 – 2018 alkalinity varied from 17.5 mgL^{-1} (monsoon season) at Site2 to 70 mgL^{-1} (pre monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 36.5 mgL^{-1} (monsoon season) to 70 mgL^{-1} (pre monsoon season) at Site 1; 17.5 mgL^{-1} (monsoon season) to 44.25 mgL^{-1} (post monsoon season) at Site 2; 20.75 mgL^{-1} (monsoon season) to 42.25 mgL^{-1} (pre monsoon season) at Site 3; 25 mgL^{-1} (monsoon season) to 48.25 mgL^{-1} (post monsoon season) at Site 4 and 27.5 mgL^{-1} (monsoon season) to 64 mgL^{-1} (post monsoon season) at Site 5. **Fig. 4.12**

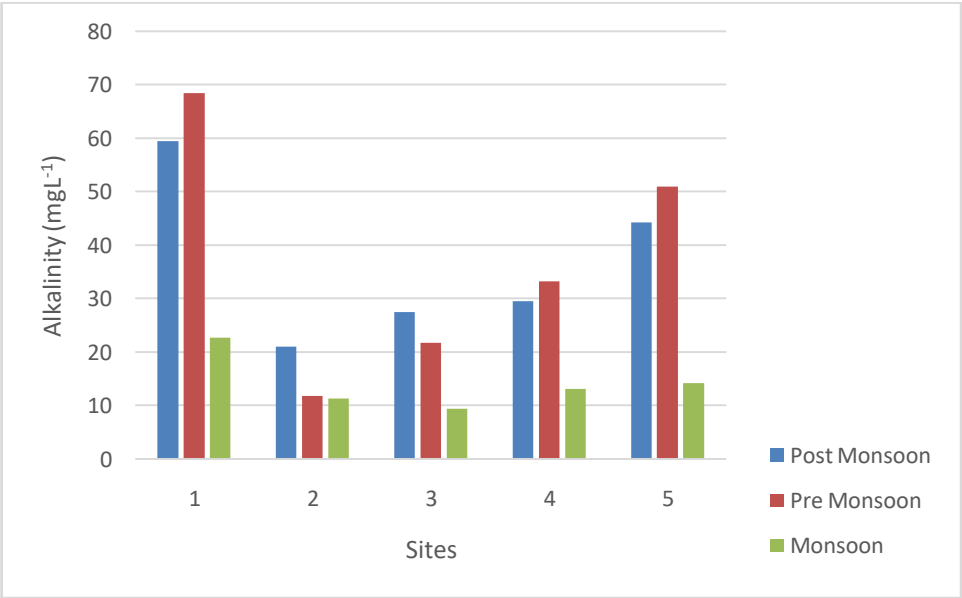


Fig. 4.11 Seasonal variation in alkalinity of water at selected study sites during 2016-2017

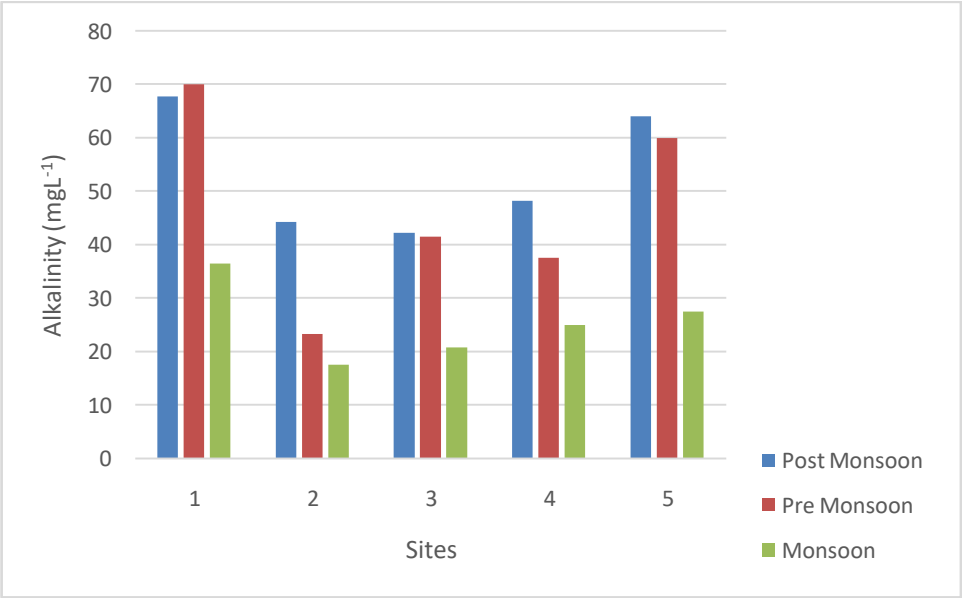


Fig. 4.12 Seasonal variation in alkalinity of water at selected study sites during 2017-2018

4.7 Chloride:

During the year 2016 – 2017 chloride varied from 34.36 mgL^{-1} (pre monsoon season) at Site 5 to 203.93 mgL^{-1} (monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 64.23 mgL^{-1} (pre monsoon season) to 125.46 mgL^{-1} (monsoon season) at Site 1; 61.96 mgL^{-1} (post monsoon season) to 136.95 mgL^{-1} (monsoon season) at Site 2;74.04 mgL^{-1} (pre monsoon season) to 203.93 mgL^{-1} (monsoon season) at Site 3; 54.60 mgL^{-1} (post monsoon season) to 105.96 mg/l (monsoon season) at Site 4;34.36 mgL^{-1} (pre monsoon season) to 55.48 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.13**

Similarly, during the year 2017 – 2018chloride varied from 28.24 mgL^{-1} (pre monsoon season) at Site 5 to 88.44 mgL^{-1} (monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 64.07 mgL^{-1} (pre monsoon season) to 88.18 mgL^{-1} (monsoon season) at Site 1; 63.6 mgL^{-1} (pre monsoon season) to 69.72 mgL^{-1} (post monsoon season) at Site 2;69.72 mgL^{-1} (pre monsoon season) to 98.34 mgL^{-1} (post monsoon season) at Site 3; 57.72 mgL^{-1} (pre monsoon season) to 73.09 mgL^{-1} (post monsoon season) at Site 4; and 28.2 mgL^{-1} (premonsoon season) to 37.25 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.14**

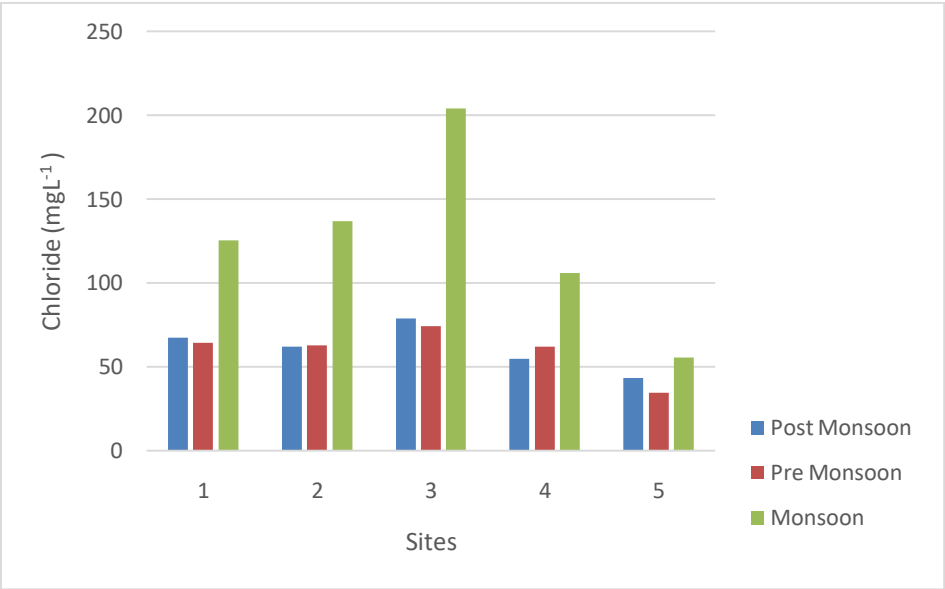


Fig. 4.13 Seasonal variation in chloride of water at selected study sites during 2016-2017

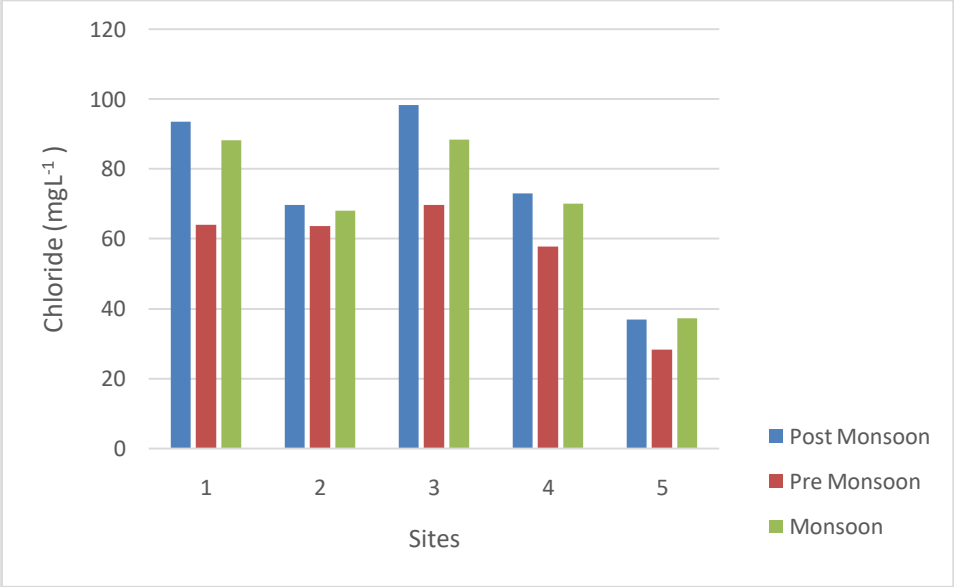


Fig. 4.14 Seasonal variation in chloride of water at selected study sites during 2017-2018

4.8 Total Hardness:

During the year 2016 – 2017 total hardness varied from 70.3 mgL^{-1} (monsoon season) at Site 5 to 205.75 mgL^{-1} (post monsoon season) at Site 1; The site wise minimum and maximum values were recorded as 116.5 mgL^{-1} (pre monsoon season) to 205.75 mgL^{-1} (post monsoon season) at Site 1;119.15 mgL^{-1} (monsoon season) to 154.5 mgL^{-1} (post monsoon season) at Site 2;164.5 mgL^{-1} (pre monsoon season) to 257.5 mgL^{-1} (post monsoon season) at Site 3; 149 mgL^{-1} (pre monsoon season) to 200.75 mgL^{-1} (post monsoon season) at Site 4; 70.3 mgL^{-1} (monsoon season) to 93 mgL^{-1} (post monsoon season) at Site 5. **Fig. 4.15**

Similarly, during the year 2017 – 2018 total hardness varied from 70.25 mgL^{-1} (monsoon season) at Site 5 to 246.75 mgL^{-1} (post monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 123.25 mgL^{-1} (pre monsoon season) to 186.75 mgL^{-1} (post monsoon season) at Site 1; 102.5 mgL^{-1} (monsoon season) to 146.5 mgL^{-1} (post monsoon season) at Site 2;175.5 mgL^{-1} (monsoon season) to 187 mgL^{-1} (post monsoon season) at Site 3; 137.75 mgL^{-1} (monsoon season) to 187 mgL^{-1} (post monsoon season) at Site 4; 70.25 mgL^{-1} (monsoon season) to 97.25 mgL^{-1} (post monsoon season) at Site 5. **Fig.4.16**

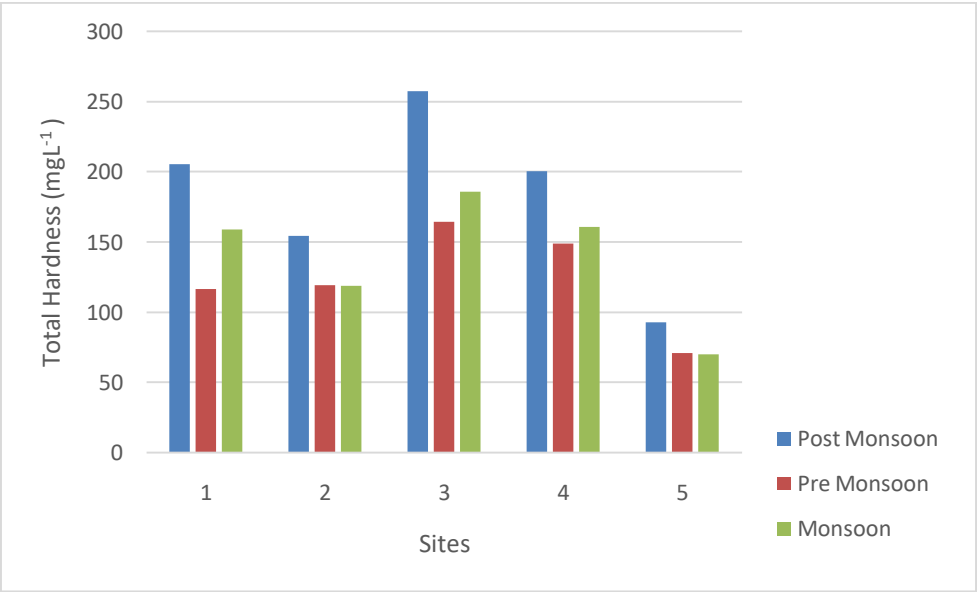


Fig. 4.15 Seasonal variation in total hardness of water at selected study sites during 2016-2017

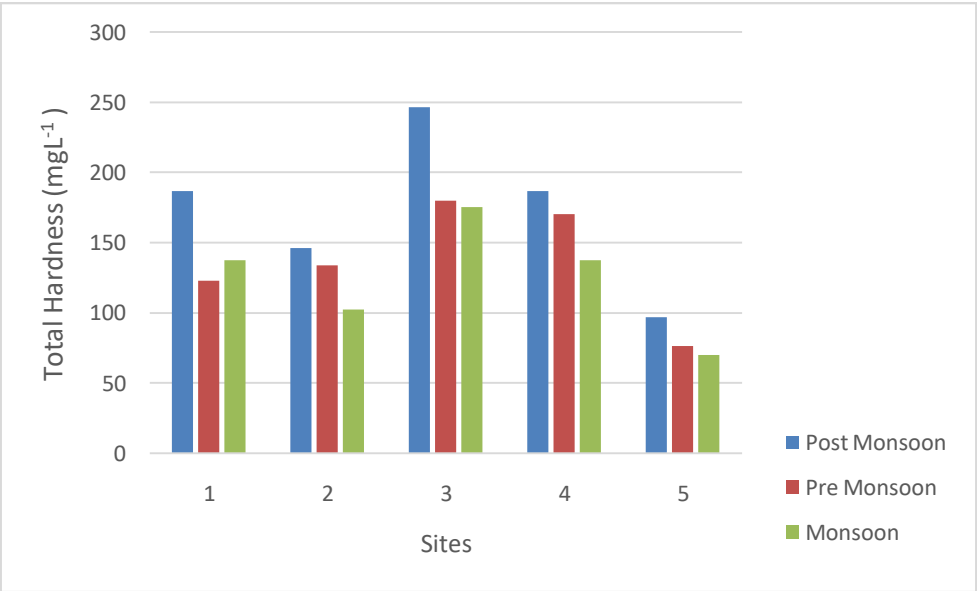


Fig. 4.16 Seasonal variation in total hardness of water at selected study sites during 2017-2018

4.9 Dissolve oxygen:

During the year 2016 – 2017 dissolve oxygen varied from 1.58 mgL^{-1} (pre monsoon season) at Site 1 to 5.72 mgL^{-1} (post monsoon season) at Site 5. The site wise minimum and maximum values were recorded as 1.58 mgL^{-1} (pre monsoon season) to 2.91 mgL^{-1} (post monsoon season) at Site 1; 3.87 mgL^{-1} (monsoon season) to 4.87 mgL^{-1} (post monsoon season) at Site 2; 3.46 mgL^{-1} (pre monsoon season) to 4.47 mgL^{-1} (pre monsoon season) at Site 3; 2.93 mgL^{-1} (monsoon season) to 4.35 mgL^{-1} (pre monsoon season) at Site 4; and 3.92 mgL^{-1} (monsoon season) to 5.72 mgL^{-1} (pre monsoon season) at Site 5. **Fig. 4.17**

Similarly, during the year 2017 – 2018 dissolve oxygen varied from 2.13 mgL^{-1} (premonsoon season) at site 1 to 5.32 mgL^{-1} (pre monsoon season) at site 5 and (pre monsoon and post monsoon season) at site 5. The site wise minimum and maximum values were recorded as 2.13 mgL^{-1} (pre monsoon season) to 2.32 mgL^{-1} (monsoon season) at Site 1; 4.32 mgL^{-1} (monsoon season) to 4.81 mg/l (post monsoon season) at site 2; 4.05 mg/l (monsoon season) to 4.33 mgL^{-1} (post monsoon season) at Site 3; 3.2 mgL^{-1} (monsoon season) to 5.41 mgL^{-1} (post monsoon season) at Site 4;3.85 mgL^{-1} (post monsoon season) to 5.32 mgL^{-1} (pre and post monsoon season) at Site 5. **Fig. 4.18**

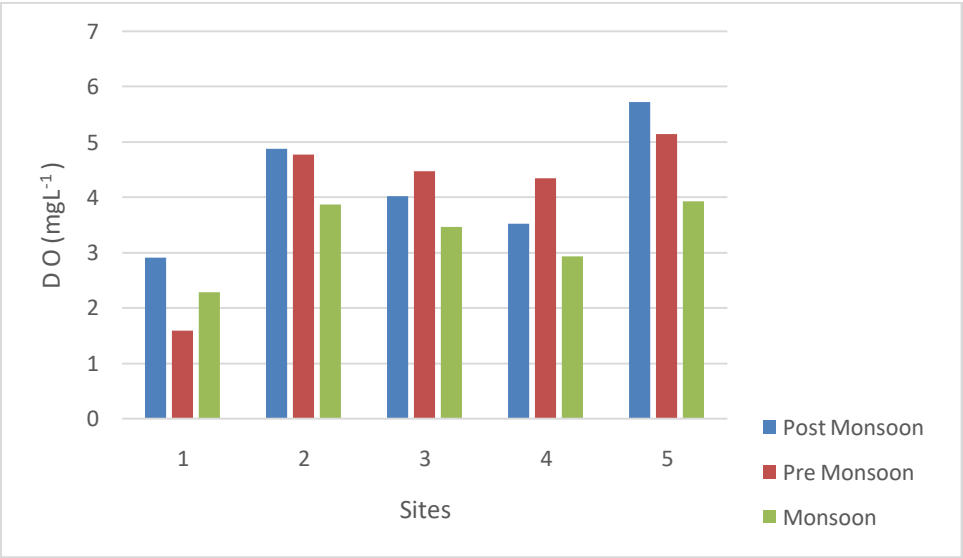


Fig. 4.17 Seasonal variation in dissolved oxygen of water at selected study sites during 2016-2017

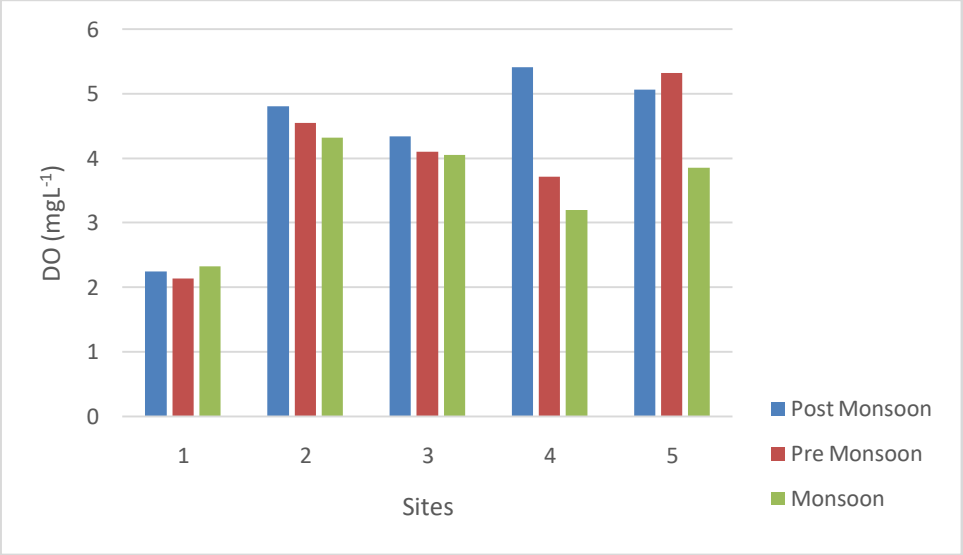


Fig. 4.18 Seasonal variation in dissolved oxygen of water at selected study sites during 2017-2018

4.10 Biological Oxygen Demand:

During the year 2016 – 2017Biological Oxygen Demand varied from 1.2 mg/l (post monsoon season) at Site 2 to 3.83 mgL^{-1} (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 2.37 mgL^{-1} (post monsoon season) to 3.83 mgL^{-1} (monsoon season) at Site 1;1.2 mgL^{-1} (post monsoon season) to 2.67 mgL^{-1} (monsoon season) at Site 2;1.57 mgL^{-1} (pre monsoon season) to 3.26 mgL^{-1} (monsoon season) at Site 3; 1.35 mgL^{-1} (pre monsoon season) to 3.1 mgL^{-1} (monsoon season) at Site 4; and 0.77 mgL^{-1} (post monsoon season) to 1.61 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.19**

Similarly, during the year 2017 – 2018Biological Oxygen Demand varied from 0.92 mgL^{-1} (pre monsoon season) at Site 5 to 4.36 mgL^{-1} (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 2.6 mgL^{-1} (pre and post monsoon season) to 4.36 mgL^{-1} (monsoon season) at Site 1;1.35 mgL^{-1} (pre monsoon season) to 2.75 mgL^{-1} (monsoon season) at Site 2; 1.5 mgL^{-1} (pre monsoon season) to 2.53 mgL^{-1} (monsoon season) respectively at Site 3; 1.27 mgL^{-1} (pre monsoon season) to 3.16 mgL^{-1} (monsoon season) at Site 4;0.92 mgL^{-1} (pre monsoon season) to 3.07 mgL^{-1} (monsoon season) at Site 5.**Fig. 4.20**

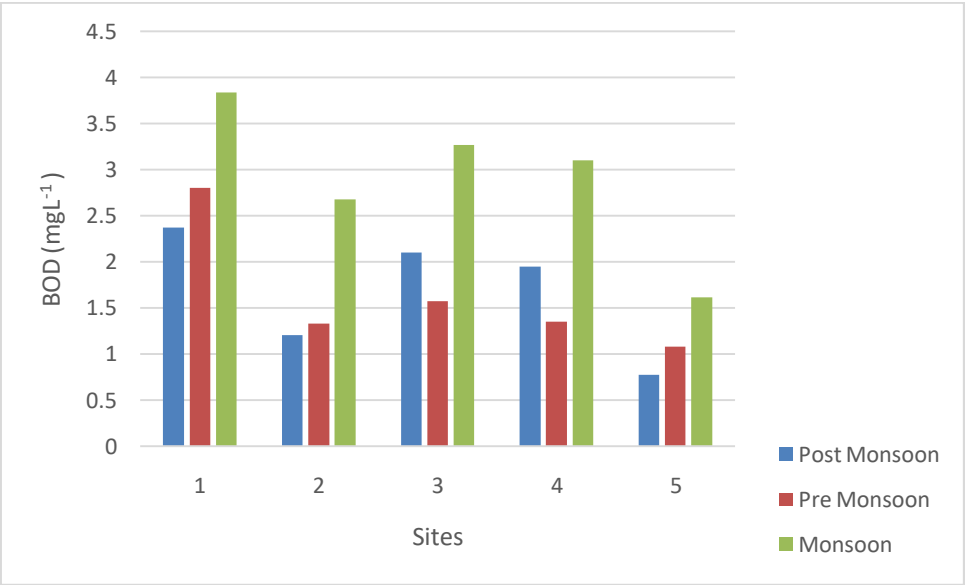


Fig. 4.19 Seasonal variation in biological oxygen demand of water at selected study sites during 2016-2017

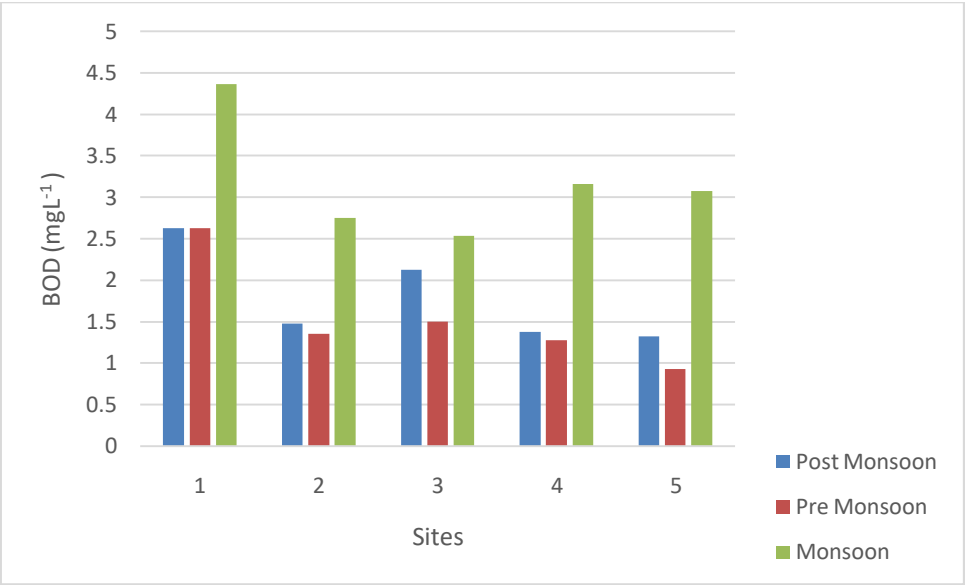


Fig. 4.20 Seasonal variation in biological oxygen demand of water at selected study sites during 2017-2018

4.11 Nitrite:

During the year 2016 – 2017nitrite varied from 0.025 mgL^{-1} (post monsoon season) at Site 5 to 0.077 mgL^{-1} (pre monsoon season) at Site 2. The site wise minimum and maximum values were recorded as 0.053 mgL^{-1} (pre monsoon season) to 0.062 mgL^{-1} (monsoon season) at Site 1; 0.033 mgL^{-1} (post monsoon season) to 0.077 mgL^{-1} (pre monsoon season) at Site 2; 0.043 mgL^{-1} (post monsoon season) to 0.075 mgL^{-1} (pre monsoon season) at Site 3; 0.036 mgL^{-1} (post monsoon season) to 0.058 mgL^{-1} (monsoon season) at Site 4; and 0.025 mgL^{-1} (post monsoon season) to 0.058 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.21**

Similarly, during the year 2017 – 2018 the observation reveals that nitrite varied from 0.025 mgL^{-1} (monsoon season) at Site 5 to 0.069 mgL^{-1} (monsoon season) at Site 3. The site wise minimum and maximum values were recorded as 0.051 mgL^{-1} (pre monsoon season) to 0.065 mgL^{-1} (post monsoon season) at Site 1; 0.026 mgL^{-1}(monsoon season) to 0.068 mgL^{-1} (pre monsoon season) at Site 2;0.036 mgL^{-1} (post monsoon season) to 0.069 mgL^{-1} (pre monsoon season) at Site 3; 0.032 mgL^{-1} (post monsoon season) to 0.048 mgL^{-1} (pre monsoon season) at Site 4; and 0.024 mgL^{-1} (monsoon season) to 0.049 mgL^{-1} (pre monsoon season) at Site 5. **Fig. 4.22**

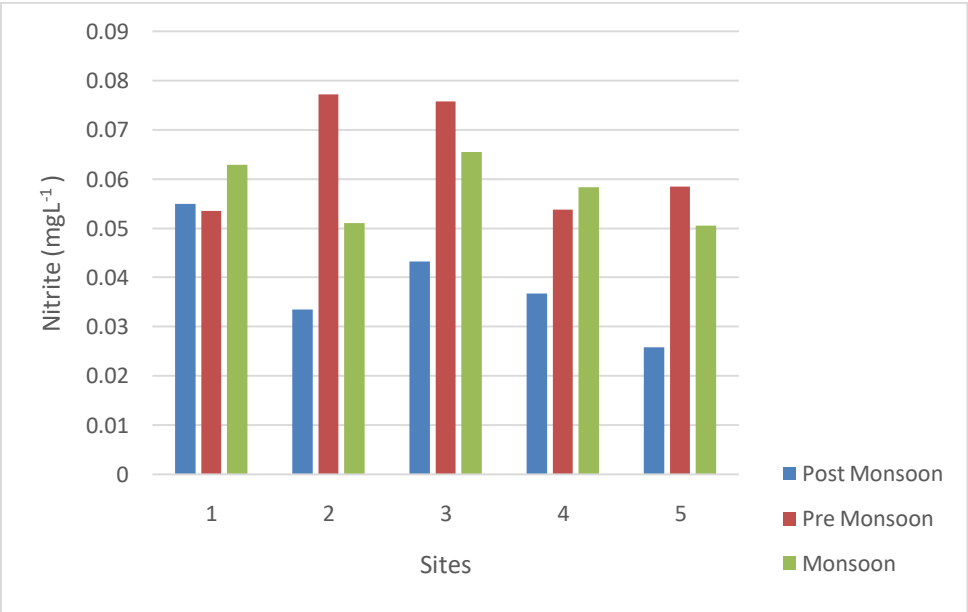


Fig. 4.21 Seasonal variation in nitrite of water at selected study sites during 2016-2017

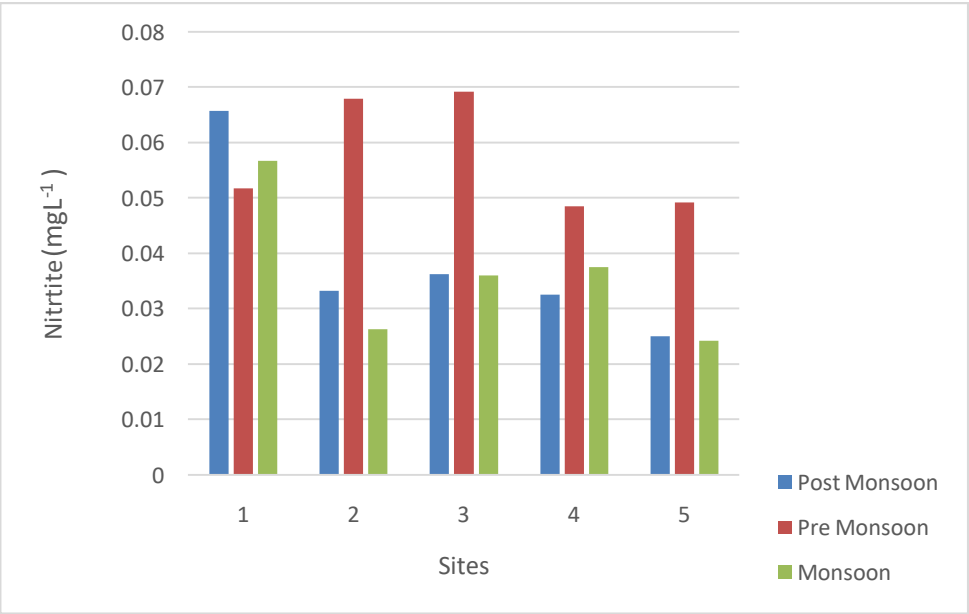


Fig. 4.22 Seasonal variation in nitrite of water at selected study sites during 2017-2018

4.12 Phosphate:

The observation reveal that during the year 2016 – 2017 phosphate varied from 0.044 mgL^{-1} (post monsoon season) at Site 1 to 0.86 mgL^{-1} (monsoon season) at Site 4. The site wise minimum and maximum values were recorded as 0.044 mgL^{-1} (post monsoon season) to 0.715 mgL^{-1} (monsoon season) at Site 1;0.057 mgL^{-1} (post monsoon season) to 0.394 mgL^{-1} (monsoon season) at Site 2; 0.056 mgL^{-1} (post monsoon season) to 0.631 mgL^{-1} (monsoon season) at Site 3;0.048 mgL^{-1} (post monsoon season) to 0.863 mgL^{-1} (monsoon season) at Site 4; 0.054 mgL^{-1} (post monsoon season) to 0.581 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.23**

The observation reveal that during the year 2017 – 2018 phosphate varied from 0.0425 mgL^{-1} (post monsoon season) at Site 1 to 0.374 mgL^{-1} (monsoon season) at Site 4. The site wise minimum and maximum values were recorded as 0.042 mgL^{-1} (post monsoon season) to 0.228 mgL^{-1} (monsoon season) at Site 1;0.059 mgL^{-1} (post monsoon season) to 0.264 mgL^{-1} (monsoon season) at Site 2;0.062 mgL^{-1} (post monsoon season) to 0.326 mgL^{-1} (monsoon season) at Site 3; 0.070 mgL^{-1} (post monsoon season) to 0.374 mgL^{-1} (monsoon season) at Site 4; and 0.061 mgL^{-1} (pre monsoon season) to 0.262 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.24**

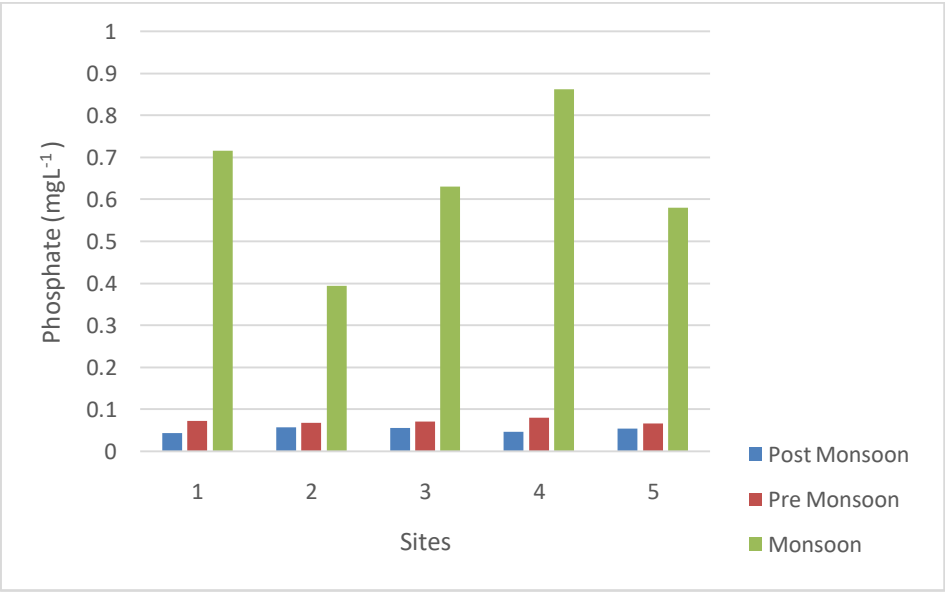


Fig. 4.23 Seasonal variation in phosphate of water at selected study sites during 2016-2017

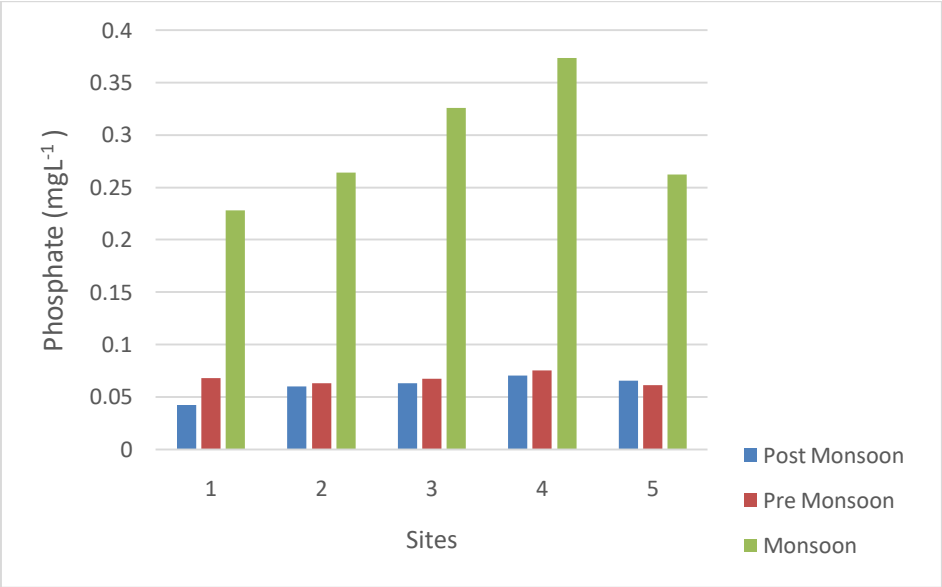


Fig. 4.24 Seasonal variation in phosphate of water at selected study sites during 2017-2018

4.13 Sulphate:

The observation revealed that during the year 2016 – 2017sulphate varied from 2.07 mgL^{-1} (pre monsoon season) at Site 2 to 4.48 mgL^{-1} (monsoon season) at Site 5. The site wise minimum and maximum values were recorded as 2.73 mg/l (pre monsoon season) to 3.58 mgL^{-1} (monsoon season) at Site 1; 2.07 mgL^{-1} (post monsoon season) to 4.13 mgL^{-1} (monsoon season) at Site 2; 2.09 mgL^{-1} (pre monsoon season) to 3.55 mg/l (monsoon season) at Site 3;2.39 mgL^{-1} (pre monsoon season) to 2.75 mgL^{-1} (monsoon season) at Site 4; 2.22 mgL^{-1} (pre monsoon season) to 4.48 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.25**

The observation revealed that during the year 2017 – 2018sulphate varied from 1.80 mgL^{-1}(post monsoon season) at site 2 to 4.25 mgL^{-1} (monsoon season) at site 3. The site wise minimum and maximum values were recorded as 1.96 mgL^{-1} (post monsoon season) to 3.68 mgL^{-1} (monsoon season) at Site 1;1.80 mgL^{-1}(pre monsoon season) to 3.51 mgL^{-1} (monsoon season) at Site 2;2.09 mg/l (post monsoon season) to 4.25 mgL^{-1} (monsoon season) at site 3;1.84 mgL^{-1} (post monsoon season) to 2.84 mgL^{-1} (monsoon season) at Site 4;2.34 mgL^{-1} (post monsoon season) to 4.20 mgL^{-1} (monsoon season) at Site 5. **Fig. 4.26**

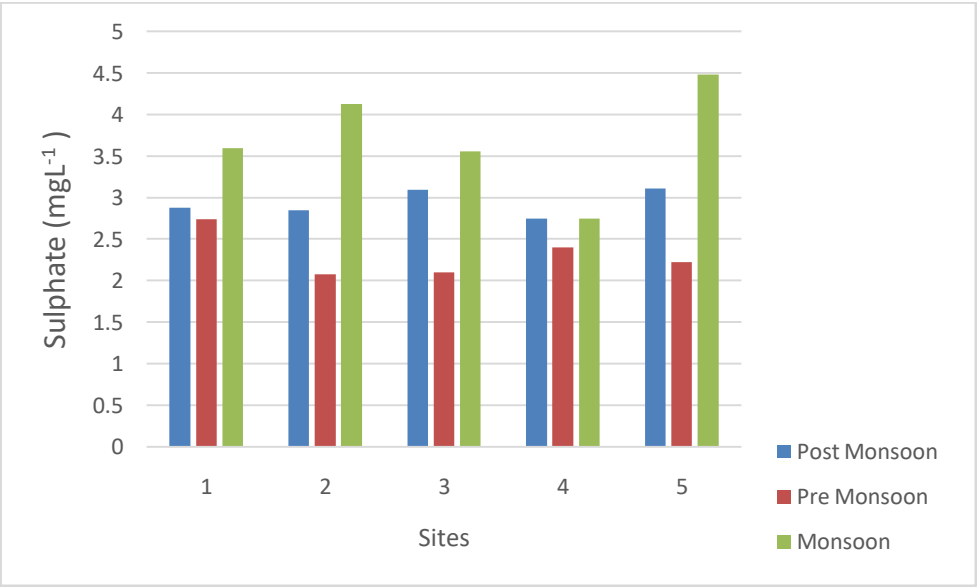


Fig. 4.25 Seasonal variation in sulphate of water at selected study sites during 2016-2017

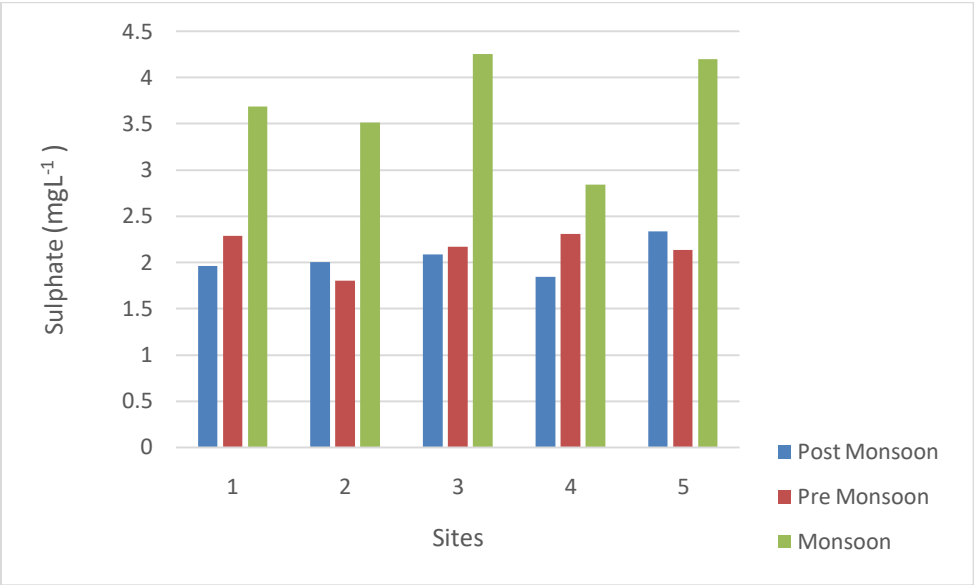


Fig. 4.26 Seasonal variation in sulphate of water at selected study sites during 2017-2018

4.14 Total Coliform:

The observation revealed thatduring the year 2016 – 2017 the number of total coliform varied from 20.325 MPN (post monsoon season) at Site 3 to 2075 MPN (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 92 MPN (pre monsoon season) to 2075 MPN (monsoon season) at Site 1;77.825MPN (pre monsoon season) to 135.525 MPN (post monsoon season) at Site 2; 20.325 MPN (post monsoon season) to 34.075 MPN (pre monsoon season) at Site 3; 23.825 MPN (pre monsoon season) to 965 MPN (monsoon season) at Site 4; and 34.75 MPN (pre monsoon season) to 1187.5 MPN (monsoon season) at Site 5. **Fig. 4.27**

The observation revealsthatduring the year 2017 – 2018 the number of total coliform varied from 11.6 MPN (pre monsoon season) at Site 3 and Site 5 to 1547.5 MPN (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 125 MPN (pre monsoon season) to 1547.5 MPN (monsoon) at Site 1; 39.325 MPN (pre monsoon season) to 132.25 MPN (monsoon season) at Site 2; 11.6 MPN (pre monsoon season) to 31 MPN (monsoon season) at Site 3; 69.5 MPN (pre monsoon season) to 466 MPN (monsoon season) at Site 4; 11.6MPN (pre monsoon season) to 977.5MPN (monsoon season) at Site 5. **Fig. 4.28**

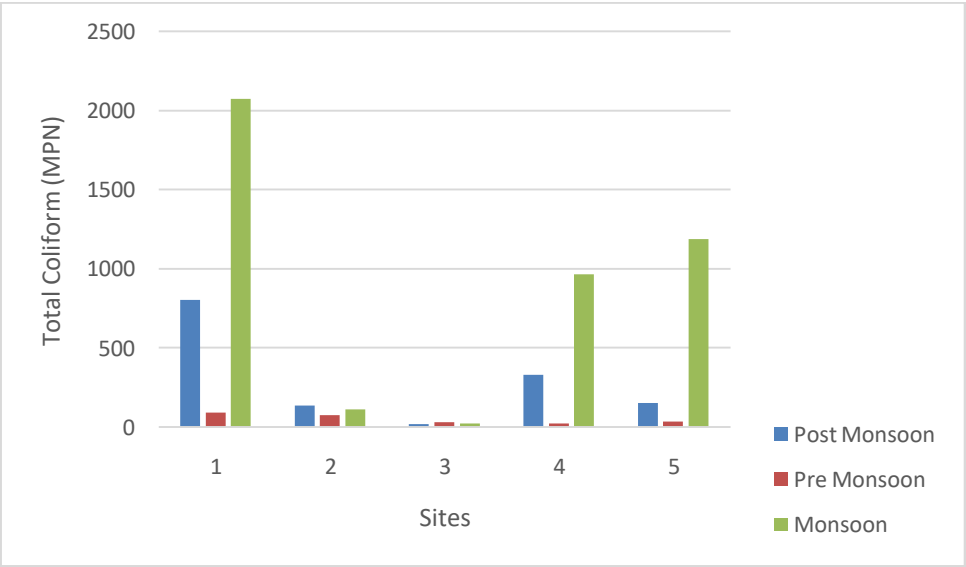


Fig. 4.27 Seasonal variation in total coliform of water at selected study sites during 2016-2017

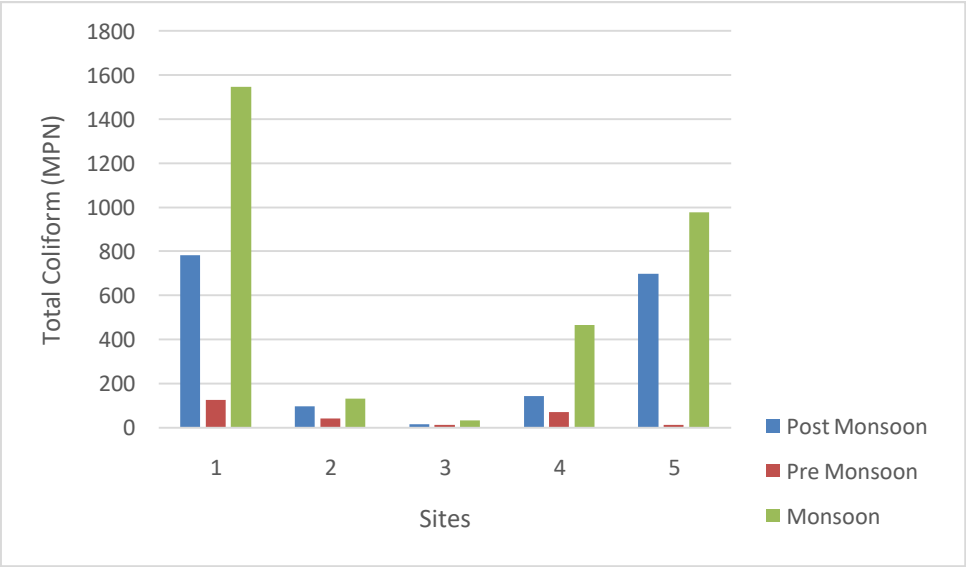


Fig. 4.28 Seasonal variation in total coliform of water at selected study sites during 2017-2018

4.15 Faecal coliform:

The observation revealed that during the year 2016 – 2017the number of faecal coliform varied from 0 MPN (pre, post and monsoon season) at Site 2, Site 3 and Site 5 to 39.5 MPN (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 0.9 MPN (pre and post monsoon season) to 39.5 MPN (monsoon season) at Site 1; 0 MPN throughout the year at site 2, 0 MPN throughout the year at Site 3, 0 MPN (pre and post monsoon season) to 6.65 MPN (monsoon season) at Site 4; and 0 MPN throughout the year at Site 5. **Fig. 4. 29**

The observation revealed that during the year 2017 – 2018the number of faecal coliform varied from 0 MPN (pre monsoon season) at Site 2, Site 3 ,Site 4 and Site 5 to 40.65 MPN (monsoon season) at Site 1. The site wise minimum and maximum values were recorded as 0.9 MPN (pre and post monsoon season) to 40.65 MPN (monsoon season) at Site 1; 0 MPN (pre and post monsoon season) to 1.825 MPN (monsoon season) at Site 2, 0 MPN (pre and post monsoon season) to 0.9 MPN (monsoon season) at Site 3, 0 MPN (pre monsoon season) to 3.75 MPN (post monsoon season) at Site 4; 0 MPN (pre and post monsoon season) to 0.9 MPN (monsoon season) at Site 5. **Fig. 4.30**

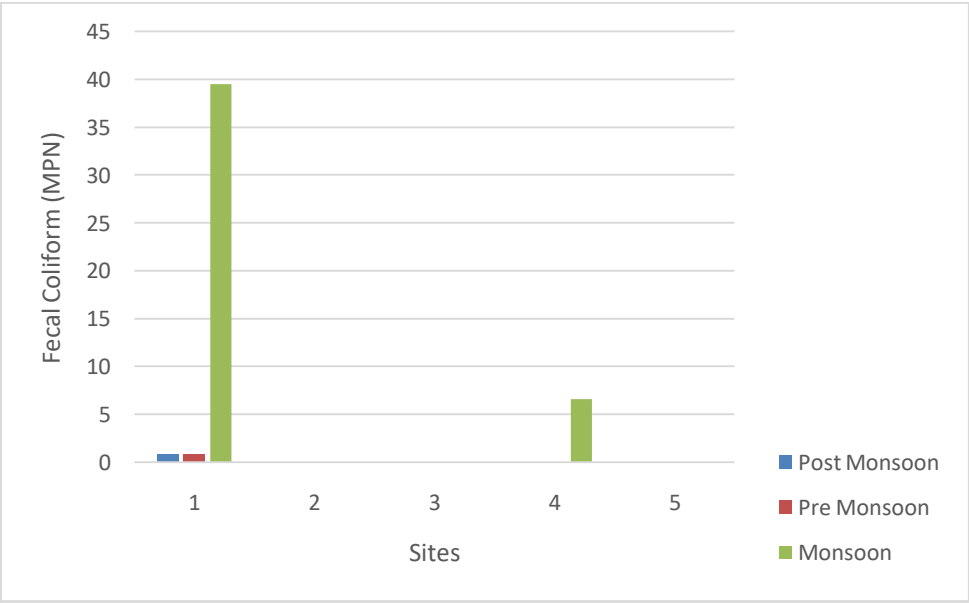


Fig. 4.29 Seasonal variation in faecal coliform of water at selected study sites during 2016-2017

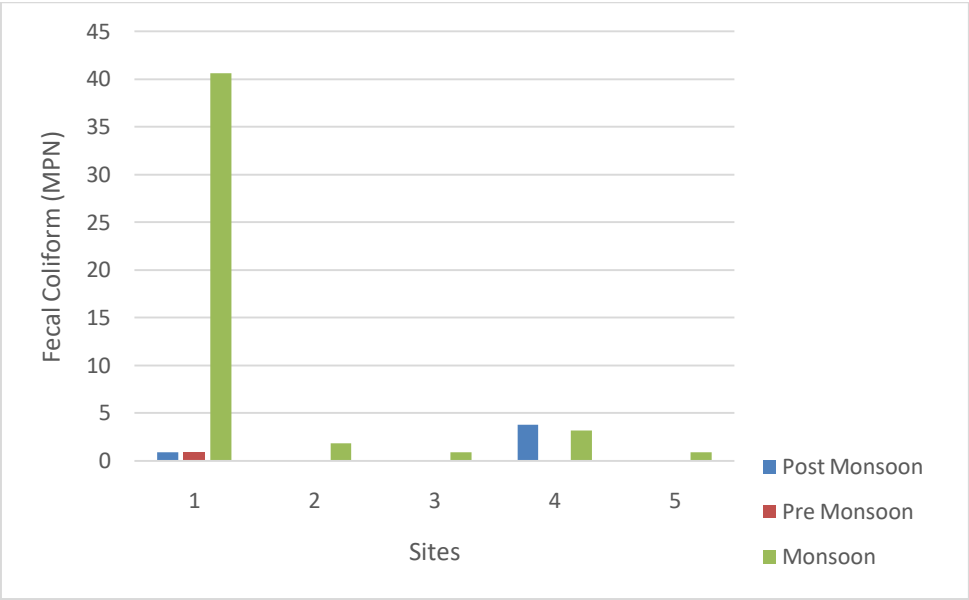


Fig. 4.30 Seasonal variation in faecal coliform of water at selected study sites during 2017-2018

CHAPTER-5

DISCUSSION

5.1 Water resources in and around Aizawl city

For the study of water resources in and around Aizawl city, survey method was employed. It was found that there are three types of water resources which are spring water, ground water and river. Zone wise survey was conducted and it was found that there are 27 water resources found so far in the north zone, 10 in the east zone, 34 in west zone and 10 in south zone. Out of total 81 water resources found 16 resources are perennial in nature whereas the rest 65 are seasonal. And there are 15 underground water, 61 spring water and 4 rivers.

The major uses of water in various places are for washing clothes and utensils, car wash and in some area they carried water from spring collected sites to their home for household use. Tlawng river is the main water resource for Aizawl city as the river water was collected and treated by PHE Department for distribution to each and every household in Aizawl.

5.2 Water quality characteristics at selected study sites:

Water quality represents the purity of water and expresses the suitability of water for various uses like drinking, industrial water supply, and irrigation, propagation of aquatic organisms and generation of hydro power. The water quality is assessed in order to determine its potability, safety of human contact and ecosystem health. Poor quality of water is due to high level of organic and inorganic substance that does not fit in the standard limits given by the government. Biological organism like bacteria also involved in deteriorating the quality of water and further resulting in many diseases.

5.2.1 Temperature:

Temperature refers to degree of hotness or coldness. Water temperature may affect water quality through biological activity (Dhagari*et al*., 2019). The temperature is a function of seasonal ambient air temperatures. It is one of the important factors in aquatic environment since it regulates physicochemical properties as well as biological activities (Kumar *et al*., 1996) and act as an important indicator of environmental quality (Gu and Li, 2002) Water in the temperature between 7 ^{o}C to 11 ^{o}C has a pleasant taste and is refreshing (Trivedi and Goel, 1986). The variation in water temperature varies on the basis of season, geographical location, air temperature and chemical reaction within water body (Ahipathi and Putlaiah, 2006). Effect of temperature include solubility of dissolved oxygen - where more gas can be dissolved in cold water than in hot water, rate of plant growth – increased water temperature can cause an increase in photosynthetic rate of aquatic plants and algae, which can lead to increased plant growth and algal blooms and harm the local ecosystems and resistance in organisms- if water becomes too hot or too cold, organisms become stressed, lowering their resistance to pollutants, disease and parasites (Burnson,1938).

Temperature during the study period shows similar trend during the study period where it was high during monsoon season in all the sites. And this could be due to high rate of deposits from the surface area which increase rate of decomposition and thus, make the temperature higher during this season. The difference between the lowest temperature and the highest is 3.9 ^{o}C. During the study period site 1 is having the highest temperature comparing to site 2, 3 and 4 because site 1 is present in an open, unprotected area where all the other under protected area. The average temperature was highest during monsoon season in all the sites and it was lower during pre-monsoon season, which could be due to water inputs such as precipitation, runoff, groundwater and water from upstream tributaries and subsequently microbial decomposition which leads into the release of catabolic energy in the form of heat and resulting into an increase in water temperature. This similar trend was also been reported by some scientists (Torgersen*et al*., 1999; Zwieniecki and Newton, 1999; Ravindra*et al*., 2003; Tepe*et al*., 2005; Begum and

Harikrishna,2008; Murthuzasab*et al*., 2010; Yuceer and Coskun, 2016 and Rios-Villamizer*et al*., 2017). The temperature of water during the study period was all within the standard given by BIS and CPCB (**Appendix- II**).

After calculating correlation coefficient (**Appendix-I**) it was observed that temperature has a positive significance with turbidity, acidity, BOD, phosphate,sulphate, total coliform and fecal coliform. And it has a negative significance with total hardness and DO content .And by using Anova statistical analysis it has been observed that the temperature of all samples has significance variation with the change in seasons (**Table 5.1**)

Table 5.1: One-way Anova for water temperature variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.685	2	12.843	23.111	0.000
Within Groups	65.015	117	.556		
Total	90.700	119			

5.2.2 Turbidity:

Turbidity is a amount of the muddiness of water, measured by fleeting a beam of light through water. Due to material suspended in water there is an occurance of cloudiness. Clay, silt, organic matter, plankton and other minute organisms cause turbidity within natural water (Mishra and Lalzahawmi, 2014). Somewhat low levels of turbidity may designate a healthy, well-performance ecosystem, with moderate amounts of minute plants and animals present to fuel the food chain. However, high levels of turbidity create several problems for stream systems. Higher turbidity levels are often related with elevated levels of micro-organisms because they sometimes led themselves attach to the dirt in the water. Therefore, we must be careful of turbid water as it generally has added pathogens, so drinking it increased our chance of getting sick (Minnesota, 2008). Turbidity of water depends on concentration of suspended material such as clay, silt or some other finely divided unrefined materials present in water (Thasangzuala and Mishra, 2014). Some effect of turbidity are reduce water clarity, aesthetically obnoxious, decreases rate of photosynthesis and increase water temperature (Vijay, 2016).

During the study period, Site 1 has obtained the highest and it was lowest in site 3 during pre-monsoon season. Among all the seasons it is also observed that turbidity was highest during monsoon season in all the sites which was cause may be due to increase in sediment load through precipitation, surface runoff resulting into higher seepage velocity of groundwater entering into the spring storage area and thus caused excessive suspended solid load and vice versa during pre-monsoon season and the work and finding trend was in conformity with the work of Mishra, 2009; Lalzahawmi, 2012. Also, the value was high in site1 during post-monsoon season because during the year 2016-2017 there was a prolonged rainfall and the was located in open area and there was disturbance in the water body,thus make the site more turbid during this year than the year 2017-2018. The same was also found in site 2. And at site 4 during 2016-2017 shows slight changes in trend during monsoon season and this is due to renovation work going on in the vicinity of the study siteand that accelerate the turbidity value. And other than prolong rainfall during the year 2016-2017 this renovation work has a post working effect to the water body and

makes the turbidity value higher in compare to the later study year during monsoon period. The value observed during the study period in all the sites was all under the permissible limits or standard given by BIS, WHO, ICMR, CPCB and ISI (**Appendix- II)**.

After calculating correlation coefficient (**Appendix-I**) it was observed that turbidity has a positive significance with chloride, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with pH, alkalinity and DO content .And by using Anova statistical analysis it has been observed that the turbidity of all samples has significance variation with the change in seasons (**Table 5.2**)

Table 5.2: One-way Anova for water turbidityvariations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.136	2	1.568	17.652	0.000
Within Groups	10.394	117	.089		
Total	13.530	119			

5.2.3 pH:

pH refers toproton concentration or how acidic or basic as water is and pH is defined as –log[H^+]. pH value varies from 0-14; pH 7 is neutral, pH<7 is acidic and pH>7 is basic. It is a measure of the comparative amount of free hydrogen and hydroxyl ions within the water. Water that has additional free hydrogen ions is acidic, whereas water that has additional free hydroxyl ions is basic. The chemical composition in the water can alter the value of pH and thus make the pH asignificant indicator of water that is changing chemically (Maudling and Harris, 1968). pH is the most vital in determining the corrosive nature of water. Lower the pH higher is the corrosive nature of water. It is also positively correlated with electrical conductance and total alkalinity. The reduce rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during summer season (Karanth, 1987). Very high pH (pH >9.5) or very low pH (pH < 4.5) values are unsuitable for most aquatic organisms (Manoj and Avinash, 2012). The optimum range for chlorine disinfection is between pH 5.5 and 7.5. High level of pH or when the water is highly alkaline it causes a bitter taste, water pipes and water-using appliance become coated with deposits and it lower the efficiency of the disinfection of chlorine, thus causing the necessity for additional chlorine when pH is high. Low pH water will corrode or dissolve metals and other substances (Lan, 1946). The pH of a waterbody reflects its water inputs and therefore the chemical characteristics of the encompassing land. The pH of runoff from the land, or of groundwater inputs to surface water, is suffering from the kinds of minerals and soils the water contacts as it moves through the land. Water draining from forests and swaps may be acidic due to weak organic acids contained in the organic matter within this ecosystem.

The pH value during the study period was found to be lowest or most acidic at site 1 and was highest at site 2. And the average pH value was found lowest during monsoon season which could be due to the fact that soil of different profiles in Aizawl are medium to strongly acidic (Lalnunsiama and Nautiyal, 2013) and the water that are in contact with this acidic soil moves through the land and when it reaches the spring collected site pH of the water become slightly acidic in nature and

thus make pH of the water become lowest or most acidic during monsoon season and vice versa during pre-monsoon and post monsoon season..Site 2 and site 3 shows slight changes in trend resulting from the human activities like washing clothes in the nearby area and the used of detergent makes changes to the trend showing higher pH value. The findings of the present study are in conformity with the work of Ali et al. (2014) and Erick *et al*. (2016). During the study period the pH during monsoon season was lower than the standard given by USHP, BIS, WHO, ICMR, CPCB and ISI (**Appendix- II)**.

After calculating correlation coefficient (**Appendix-I**) it was observed that turbidity has a positive significance with chloride, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with pH, alkalinity and DO content .And by using Anova statistical analysis it has been observed that the pH of all samples has significance variation with the change in seasons (**Table 5.2**)

Table 5.2: One-way Anova for water pH variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.136	2	1.568	17.652	0.000
Within Groups	10.394	117	.089		
Total	13.530	119			

5.2.4 Oxidation reduction potential:

The oxidation reduction potential (ORP) measurements of water reflect the tendency of major constituents in the water to accept or lose electrons. Even though ORP measurements are important and can provide helpful information toward protecting public health, they are not widely perform by the drinking water society for a variety of reasons. The concentration of oxides and reduction in pH and temperature are the main factors that affect the ORP in water (Fang *et al*., 2013). ORP is a parameter assessing the microbial kill- rate of a disinfectant (Zhang *et al*., 2017) and is one of the main control parameters of wastewater treatment processes (Ruano*et al*., 2012).

The highest oxidation reduction potential was found at site 3 and was found to be lowest at site 2. The trend in site 1 was opposite during the two study period whereas in site 4 and site 5 ORP value was higher during pre-monsoon season comparing to post monsoon and in 2016-2017. The value was highly accelerated during monsoon season in site3 during 2017-2018 which could be due to increase in temperature during monsoon season that in turn increase the ORP value. And the average value of the ORP during the study period was found to be high during monsoon season which are cause by the reduction of pH value during monsoon season, as oxidation reduction potential tends to decrease at alkaline conditions (James *et al*., 2004). The study was in conformity with the work of Copeland and Lytle, 2014.

After calculating correlation coefficient (**Appendix-I**) it was observed that ORP has a positive significance with acidity, chloride, total hardness, BOD, phosphate and sulphate. And it has a negative significance with pH and alkalinity content .And by using Anova statistical analysis it has been observed that the ORP of all samples has significance variation with the change in seasons (**Table 5.4**)

Table 5.4: One-way Anova for water ORP variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4579.317	2	2289.659	5.537	0.005
Within Groups	48380.973	117	413.513		
Total	52960.290	119			

5.2.5 Acidity:

The acidity of water is its capacity to neutralize hydrogen ions. It may be cause by mineral acids such as sulphuric acid or by hydrochloric acids or by dissolved carbon dioxide. In consumable water, CO_2 is the major cause of acidity. Drinking water with high acidity is likely to be corrosive to copper water pipes and to solder which joins those pipes (Mishra and Lalzahawmi, 2014). Uncombined CO_2, organic acids and salts of strong and weak bases are the otherr factors responsible that cause variation in acidity value.(Mishra *et al*., 2009). The mineral acidity corresponds to pH<4 and CO_2 corresponds to pH>8.5 due to dissolution of carbon dioxide in water and algal photosynthesis. Although there is no particular limit for acidity in water, however, increase in acidity tends to contribute to corrosives and influences the rate of chemical reactions, chemical speciation, and biological activities and is also injurious for human health. Acidic water is less buffered and less productive because sufficient amount of bicarbonates are not dissolved to give CO_2 for a high rate of photosynthesis. Warren (1971) argued that lowering of pH in water is the result of decomposition of organic matter and finally releases excess of CO_2.

The present study revealed that there is high value of acidity at site 1 and site 5 during post monsoon season which is due to leaching down the organic material beneath the earth surface to the groundwater through precipitation during monsoon season and has been slowly enters the spring collected sites and thus increase the decomposition of organic matter that accelerate the acidity of water. It was observed that the average acidity value was higher during 2017-2018 comparing to 2016-2017 which shows that there are higher organic load that increase rate of decomposition and that inturn increase the level of CO_2 from the activity of microorganisms and then resulting into carbonic acidduring the later year of studies. Changes in trend was observed at site 2 between postmonsoon and monsoon season where the value was high in monsoon during 2016-2017 whereas it was high during post monsoon season during 2017-2018 and this could be due to the fact that there were more dissolved carbon dioxide in monsoon during this years at site 2 resulting from reduction ofthe oxygen concentration in waters that contain organic matter.Also, it could be due to

prolong rainfall during the later year and as the rain water is slightly acidic in nature, it thus make the spring water become acidic and the findings was in conformity with the work of Misrhra and Tripathi (2000, 2001, 2003), Shrivastava*et al*. (2010) and Singh *et al*. (2010).

After calculating correlation coefficient (**Appendix-I**) it was observed that acidity has a positive significance with temperature, ORP, alkalinity, total hardness. And it has a negative significance with pH, DO content .And by using Anova statistical analysis it has been observed that the acidity of all samples has significance variation with the change in seasons (**Table 5.5**)

Table 5.5: One-way Anova for water acidity variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15680.338	2	7840.169	13.475	0.000
Within Groups	68073.744	117	581.827		
Total	83754.081	119			

5.2.6 Alkalinity:

Alkalinity is a determination of the ability of water to neutralize acids. It is due to the presence of Calcium, Magnesium, Sodium and Potassium. Large amount of alkalinity imparts a bitter taste, harmful for irrigation as it damages soil and hence reduce crop yield (Sunal and Saseetharan, 2008). In natural water, alkalinity is due to free hydroxyl ions and dissolution of CO_2 in water (Frank, 1987). In addition it is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. It is used in determining the ability of stream to neutralize acidic pollution from rainfall or wastewater (Matthess, 1982). Trivedy and Goel (1986) reported that alkalinity is itself not harmful to human beings.

In the sample analysed, alkalinity were found to be highest at site 1 and site 2 is the lowest obtained during the study period. And the average value was found to be high during pre-monsoon season during the previous year of the study period. Similar trend was observed during 2016-2017 in site 1, site 4 and site 5. Whereas in site 2 and site 3 the alkalinity value was higher during post-monsoon in the year 2016-2017 while it was lower during pre-monsoon season during the year 2017-2018 which may be due to more sewage discharge that leach to the water body from the nearby settlement area and also when the volume of water gets reduced during pre-monsoon in the spring collection point the sewage that leach down to the water body become more concentration and thus make the value higher during pre-monsoon season.Also higher alkalinity during pre monsoon season was due to shortage of water supply and that makes the people in the nearby areas are depending more on the spring water especially for washing pruposes and when there are more disturbances in the area then the value of alkalinity become higher.Unni*et al*. (1992) suggested that alkalinity value higher than 50mgL^{-1} indicates the entry of sewage in the water body in considerable amount, which means that there is an entry of sewage at site 1, site 2 , site 3 ,site 4 and site 5 during pre-monsoon season that seeps from the higher altitude and thus explains the highest value at site 1 where the site is kept unprotected . The value of total alkalinity having less than 200 mgL^{-1} are desirable for drinking and domestic purposes (John and Shiva, 2017), which means that the water in the in allthe sites throughout the study period in under permissible limits

although there is an entry of sewage water quality during the study period from the five selected sites are under permissible limit for drinking and domestic purposes. The result observed during the study period are all under the standard given by BIS, WHO and CPCB(**Appendix- II)**.

After calculating correlation coefficient (**Appendix-I**) it was observed that acidity has a positive significance with temperature, ORP, alkalinity, total hardness. And it has a negative significance with pH, DO content .And by using Anova statistical analysis it has been observed that the alkalinity of all samples has significance variation with the change in seasons (**Table 5.6**)

Table 5.6: One-way Anova for water alkalinity variations.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15007.650	2	7503.825	15.885	.000
Within Groups	55268.610	117	472.381		
Total	70276.260	119			

5.2.7 Chloride:

Chloride bearing rock minerals like Sodalite and Chlorapatite, which are very small constituents of igneous and metamorphic rocks and liquid inclusions which comprise very unimportant fraction of the rock volume, are minor sources of chloride in spring water. Chloride salts being highly soluble and free from chemical reactions with minerals of reservoir rocks, remain stable once they enter in solution (Dhirendra*et al*., 2015). And in fresh waters the sources include soil and rock formations, spray and waste discharges. Sewage contains large amounts of Chloride because sewage is such an upscale source of chloride, a high result may indicate pollution of water by a sewage effluent. Chloride doesn't pose a hazard to humans and therefore the principal consideration is in reference to palatability. At levels above 250mg/l Cl water will begin to taste salty and can become increasingly objectionable as the concentration rises further. A rise of even 5mg/l at one station may give rise to suspicious of a sewage discharge (EPA, 2001).

During the study period it's has been observed that the significance of Chloride content was high at site 3 and site 1 and was low at site 5. The typical value was found to be highest during monsoon season and the value was highly accelerated at site 3 during monsoon 2017, which may flow from the occurrence of landslide just beside the spring water collection point as rocks and soils being one among the sources of chloride content especially in fresh water. The study period show different trends where in 2016-2017 the value was found highest during monsoon season in all the sites where in 2017-2018 the chloride content was found highest during post monsoon season which could be due to prolonged rainfall during this year comparing to the previous year and as sewage discharge is also one of the main sources of chloride in water, the more rainfall occurred the more there is leaching of sewage discharge to the water body and thus results in high chloride content. It is reported that the higher value of Chloride is associated with increasing level of pollution (Umavathi, 2007). The chloride content of all the samples during the study periods are under the permissible limits for drinking water given by BIS, WHO, ICMR, CPCB and ISI (**Appendix- II)** . Although the average value of chloride content found during the study period was under the permissible limits, there is declining in

the quality of water during the later year which means that there are chances that the water quality can soon exceed the permissible limit if the pollution keeps on increasing.

After calculating correlation coefficient (**Appendix-I**) it was observed that chloride has a positive significance with ORP, turbidity, total hardness, BOD, phosphate and faecal coliform. And it has a negative significance with alkalinity, pH, DO content .And by using Anova statistical analysis it has been observed that the chloride of all samples has significance variation with the change in seasons (**Table 5.7**)

Table 5.7: One-way Anova for water chloride variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30724.488	2	15362.244	8.552	0.000
Within Groups	210179.239	117	1796.404		
Total	240903.727	119			

5.2.8 Total Hardness:

It is the property of water which prevents the lather formation with soap and increases the boiling points of water (Nushe*et al*.,2017). The hardness values fluctuated between 48 and 360 mg/L thereby indicating hard water to very hard water nature of the springs (Moyle, 1945). The degree of hardness of drinking water is important for aesthetic acceptability by consumers and for economic and operational considerations (WHO, 2011). Water hardness is due to the availability of calcium and magnesium salts. Hardness usually enters groundwater as the water percolate through minerals containing calcium or magnesium. The most common sources of hardness are limestone (which introduces calcium into the water) and dolomite (which introduces magnesium.) Since, hardness enters the water in this manner groundwater generally has a greater hardness than surface water (Prepas*et al.*, 2001).The hardness is defined as contents of divalent metallic ions which react with sodium soaps to produce solid soaps or scummy residue, and which react with negative ions when the water heated with boilers to produce solid boilers scales (Todd,2007). High hardness of drinking water causes gastroenteritis in humans (Maindoli*et al*., 2018).

The present study revealed that total hardness was found to be highest at site 3 and it was followed by site 1, 4, 2 and it was found lowest at site 5. The high value obtained at site 3 could be due to low altitude comparing to other sites and causehigh content of calcium and magnesium saltsas hardness generally enters groundwater as the water percolates through minerals containing calcium or magnesium and as it travels through longer distance from higher areas to lower areas. Also another reason for site 3 holds the highest value could be due to the fact that more people in the nearby areas are washing clothes in the spring collected site. Although the value was high, it was found to be within permissible limits and can be declare as potable water.The average value was high during post monsoon season where it was low during pre-monsoon season. The two years study period show more or less similar trend where the total hardness was usually high during post monsoon season. The findings reveal that the total hardness of water from the study area during sampling

period was all under the standard given by BIS, WHO, ICMR and CPCB (**Appendix- II).**

After calculating correlation coefficient (**Appendix-I**) it was observed that total hardness has a positive significance with chloride, ORP, acidity, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with temperature, pH and DO content .And by using Anova statistical analysis it has been observed that the total hardness of all samples has significance variation with the change in seasons (**Table 5.8**)

Table 5.8: One-way Anova for water total hardness variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57363.224	2	28681.612	12.020	0.000
Within Groups	279182.149	117	2386.172		
Total	336545.373	119			

5.2.9 Dissolved Oxygen (DO):

Dissolved oxygen is a most important indicator of water quality. When the value drop below levels necessary for sustaining aquatic life, it becomes significant water quality impairment, often refer to as low dissolved oxygen (DO). DO express the concentration of oxygen molecular in the water and it depend on temperature of water and biological demand. DO is enter to thewater through several method like direct dispersal of oxygen from the atmosphere, wind and wave action and photosynthesis. It is used in aerobic decomposition of organic matter, respiration of aquatic organism and chemical oxidation of minerals. As DO is used by many organisms in the water, it tends to change rapidly (WHO, 2004). Freshwater holds more oxygen than saltwater. The quantity of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure. Level of DO content changes depending on factors including water temperature, time of day, season, depth, altitude and rate of flow. Water at higher temperatures and altitudes will have less DO. DO reach its peak during the day. At night, it decreases as photosynthesis stopped (WHO,2008). Stagnant water contained less DO. Bacteria in water can use oxygen as organic matter decays. Sewage, addition of nutrients, changing the flow of water, rising the water temperature and addition of chemicals are the sources that affect DO content due to anthropogenic activities(Rao*et al.*, 2013).

From the present study, the dissolved oxygen content was found lowest at site 1 as the site was located in an open area where there were no protection of the spring collected sites and its surroundings, and the chances for the entry of sewage water is very high because there is a drainage system adjacent to the site and thus decrease the value of DO content in site 1. The average DO contentwas found highest at site 5 which is due to entering less amount of sewage . In term of seasons, the average value of DO content during the study period was found highest during post monsoon season and it was lowest during monsoon season. The dissolved oxygen content in at all sites during monsoon season was lowest among the three compared seasons as the amount of precipitation was highest during monsoon season there are more entry of sewage form the nearby settlement areas and there will be more movement of water at each site and this has in turn increase the dissolved oxygen content in the spring

water collected sites and this trend was followed in both the year 2016-2017 and 2017-2018. Also the low dissolved oxygencontent could be due to more decomposition or entry of decaying matter as well as leaching of sewage through rain water run-off and many other means that in turn releases heat within the water body that warm the water and thus decrease the DO capacity within the sampling site during monsoon season. The finding was in conformity with the work of Araoye, 2009 and except for site 1 and site 4 DO content in the study sites was under standard given by BIS, WHO and CPCB(**Appendix- II)** during pre-monsoon and post monsoon season where it was lower at site 1 during monsoon season**.**

After calculating correlation coefficient (**Appendix-I**) it was observed that DO did not have a positive significance with any of the parameters studied. And it has a negative significance with temperature, ORP, turbidity, acidity, chloride, BOD, nitrite, phosphate, sulphate and faecal coliform. And by using Anova statistical analysis it has been observed that the dissolved oxygen of all samples has no significance variation with the change in seasons (**Table 5.9**)

Table 5.9: One-way Anova for water DO variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.967	2	7.483	2.866	0.061
Within Groups	305.503	117	2.611		
Total	320.470	119			

5.2.10 Biological Oxygen Demand:

BOD measurement is used to determine the level of organic pollutants in water. It gives a detail account of the amount of oxygen consumed by aerobic biological organisms for the degradation of organic matters and also the oxygen required for the oxidation of various chemical processes in water. The BOD level increases with an increase in the amount of readily metabolic organics in water (Rasool*et al*.,2003). An increase in BOD content during the monsoon season is due to the influx of organic waste and enhanced microbial activities (Prasannakumari*et al*.,2003). IfBOD is low, the water is clear and without organism. In the case of existence of any organism they do not use oxygen (Tchobanoglous*et al*.,2003; Reza *et al*., 2014).

From the present study the highest BOD level was observed at site 1 and of all the seasons being studied it has been found that highest biological oxygen demand was found during monsoon season and this trend was seen in both the year 2016-2017 to 2017-2018 which is due to an increase level of rainfall during monsoon resulting into entering of more organic materials and expands the microbial population resulting due to high concentration of untreated organic waste discharge into the water that increase the biological oxygen demand and this trend was followed in both the year studied. Site where there is low amount of BOD, we observe a smaller microbial population. During 2016-2017 higher value of BOD was observed at pre monsoon comparing to the later year which may be due to occurance of disturbances in the spring collected site that and thus increase the biological oxygen demand in the water. Placeswhere there was an entrance of wastewater and raw and untreated wastewaters there is high level of BOD (Quinn *et al*.,2005). Monitoring of BOD provides us with enough information about the water body (Tyagi*et al*., 1999). The BOD showed a reverse trend in results in comparision with the DO content of water and the study was in conformity with the study of Mishra &Tripathi, 2000,2001; Ravindra*et al*., 2003;Ghavzan *et al*., 2006; Dulo, 2008; Lalparmawii and Mishra, 2012; Pathak*et al*.,2012; Hasan*et al*., 2014. Higher value in site 1 was observed comparing to other parameters which indicate lower quality of

the water. The value observed in other sites was all below the standard given by BIS, CPCB and ISI (**Appendix II**).

After calculating correlation coefficient (**Appendix-I**) it was observed that BOD has a positive significance with temperature, ORP, turbidity, chloride, phosphate, sulphate, total coliform. And it has a negative significance with pH, alkalinity and DO content.And by using Anova statistical analysis it has been observed that the BOD of all samples has significance variation with the change in seasons (**Table 5.10**)

Table 5.10: One-way Anova for water BOD variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	37.866	2	18.933	20.918	0.000
Within Groups	105.896	117	.905		
Total	143.762	119			

5.2.11 Nitrite:

Nitrites are a salt or Easter anion of nitrous acid, which can be naturally or artificially occurring in groundwater. There is an occurance of nitrites from fertilizers through run-off water, sewage and mineral deposits. High level of nitrite was toxic to humans and animals, especially infants. When it enter the body it act as nitrate, a nutrient which is essential to plant growth, and can be converted into nitrite, which disrupts the oxygen delivering ability of hemoglobin in the bloodstream. Increasing in nitrites in water can be due to use of corrosion inhibitors in industrial process water. Nitrites is an inorganic pollutants which degrades the water quality of drinking water (Almasri, 2007;Anjali*et al*.2017).

From the present study it has been observed that nitrite value was found to be highest during pre-monsoon season and it was lowest during post monsoon season. During post monsoon season the value was highest at site 2 and 3 for 2016-17 and 2017-18 and it was lowest at site 4 and the occurrence of this trend could be due to low amount of water and the nitrite leaching from the surface during rainy period in the water body become concentrated during pre-monsoon season and vice versa for monsoon and post monsoon season. The high value of nitrite being observed during pre-monsoon season was due to decrease in volume of water in the spring water collected sites and during post monsoon season the increase in water volume diluted the nitrite content and thus, we observed lowest value of nitrite during post monsoon season. Comparing the two years of studies, higher value observed during monsoon 2016-2017 comparing to 2017-2018 could be due to more precipation during the year and then the rainwater carries the sewage, animals waste as well as septic tanks which are the various sources of nitrate in water. The value observed throughout the study period for various seasons are below the standard given by ISI (**Appendix-II).**

After calculating correlation coefficient (**Appendix-I**) it was observed that nitrite has no positive significance with any other parameters. And it has a negative significance with DO content .And by using Anova statistical analysis it has been observed that the nitrite content of all samples has significance variation with the change in seasons (**Table 5.11**)

Table 5.11: One-way Anova for water nitrite variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.007	2	.003	5.178	0.007
Within Groups	.078	117	.001		
Total	.085	119			

5.2.12 Phosphate:

Phosphates are of three type orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate each compound contains phosphorous in a different chemical arrangement. There is an occurance of phosphate in living and decaying plant and animal remains, as free ions or weakly chemically bounded in aqueous systems, chemically bond to sediments and soils, or as mineralized compound in soil, rocks, and sediments. Orthophosphate are formed by natural processes, but major man-influenced sources include partially treated and untreated sewage, runoff from agricultural site, and application of fertilizers in nearby settlement. The presence of phosphate in water is most likely due to human activities (Aflukwa and Eboatu, 2013). The used of phosphate based detergents has impacted on the water quality by introducing excess nutrients to the water (Egemen, 2000). In most developing countries, discharges from point sources have increased significantly as a result of industrialization and high living standards (Smith *et al.*, 1999).

The concentration of phosphate during the period was found to be highest in monsoon season and it was obvious that the rain water run-off from the surrounding areas has increase the level of phosphate content in the water body. And it was lowest in post monsoon season and this trend was followed in both the year 2016-2017 and 2017-2018. From the observation it is clear that phosphate content in the water body was mainly due to human activities which enter during rainy season although the values was not high to take phosphate content found in the sample as a serious matter as there was no value found exceeding the standard value given by USHP and CPCB **(Appendix-II).**

After calculating correlation coefficient (**Appendix-I**) it was observed that phosphate has a positive significance with sulphate, total coliform, faecal coliform, temperature, ORP, turbidity, chloride and BOD. And it has a negative significance with pH, alkalinity and DO content .And by using Anova statistical analysis it has been observed that the phosphate content of all samples has significance variation with the change in seasons (**Table 5.12**)

Table 5.12: One-way Anova for water phosphate variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.115	2	2.058	59.601	0.000
Within Groups	4.039	117	.035		
Total	8.155	119			

5.2.13 Sulphate:

Spring water contain sulphate ions and most of these ions are also soluble in water. Many sulphate ions are produce by oxidation process of their ores, they also present in industrial wastes (Dohare*et al*., 2014). Contaminated water and waste water has high sulphate concentration (Saleem*et al*., 2016). Sulphate is widely distributed in nature and may be present in natural water in substantial concentration. In numerous minerals, including barite, epsomite and gypsum there in an occurance of sulphate naturally (APHA, 2003).

The value of sulphate during the study period was highest in monsoon season and lowest in pre-monsoon season. It has been observed that there is only trace amount of sulphate content in all study site as there is no industrial area and it is clear that the sulphate concentration result only from natural oxidation process. According to World Health Organization 2004, typical sulphate levels in fresh spring water are in the vicinity of 20mg/l, which means the value found in all the study are below the standard value during the study period. Thus, do not have a noticeable taste and may not contribute to corrosion of distribution systems (WHO, 2008). Although there was change in the values observed during the study period, all the values observed are way below the standard given by USHP, BIS, WHO and ICMR **(Appendix-II).**

After calculating correlation coefficient (**Appendix-I**) it was observed that sulphate has a positive significance with temperature, ORP, turbidity, BOD, phosphate and total coliform. And it has a negative significance with pH, alkalinity and DO content .And by using Anova statistical analysis it has been observed that the sulphate content of all samples has significance variation with the change in seasons (**Table 5.13**)

Table 5.13: One-way Anova for water sulphate variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	50.114	2	25.057	30.768	0.000
Within Groups	95.282	117	.814		
Total	145.396	119			

5.2.14 Total Coliform:

Total coliform are one of the most important microbiological parameters of water quality (Dufour, 1977). The presence of *E. coli* in water indicates that the water was contaminated by faecal material of humans or other warm-blooded animals. 2002. Several environmental factors including temperature, pH, dissolved oxygen, nutrients and the native microorganisms also influence the decay of coliform bacteria Natural spring waters originate from groundwater and are usually rich in minerals such as calcium, magnesium, and potassium (An and Breindenbach, 2005). Since an adequate mineral uptake is considered to be wholesome to life, people often drink the spring water for health purposes. However, bacteria can contaminate spring waters. Microbial contamination is the most common reason for water to be deemed unsafe for drinking (WHO, 2006).

The most probable number of total coliform found in the study sites were highly accelerated at site 1 which was followed by site 5 during the study period and it was found lowest at site 3 which was followed by site 2. The highest average value was observed during monsoon season and it was lowest during pre-monsoon season in all the sites. The same trend was observed during the two study year. Obtaining high value of total coliforms at site1 could be due to market waste that leached down to the water body and also site 1 was located in an open unprotected area that enable bacteria to enter easily in the water body. From the present study, findings clearly indicate the presence of microbes in the samples collectedans higher value was observed during post monsoon season at site 1 and site 5 which may be due to prolonged rainfall(Bumadian*et al*., 2013).

After calculating correlation coefficient (**Appendix-I**) it was observed that total coliform has a positive significance with temperature, turbidity, BOD, phosphate, sulphate, faecal coliform. And it has a negative significance with total hardness of the water .And by using Anova statistical analysis it has been observed that the total coliform of all samples has significance variation with the change in seasons (**Table 5.14**)

Table 5.14: One-way Anova for water total coliform variations.

Seasons	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9828096.350	2	4914048.175	11.164	0.000
Within Groups	51498372.539	117	440157.030		
Total	61326468.889	119			

5.2.15 Fecal Coliform:

There is an occurance of coliform bacteria present in the environment and feces of all warm-blooded animals and humans. Coliform bacteria are unlikely to cause illness. Most pathogens that can contaminate water supplies come from the feces of humans or animals, could also be present in wastewaters. Fecal coliform are persistence without multiplication in the environment (Nigel, 2003). The presence of faecal coliform in a borehole water occurs when fecal matter from a nearby septic tank infiltrates in borehole chambers and introduces bacteria and other pathogenic microorganisms into such water drawn from the borehole (Birmingham *et al*., 1997).

During the study period site 2, 3, 4 and 5 do not have fecal contamination, whereas there was a trace amount in site during pre-monsoon and post monsoon season. But during monsoon season in both the year fecal coliform contamination was observed in all the study area. The result shows that the concentration of fecal coliform was much higher in site 1 than that observed in site 2, site 3, site 4 and site 5, and this was clearly due to rearing of pigs in the nearby areas, animals like dogs, cats excreta that leached down to the water body when there is high precipitation and could also be due to leakage of septic tank from the human settlement areas. Also, site 1 is present in open or unprotected area which may increase the chances for the entry of fecal matter into the water body as compare to the other sites that was located under protection through constructing walls to the spring water collection point. Zero standard value was giver for fecal coliform content in water, which means that no fecal coliform is wanted in water for drinking purposes.

After calculating correlation coefficient (**Appendix-I**) it was observed that fecal coliform has a positive significance with temperature, turbidity, chloride, phosphate, total coliform. And it has a negative significance with DO content .And by using Anova statistical analysis it has been observed that the faecal coliform of all samples has significance variation with the change in seasons (**Table 5.15**)

Table 5.15: One-way Anova for water faecalcoliformvariations.

Season	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2159.214	2	1079.607	6.492	0.002
Within Groups	19457.739	117	166.305		
Total	21616.953	119			

5.3 Strategies for better management options and utilities:

Water can be objectionable for domestic purposes if it is contaminated with different types of pollutants and becomes threat to the health. Thus, it is always important to keep and maintain the quality of spring water especially the one which are regularly used for household purposes. Therefore, from the outcome of the present investigation, the following recommendations may be taken into consideration in order to maintain better quality of potable water:

1. As for sewage, trade waste control can be used to minimize the presence of chemical in sewage that could leach down and enters the water body.
2. There should be a proper management and maintenance of sanitary system to avoid leakage as runoff from the leaking area could enter the spring water collected point.
3. We need to minimize rearing of pet animals as well as pigs at human settlement areas, for they are one of the main contributors of coliform contamination.
4. Increase plantation near the water resource area as well as human settlement, as increasing plantation will increase the water retention which in turn accelerates the growth of plant. With increase in number of plants near water sources, the soil become less porous and enable to hold more water than porous soil and this will increase the filter efficiency of water in removing impurities.
5. To strictly restrict throwing of garbage from any kind of sources.
6. Regular cleaning of the collection point will also help in maintaining the quality of water.
7. Avoid throwing of detergent waste in the nearby spring water collection point.
8. By making strict rules and regulation in water sources and collection area, potable quality of water can be improve.
9. Reducing demand of water as well as reducing of waste water is also crucial in maintaining water quality, because runoff water will carry different types

of water pollutant and will contaminate the water body when it reaches the spring collected site.

10. There should be proper treatment facilities not only at Government level but also at local level, because long term consumption of polluted water can result in long term effect to human and environment. Contaminated water can be easily treated by boiling, chlorination as well as sun disinfection. This will purify the water at some extend for household consumption.
11. Form the research work conducted water quality also depends on storage technique. Comparing to water located in an open area, protecting the water collected site by walls at all possible sides protect the entry of unwanted material to the water body and this keeps and maintain the quality of water for a long period of time. Thus creating walls or protecting the water collected as well as sources of water is another management strategies in maintaining water quality.

CHAPTER- 6

SUMMARY AND CONCLUSIONS

SUMMARY

The present study was conducted during September 2016 to August 2018, the study period was divided into three season viz., Pre-monsoon (January to April), Monsoon (May to August) and Post-monsoon (September to December). Water samples were analyzed every month and the data were compared seasonally to check significance in the water quality. The objectives of this study are to survey and describe water resources in and around Aizawl city, to analyze the physical and chemical characteristics of the selected perennial spring water and to suggest strategies for better management options and utility. From the observation it can be summarized as follows:

In order to study the water resources in and around Aizawl city, survey method was employed. It was found that there are three types of water resources which are spring water, ground water and river. Zone wise survey was conducted and it was found that there are 27 water resources found so far in the north zone, 10 in the east zone, 34 in west zone and 10 in south zone. Out of total 81 water resources found, 16 resources are perennial in nature whereas the rest 65 are seasonal.

To study the water quality of five selected sites, 15 parameters were analyzed. All the data except dissolved oxygen, biological oxygen demand and total coliforms were within the permissible limits given by various scientific agencies. Statistical analysis was done to find correlation between each parameters as well as significant change between different seasons. The observation on the studied water quality parameters were as follows:

1. The value of temperature varied from 19.2 ^{o}C to 23 ^{o}C during the study period. It was high during monsoon and post monsoon season where as lower during pre-monsoon season. Water temperature was mainly depended on the surface temperature. Temperature has great effect on the metabolic activities

of aquatic organism. High value of temperature can disrupts the dissolved oxygen of the water body.

2. During the study period the turbidity values range from 0 NTU to 2.3 NTU, maximum value was observed during monsoon season and minimum during pre-monsoon season. The value of turbidity was affected by run-off and sedimentation from the surface during rainy seasons. High turbidity value makes the water unfit for consumption and can eradicate the photosynthetic activity inside the water body by reducing intensity of sunlight.
3. The pH values of the study range from 5.84 to 6.79 during the study period. This shows that the water quality in acidic in nature. Minimum values were found during monsoon season and maximum during pre-monsoon and post-monsoon season. pH of the water body is mainly depend on the surface soil quality. Rain water is acidic which neutralize the alkalinity of the water body.
4. During the study period the oxidation reduction potential varied from 12µV to 97.9 µV. Maximum values were found at monsoon season and minimum at pre-monsoon season. The oxidation reduction potential value was affected by different solids dissolved in water which enters through run-off from the surrounding areas. High oxidation reduction potential may indicate more sediments and minerals in the water body.
5. The value of acidity ranges from 22 mg/l to 116mg/l. the maximum value was during post monsoon season and minimum during pre-monsoon season. The acidity of surface water is mainly due to carbonic acid dissolved in the water body from bicarbonates containing materials and also from free carbon dioxide in the surface and water body. The free carbon dioxide dissolved in the water in the processed of condensation. High acidity in the water may corrode other substances and may also disrupt some aquatic micro and macro organisms.
6. During the study period the value of alkalinity ranges from 2mg/l to 140 mg/l. The value of alkalinity was found to be higher during pre-monsoon season and low during monsoon season. Alkalinity was mainly due to hydroxyl ions and bicarbonates present in the water body, the value of alkalinity lower during monsoon could be due dilution of these ions by rain

water in the water bodies which is acidic that neutralize the alkaline molecules.

7. Chloride is the naturally occurring chemical in rocks and soil. The value of chloride in the study sites carried from 21.493 mg/l to 394.88 mg/l chloride value was higher during rainy seasons and there is only little difference compared to different seasons which shows that chloride do not enter to water body from run-off and other sources. High amount of chloride in water body may affect the taste of the water body.
8. The total hardness of the study site during the study period ranges from 53 mg/l to 246 mg/l. the value of alkalinity is more or less constant throughout every season. But there is a great difference in different sites. It is caused mainly due to the presence of calcium and magnesium ions which are naturally present in rocks and soils. Total hardness may not be included in water pollutants but high hardness in water caused economic hardships and may also results in bad taste of the water.
9. The dissolved oxygen valued varied from 0.7 mg/l to 5.9 mg/l during the study period, most of the sites at different seasons were under permissible limits which are mainly 4-6 mg/l. The amount of dissolved oxygen was found to be higher during pre-monsoon season where water temperature is lower, this may be due to decreased of metabolic reaction of aerobic organisms which lower the rate of respiration. Low level of dissolved oxygen indicates high population of microorganisms in the water body.
10. The biological oxygen demand of the study site values ranges from 0.5 mg/l to 4.95 mg/l during the study period. The value was found to higher during monsoon season where temperature was raised in every site which is due to increased metabolic reaction that intense the rate of respiration. The increased value of biological oxygen demand may indicate high aerobic microbial population. The permissible limits for biological oxygen demand shows that the amount should be always less than 3 mg/l for drinking water.
11. The nitrite value rage from 0.001 mg/l to 0.097 mg/l during the study period. It was higher during pre-monsoon season and lower during monsoon season in most of the study sites. This is due to dilution of nitrite ions by rain water

in monsoon seasons and the amount of nitrate ions enters into the water body during rainy seasons get convert into nitrite ions which is concentrated in the water body during pre-monsoon season as a result of fewer water through this period. Consumption of high level of nitrite in water bodies is unfit for drinking purposes as it can affect health especially on infants and children.

12. During the study period the phosphate content of different study sites ranges from 0.034 mg/l to 1.184 mg/l. the value of phosphate was observed to be high during monsoon season and low during pre- monsoon and post-monsoon season. The amount of phosphate in natural water is greatly affected by human activities like consumption of chemical fertilizers in agriculture and decomposition of organic wastes. From the observation it is clear that phosphate ions enter to water bodies from surface through leaching due rainy season.
13. The amount of sulphate in different site varied from 1.32 mg/l to 6.85 mg/l during the study period. The maximum value was observed during monsoon season and minimum during pre-monsoon season. The observation shows that there is only trace amount of sulphate content in all the study site due to absence industrial region near the surrounding areas and it is clear that the sulphatepresent in water body of the selected sites were formed only from natural oxidation process.
14. The total coliform value of the study sites ranges from 3.6 mg/l to 2400 mg/l during the study period. The maximum value was observed during monsoon and post-monsoon season and lower during pre-monsoon season. From the observation it is clear that the total coliform was affect by domestic waste leaching from the surrounding areas. High amount of total coliform may indicate the presence of pathogenic microorganisms. It is unsafe to consume water having high total coliform values as it can result different water borne diseases.
15. During the study period the fecal coliform value ranges from 0 mg/l to 93 mg/l in the study sites. The value was observed to be high during monsoon season and low during pre-monsoon and post-monsoon season. The fecal coliform was mainly produced from feces of human and animals. The

elevated value during monsoon season could be due to leaching of fecal waste from the surrounding areas especially from septic tank and from pigs sty in which their excreta are openly disposed in the surface of the surrounding areas. The amount of faecal coliform should always be zero for drinking water as their presence indicates existence of pathogenic microorganisms harmful for human health.

CONCLUSIONS

From the observation, it can be concluded that the physico-chemical quality of the selected study sites were under permissible limits except for dissolved oxygen and biological oxygen demand. The bacteriological properties of the study sites exceed permissible limits especially during monsoon seasons. The water from different selected sites needs to be disinfected before consumption. As most of the parameters are higher during monsoon it shows that there were no proper drainage systems and different kind of domestic waste enters to the water body through run-off and leaching. The water resources needs better management to prevent them from being severely polluted in near future. There is also need of proper waste management and awareness of its importance to the people to save our valuable water sources.

1) Temperature during the study period shows similar trend for the two years where it was high during monsoon season in all the sites. The average temperature was highest during monsoon season in all the sites and it was lower during pre-monsoon season. Temperature has a positive significance with turbidity, acidity, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with total hardness and DO content .And by using Anova statistical analysis it has been observed that the temperature of all samples has significance variation with the change in seasons.
2) Among all the seasons it is also observed that turbidity was highest during monsoon season in all the sites which was cause may be due to increase in sediment load through precipitation, surface runoff resulting into higher seepage velocity of groundwater entering into the spring storage area and thus caused excessive suspended solid load and vice versa during pre-monsoon season. The value observed during the study period in all the sites was all under the permissible limits or standard given by BIS, WHO, ICMR, CPCB and ISI. It was observed that turbidity has a positive significance with

chloride, BOD, phosphate,sulphate, total coliform and fecal coliform. And it has a negative significance with pH, alkalinity and DO content.

3) The average pH value was highest during post monsoon season . During the study period the pH during monsoon season was lower than the standard given by USHP, BIS, WHO, ICMR, CPCB and ISI.It was observed that turbidity has a positive significance with chloride, BOD, phosphate, sulphate, total coliform and fecal coliform. And it has a negative significance with pH, alkalinity and DO content.It has been observed that the turbidity of all samples has significance variation with the change in seasons.
4) The highest oxidation reduction potential was found to be highest at site 3 and was found to be lowest at site 2. The trend in site 1 was opposite in the two study period whereas in site 4 and site 5 ORP value was higher during pre-monsoon season comparing to post monsoon and in 2016-2017. The average value of the ORP during the study period was found to be high during monsoon season. It was observed that ORP has a positive significance with acidity, chloride, total hardness, BOD, phosphate and sulphate. And it has a negative significance with pH and alkalinity content.
5) The present study revealed that there is high value of acidity at site 1 and site 5 during post monsoon season Changes in trend was observed at site 2 between post monsoon and monsoon season where the value was high in monsoon during 2016-2017 and was high during post monsoon season during 2016-2017. It was observed that acidity has a positive significance with temperature, ORP, alkalinity, total hardness. And it has a negative significance with pH, DO content .
6) The average value was found to be high during pre-monsoon season. Similar trend was observed during the study period in site 1, site 2 and site 3. Whereas in site 4 and site 5 the alkalinity value was higher during pre-monsoon comparing to post monsoon season in the year 2016-2017 while it was lower during pre-monsoon season during the year 2017-2018. It was observed that acidity has a positive significance with temperature, ORP, alkalinity, total hardness. And it has a negative significance with pH, DO content .

7) The value of Chloride content was high at site 3 and site 1 and was low at site 5. The average value was found to be highest during monsoon season and the value was highly accelerated at site 3 during monsoon 2017. The study period show different trends where in 2016-2017 the value was found highest during monsoon season in all the sites where in 2017-2018 the chloride content was found highest during post monsoon season.It was observed that chloride has a positive significance with ORP, turbidity, total hardness, BOD, phosphate and faecal coliform. And it has a negative significance with alkalinity, pH, DO content.
8) Total hardness was found to be highest at site 3 and it was followed by site 1, 4 and 3. And it was found to lowest at site 5. The average value was high during post monsoon season where it was low during pre-monsoon season. The two years study period show more or less similar trend where the total hardness was usually high during post monsoon season. It was observed that total hardness has a positive significance with chloride, ORP, acidity, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with temperature, pH and DO content.
9) Total hardness was found to be highest at site 3 and it was followed by site 1, 4 and 3. And it was found to lowest at site 5. The two years study period show more or less similar trend where the total hardness was usually high during post monsoon season. The findings reveal that the total hardness of water from the study area during sampling period was all under the standard given by BIS, WHO, ICMR and CPCB. It was observed that total hardness has a positive significance with chloride, ORP, acidity, BOD, phosphate, sulphate, total coliform and faecal coliform. And it has a negative significance with temperature, pH and DO content.
10) The dissolved oxygen content was found lowest at site 1 and it was followed by site 4, 3, 2 and was found highest at site 5. And the average value of DO content during the study period was found highest during post monsoon season and it was lowest during monsoon season. The dissolved oxygen content in at all sites during monsoon season was lowest among the three compared seasons and this trend was followed in both the year 2016-2017

and 2017-2018. It was observed that DO did not have a positive significance with any of the parameters studied. And it has a negative significance with temperature, ORP, turbidity, acidity, chloride, BOD, nitrite, phosphate, sulphate and fecal coliform.

11) The highest BOD level was observed at site 1 and of all the seasons being studied it has been found that highest biological oxygen demand was found during monsoon season and this trend was seen in both the year 2016-2017 to 2017-2018. The BOD showed a reverse trend in results in comparision with the DO content of water. It was also observed that BOD has a positive significance with temperature, ORP, turbidity, chloride, phosphate, sulphate, total coliform. And it has a negative significance with pH, alkalinity and DO content.

12) It has been observed that nitrite value was found to be highest during pre-monsoon season and it was lowest during post monsoon season. During post monsoon season the value was highest at site 2 and 3 for 2016-17 and 2017-18 and it was lowest at site 4. The value observed throughout the study period for various seasons are below the standard given by ISI. After calculating correlation coefficient (**Appendix-I**) it was observed that nitrite has no positive significance with any other parameters. And it has a negative significance with DO content.

13) The concentration of phosphate during the period was found to be highest in monsoon season. And it was lowest in post monsoon season and this trend was followed in both the year 2016-2017 and 2017-2018. It was observed that phosphate has a positive significance with sulphate, total coliform, faecal coliform, temperature, ORP, turbidity, chloride and BOD. And it has a negative significance with pH, alkalinity and DO content.

14) The value of sulphate during the study period was highest in monsoon season and lowest in pre-monsoon season. It has been observed that there is only trace amount of sulphate content in all study sites. It was observed that sulphate has a positive significance with temperature, ORP, turbidity, BOD, phosphate and total coliform. And it has a negative significance with pH, alkalinity and DO content .And by using Anova statistical analysis it has been

observed that the turbidity of all samples has significance variation with the change in seasons

15) The most probable number of total coliform found in the study sites were highly accelerated at site 1 which was followed by site 5 during the study period and it was found lowest at site 3 which was followed by site 2. The highest average value was observed during monsoon season and it was lowest during pre-monsoon season in all the sites. The trend was followed in both the year. It was observed that total coliform has a positive significance with temperature, turbidity, BOD, phosphate, sulphate, faecal coliform. And it has a negative significance with total hardness of the water.

16) During the study period site 2, 3, 4 and 5 do not have faecal contamination, whereas there was a trace amount in site during pre-monsoon and post monsoon season. But during monsoon season in both the year faecal coliform contamination was observed in all the study area. The result shows that the concentration of faecal coliform was much higher in site 1 than that observed in site 2, site 3, site 4 and site 5. It was observed that faecal coliform has a positive significance with temperature, turbidity, chloride, phosphate, total coliform. And it has a negative significance with DO content.

17) The findings reveal that there is an ample scope of treatment of spring water before use for drinking purpose, as long term utilization of untreated water with traces of pollutant may cause different types of diseases/illnesses in human beings.

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APPENDIX- I: Correlation coefficient (r) between parameters of water quality for all sites during 2016 to 2018. **(**** - Correlation is Significant at the 0.01 level and *- Correlation is Significant at the 0.05 level **).**

PARAMETERS	Temp (o C)	ORP (µV)	Tur. (NTU)	pH	Acidity (mg/l)	Alk (mg/l)	Chlo (mg/l)	Total H	DO (mg/l)	BOD (mg/l)	N (mg/l)	P (mg/l)	S (mg/l)	TC (MPN)	FC (MPN)
Temp. (^{o} C)	1	0.159	.341**	-.279**	.289**	-0.175	0.131	-.285**	-.253**	.332**	-0.079	.394**	.354**	.490**	.269**
ORP (µV)		1	0.169	-.890**	.297**	-.220*	.279**	.203*	-.219*	.297**	0.001	.408**	.355**	-0.054	-0.125
Tur. (NTU)			1	-.183*	0.068	-0.13	.330**	0.055	-.321**	.385**	0.129	.529**	.327**	.403**	.473**
pH				1	-.283**	.226*	-.222*	-0.111	0.153	-.244**	0.015	-.432**	-.473**	-0.104	0.089
Acidity (mg/l)					1	.405**	0.076	.190*	-.216*	0.091	-0.124	0.151	0.109	0.13	0.026
Alkalinity(mg/l)						1	-.261**	-0.046	0.018	-.218*	-0.03	-.347**	-.234*	0.026	-0.057
Chloride (mg/l)							1	.333**	-.296**	.371**	0.117	.467**	0.163	-0.026	.211*
Total H. (mg/l)								1	-0.163	0.089	-0.009	0.02	-0.127	-.256**	-0.084
DO (mg/l)									1	-.609**	-.235**	-.239**	-.293**	-0.176	-.238**
BOD (mg/l)										1	0.17	.406**	.274**	.198*	0.179
Nitrite (mg/l)											1	0.02	0.021	0.149	0.094
Phosphate (mg/l)												1	.379**	.319**	.186*
Sulphate (mg/l)													1	.258**	0.145
TC(MPN)														1	.507**
FC(MPN)															1

APPENDIX-II: Water standards of physico-chemical parameters of water by different scientific agencies.

Parameters	USHP	BIS	WHO	ICMR	CPCB	ISI
Temperature	-	25-30	-	-	25-30	-
Turbidity	-	1	5	5	10	10
pH	6-8.5	6.5-8.5	6.5-8.5	6.5-9.2	6.5-8.5	6.5-8.5
ORP	-	-	-	-	-	-
Acidity	-	-	-	-	-	-
Alkalinity	-	200-600	200-600	-	600	-
Chloride	-	250	200	250	1000	250
Total Hardness	-	300	500	300-600	300-600	-
DO	>4	4mg/l-6	5-6mg/l	-	4-6mg/l	>5
BOD	-	<3	-	-	<2-3	<4
Nitrite	-	-	-	-	-	1
Phosphate	0.1	-	-	-	0.05-0.10	-
Sulphate	250	150	200	150	-	-
Total Coliform	-	-	-	-	-	-
Fecal Coliform	-	-	-	-	-	-

APPENDIX – III : Seasonal variations of temperature.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	21.775	21.575	22.5	22.425	21.475	22.525
2	21.225	20.95	21.5	21.325	20.775	21.725
3	20.925	20.45	22	20.95	20.2	21.9
4	20.8	20.55	22.125	20.875	20.825	21.95
5	20.55	20.325	21.625	20.475	20.45	21.975

APPENDIX – IV : Seasonal variations of turbidity.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	0.875	0.425	1.15	0.325	0.375	0.85
2	0.525	0.15	0.825	0.2	0.2	0.4
3	0.175	0.1	0.5	0.275	0.125	0.325
4	0.1	0.475	0.975	0.275	0.175	0.375
5	0.35	0.225	0.525	0.225	0.125	0.275

APPENDIX – V : Seasonal variations of pH.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	5.8925	6.075	5.9775	6.365	6.48	6.2425
2	6.325	6.6975	5.955	6.685	6.77	6.0325
3	5.63	5.755	5.5625	6.255	6.0675	5.5975
4	5.89	5.87	5.7225	6.2875	6.3375	5.9375
5	5.87	5.9875	5.755	6.0425	6.3125	6.055

APPENDIX – VI : Seasonal variations of ORP.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	64.425	64.5	56.6	40.025	43.25	45.95
2	40.025	24.25	60.275	29.4	27.25	57.675
3	75	76.75	81.65	55.65	55.75	81.225
4	63.875	66	73.725	49.575	39.5	63.125
5	59.85	68	68.425	50.225	37.85	55.35

APPENDIX – VII : Seasonal variations of total alkalinity.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	59.5	68.5	22.65	67.75	70	36.5
2	21	11.75	11.275	44.25	23.25	17.5
3	27.5	21.75	9.325	42.25	41.5	20.75
4	29.5	33.25	13.125	48.25	37.5	25
5	44.25	51	14.125	64	60	27.5

APPENDIX – VIII : Seasonal variations of acidity.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	70.5	51	54.125	93.5	42.75	65.5
2	11	6	21.625	32.25	6	19.5
3	48.75	27	34.75	64.75	29	45.25
4	45	24.75	37.875	63	22.5	46
5	64.25	42.5	43.375	79	40.5	63

APPENDIX – IX : Seasonal variations of chloride.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	67.16125	64.23	125.46	93.595	64.075	88.1825
2	61.969	62.605	136.9575	69.7875	63.6	68.0425
3	78.6055	74.0425	203.9375	98.345	69.725	88.44
4	54.6045	62.0425	105.96	73.0975	57.725	70.0075
5	43.29825	34.3625	55.48	36.925	28.2	37.25

APPENDIX – X : Seasonal variations of total hardness.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	205.75	116.5	159.15	186.75	123.25	137.75
2	154.5	119.5	119.15	146.5	134.25	102.5
3	257.5	164.5	185.8	246.75	180.25	175.5
4	200.75	149	160.8	187	170.5	137.75
5	93	71	70.3	97.25	76.5	70.25

APPENDIX – XI: Seasonal variations of DO.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	2.9125	1.5875	2.2875	2.25	2.1375	2.325
2	4.875	4.775	3.875	4.8125	4.55	4.325
3	4.025	4.475	3.4625	4.3375	4.1	4.05
4	3.525	4.35	2.9375	5.4125	3.7125	3.2
5	5.725	5.15	3.925	5.0625	5.325	3.85

APPENDIX – XII: Seasonal variations of BOD.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	2.375	2.8	3.8375	2.625	2.625	4.3625
2	1.2	1.325	2.675	1.475	1.35	2.75
3	2.1	1.575	3.266667	2.125	1.5	2.5375
4	1.95	1.35	3.1	1.375	1.275	3.1625
5	0.775	1.075	1.6125	1.325	0.925	3.075

APPENDIX – XIII : Seasonal variations of Nitrite-N.

Sample	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	0.05495	0.0535	0.06295	0.06575	0.05175	0.05675
2	0.0335	0.07725	0.05105	0.03325	0.068	0.02625
3	0.04325	0.07575	0.06545	0.03625	0.06925	0.036
4	0.03675	0.05375	0.0583	0.0325	0.0485	0.0375
5	0.02575	0.0585	0.0506	0.025	0.04925	0.02425

APPENDIX – XIV : Seasonal variations of Phosphate-P.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	0.0445	0.073	0.71575	0.0425	0.06775	0.228
2	0.05725	0.068	0.39475	0.05975	0.06275	0.26425
3	0.0565	0.07225	0.631	0.06275	0.0675	0.326
4	0.048	0.08075	0.8635	0.0705	0.075	0.374
5	0.0545	0.06675	0.58125	0.0655	0.06125	0.26225

APPENDIX – XV : Seasonal variations of sulphate.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	2.875	2.7375	3.5925	1.965	2.285	3.6875
2	2.85	2.0775	4.13	2.005	1.8025	3.515
3	3.0925	2.095	3.555	2.09	2.17	4.2575
4	2.7475	2.3975	2.75	1.8475	2.3075	2.84
5	3.1075	2.2225	4.4825	2.34	2.1325	4.205

APPENDIX – XVI : Seasonal variations of total coliform.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	803.5	92	2075	782.5	125	1547.5
2	135.525	77.825	111.5	97.25	39.325	132.25
3	20.325	34.075	23.525	14.675	11.625	31
4	332	23.825	965	142.5	69.5	466
5	152	34.75	1187.5	699	11.6	977.5

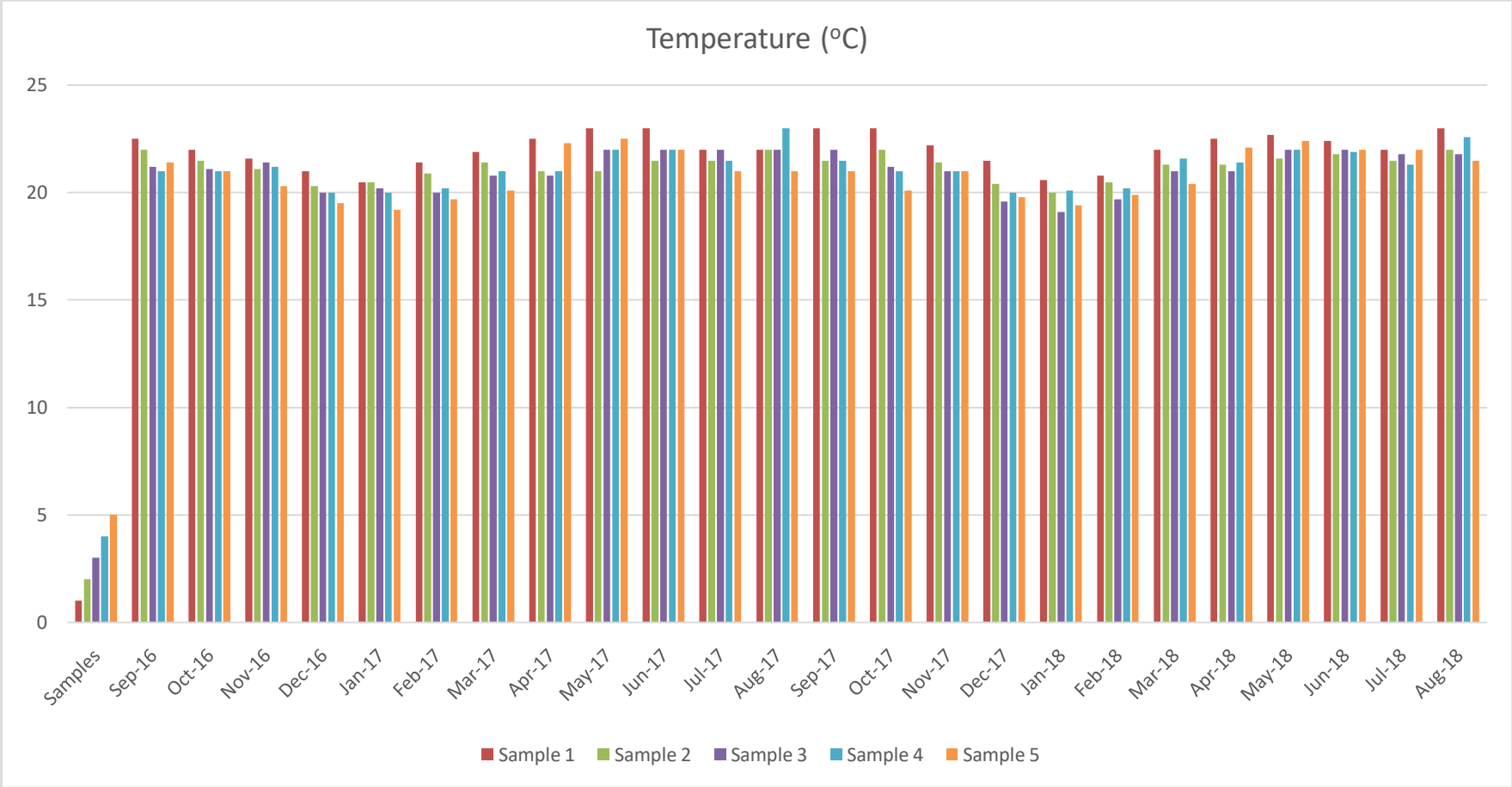
APPENDIX – XVII : Seasonal variations of faecal coliform.

Samples	Post Monsoon 2016-2017	Pre Monsoon 2016-2017	Monsoon 2016-2017	Post Monsoon 2017-2018	Pre Monsoon 2017-2018	Monsoon 2017-2018
1	0.9	0.9	39.5	0.9	0.9	40.65
2	0	0	0	0	0	1.825
3	0	0	0	0	0	0.9
4	0	0	6.65	3.75	0	3.175
5	0	0	0	0	0	0.9

APPENDIX – XVIII : Monthly variations of temperature.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	22.5	22	21.6	21	20.5	21.4	21.9	22.5	23	23	22	22	23	23	22.2	21.5	20.6	20.8	22	22.5	22.7	22.4	22	23
2	22	21.5	21.1	20.3	20.5	20.9	21.4	21	21	21.5	21.5	22	21.5	22	21.4	20.4	20	20.5	21.3	21.3	21.6	21.8	21.5	22
3	21.2	21.1	21.4	20	20.2	20	20.8	20.8	22	22	22	22	22	21.2	21	19.6	19.1	19.7	21	21	22	22	21.8	21.8
4	21	21	21.2	20	20	20.2	21	21	22	22	21.5	23	21.5	21	21	20	20.1	20.2	21.6	21.4	22	21.9	21.3	22.6
5	21.4	21	20.3	19.5	19.2	19.7	20.1	22.3	22.5	22	21	21	21	20.1	21	19.8	19.4	19.9	20.4	22.1	22.4	22	22	21.5

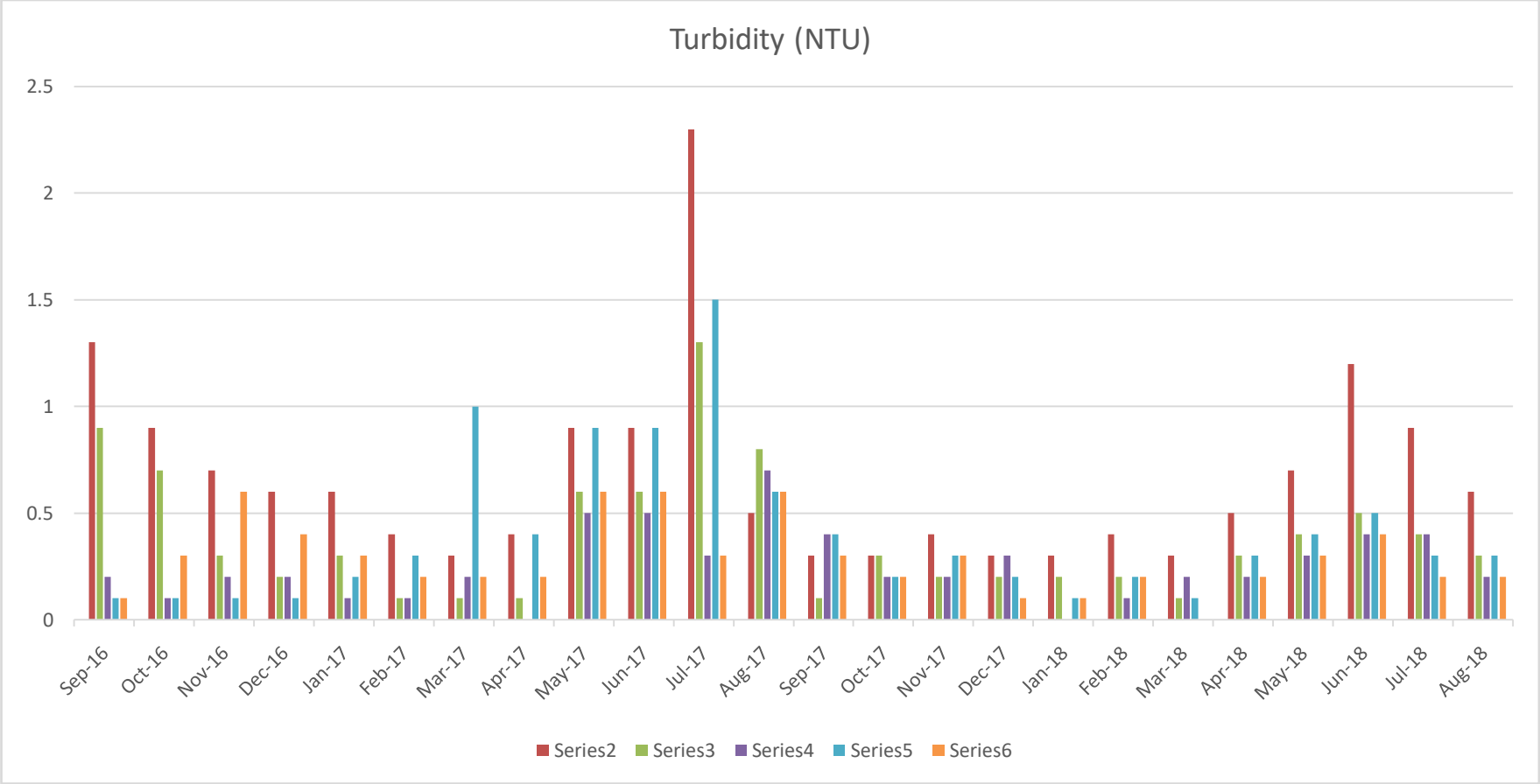
APPENDIX – XIX : Graph representing monthly variations of temperature.



APPENDIX – XX: Monthly variations of turbidity.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	1.3	0.9	0.7	0.6	0.6	0.4	0.3	0.4	0.9	0.9	2.3	0.5	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.5	0.7	1.2	0.9	0.6
2	0.9	0.7	0.3	0.2	0.3	0.1	0.1	0.1	0.6	0.6	1.3	0.8	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.3	0.4	0.5	0.4	0.3
3	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0	0.5	0.5	0.3	0.7	0.4	0.2	0.2	0.3	0	0.1	0.2	0.2	0.3	0.4	0.4	0.2
4	0.1	0.1	0.1	0.1	0.2	0.3	1	0.4	0.9	0.9	1.5	0.6	0.4	0.2	0.3	0.2	0.1	0.2	0.1	0.3	0.4	0.5	0.3	0.3
5	0.1	0.3	0.6	0.4	0.3	0.2	0.2	0.2	0.6	0.6	0.3	0.6	0.3	0.2	0.3	0.1	0.1	0.2	0	0.2	0.3	0.4	0.2	0.2

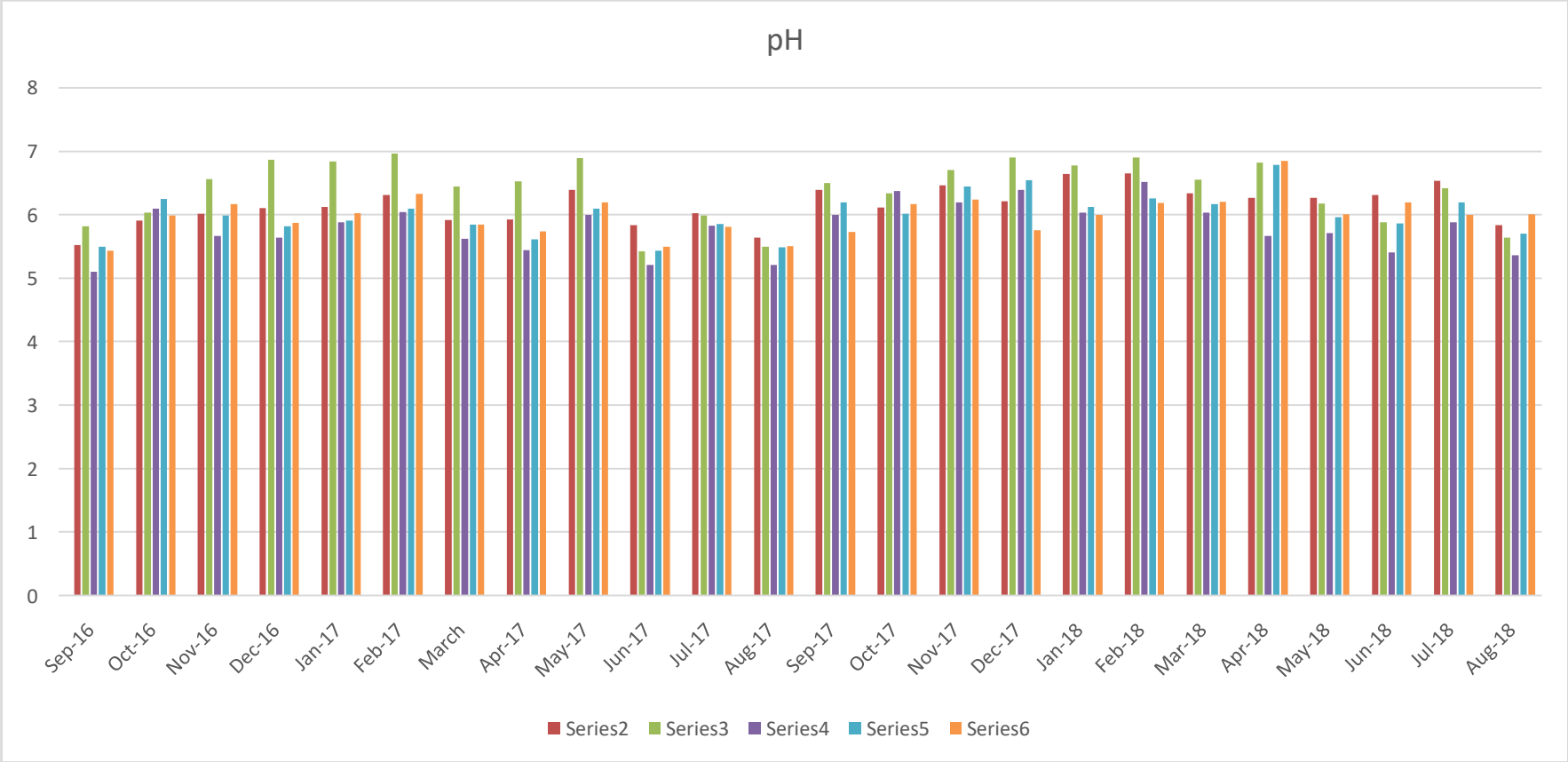
APPENDIX – XXI: Graph representing monthly variations of turbidity.



APPENDIX – XXII : Monthly variations of pH.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	5.53	5.91	6.02	6.11	6.13	6.32	5.92	5.93	6.4	5.84	6.03	5.64	6.4	6.12	6.47	6.22	6.65	6.66	6.34	6.27	6.27	6.32	6.54	5.84
2	5.82	6.04	6.57	6.87	6.84	6.97	6.45	6.53	**6.9**	5.43	5.99	5.5	6.5	6.34	6.71	6.91	6.78	6.91	6.56	6.83	6.18	5.89	6.42	5.64
3	5.11	6.1	5.67	5.64	5.89	6.05	5.63	5.45	6	**5.21**	5.83	**5.21**	6	6.38	6.2	6.4	6.04	6.52	6.04	5.67	5.72	5.41	5.89	5.37
4	5.5	6.25	5.99	5.82	5.91	6.1	5.85	5.62	6.1	5.44	5.86	5.49	6.2	6.02	6.45	6.55	6.13	6.26	6.17	6.79	5.97	5.87	6.2	5.71
5	5.44	5.99	6.17	5.88	6.03	6.33	5.85	5.74	6.2	5.5	5.81	5.51	5.73	6.17	6.24	5.76	6	6.19	6.21	6.85	6.01	6.2	6	6.01

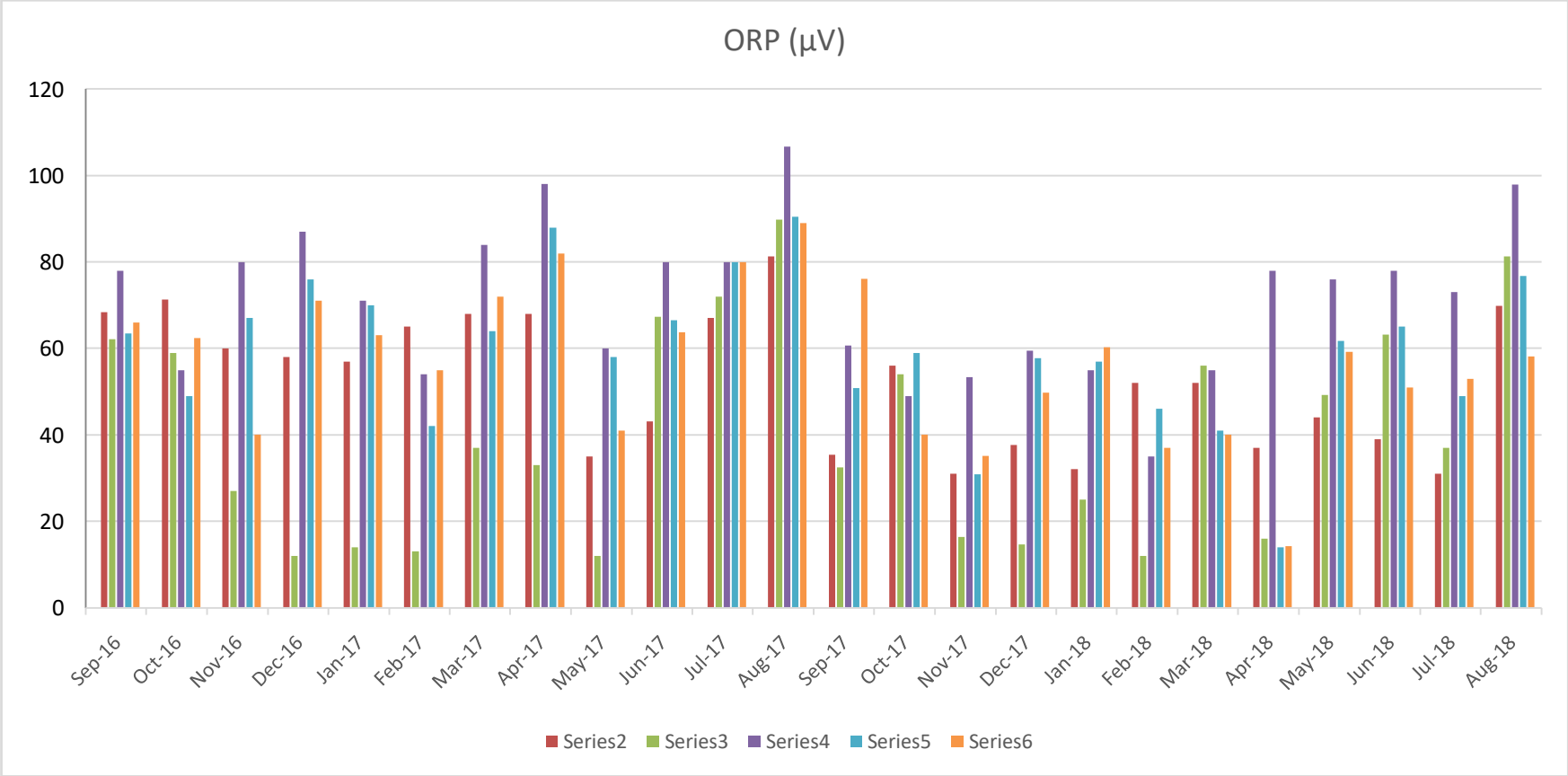
APPENDIX – XXIII : Graph representing monthly variations of pH.



APPENDIX – XXIV : Monthly variations of ORP.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	68.4	71.3	60	58	57	65	68	68	35	43.1	67	81.3	35.4	56	31	37.7	32	52	52	37	44	39	31	69.8
2	62.1	59	27	12	14	13	37	33	12	67.3	72	89.8	32.5	54	16.4	14.7	25	12	56	16	49.2	63.2	37	81.3
3	78	55	80	87	71	54	84	98	60	79.9	80	106.7	60.7	49	53.4	59.5	55	35	55	78	76	78	73	97.9
4	63.5	49	67	76	70	42	64	88	58	66.5	80	90.4	50.8	59	30.8	57.7	57	46	41	14	61.7	65	49	76.8
5	66	62.4	40	71	63	55	72	82	41	63.7	80	89	76.1	40	35.1	49.7	60.2	37	40	14.2	59.2	51	53	58.2

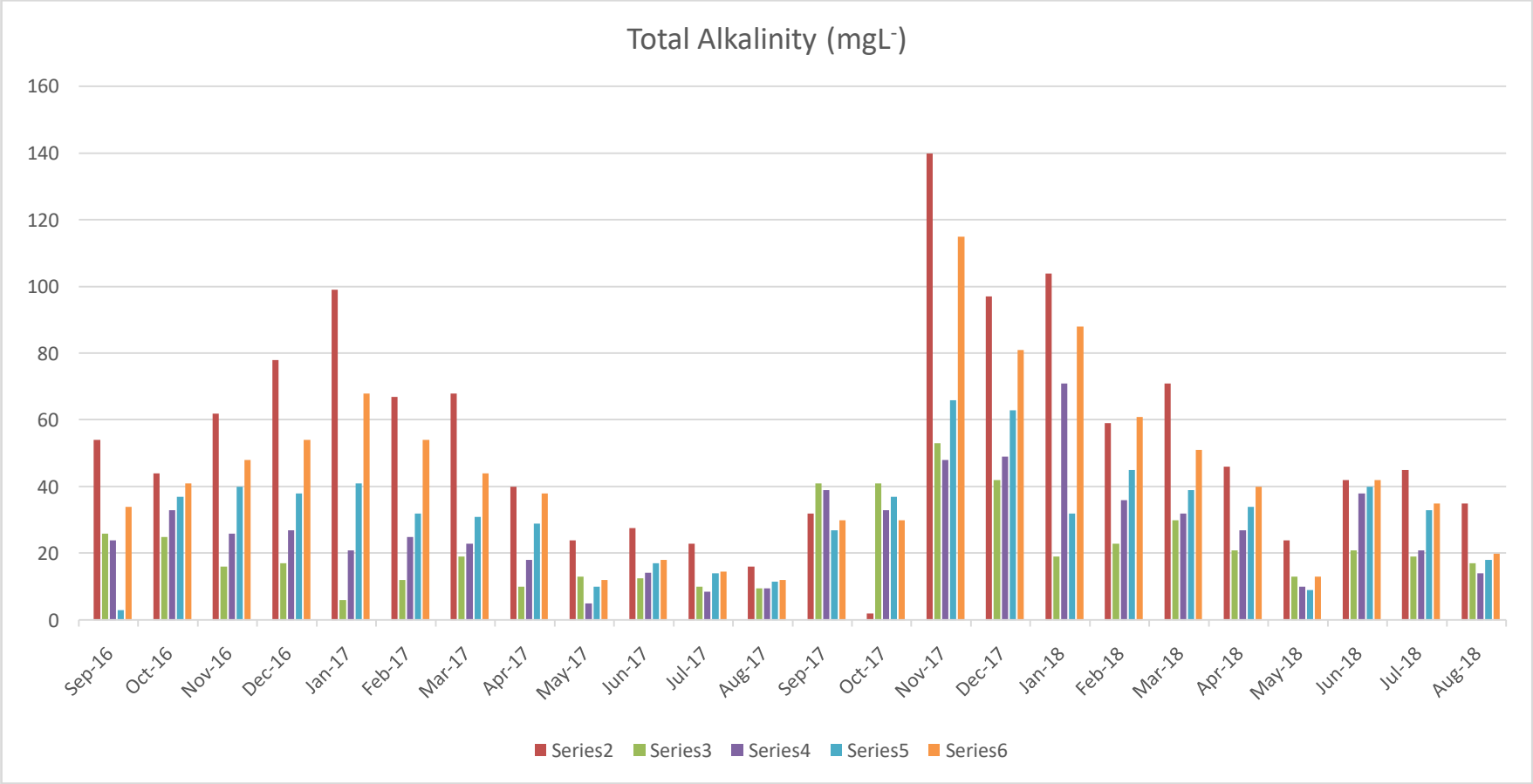
APPENDIX – XXV : Graph representing monthly variations of ORP.



APPENDIX – XXVI : Monthly variations of total alkalinity.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	54	44	62	78	99	67	68	40	24	27.6	23	16	32	2	140	97	104	59	71	46	24	42	45	35
2	26	25	16	17	6	12	19	10	13	12.6	10	9.5	41	41	53	42	19	23	30	21	13	21	19	17
3	24	33	26	27	21	25	23	18	5	14.3	8.5	9.5	39	33	48	49	71	36	32	27	10	38	21	14
4	3	37	40	38	41	32	31	29	10	17	14	11.5	27	37	66	63	32	45	39	34	9	40	33	18
5	34	41	48	54	68	54	44	38	12	18	14.5	12	30	30	115	81	88	61	51	40	13	42	35	20

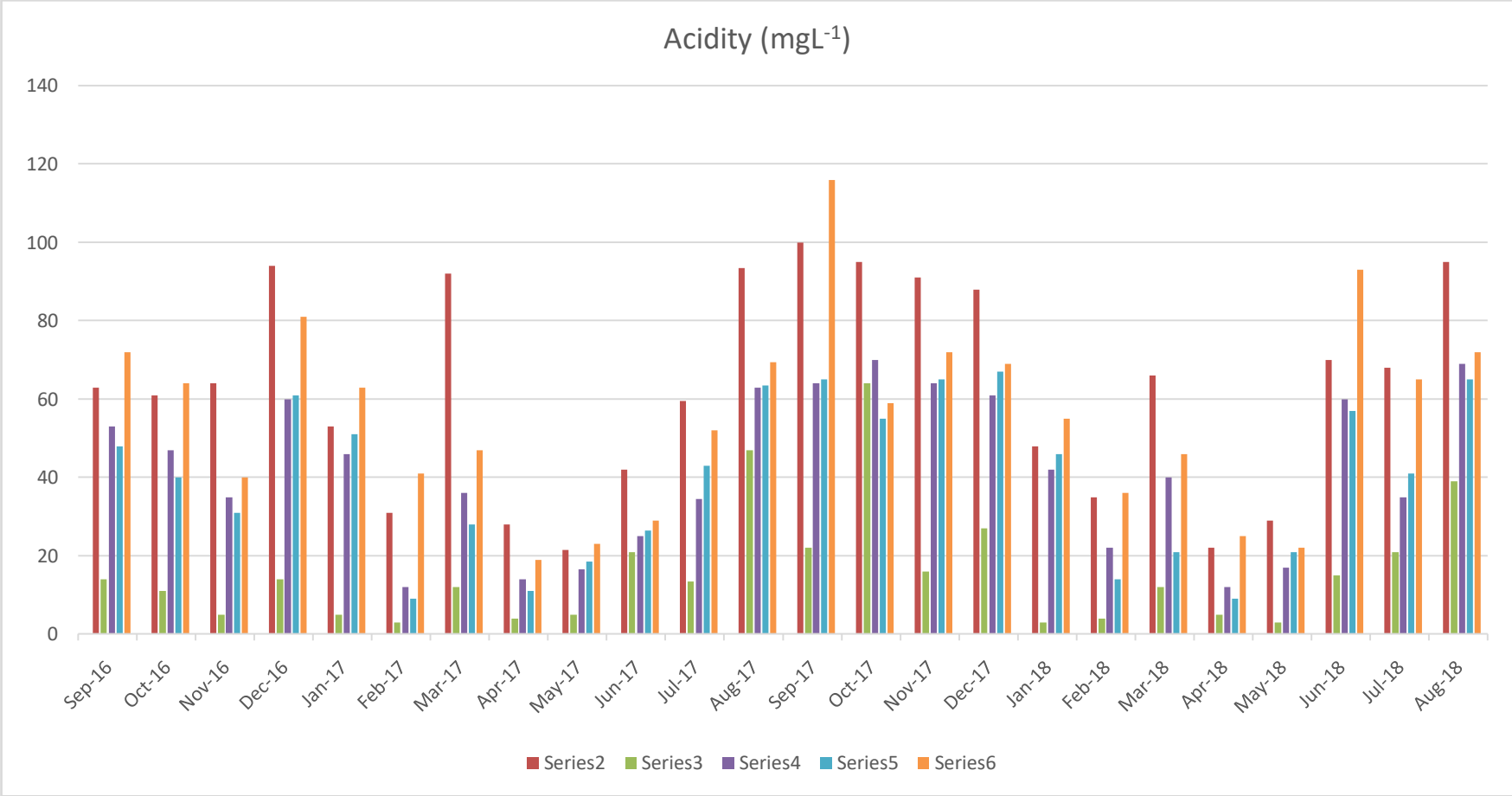
APPENDIX – XXVII : Graph representing monthly variations of total alkalinity.



APPENDIX – XXVIII : Monthly variations of acidity.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	63	61	64	94	53	31	92	28	21.5	42	59.5	93.5	100	95	91	88	48	35	66	22	29	70	68	95
2	14	11	5	14	5	3	12	4	5	21	13.5	47	22	64	16	27	3	4	12	5	3	15	21	39
3	53	47	35	60	46	12	36	14	16.5	25	34.5	63	64	70	64	61	42	22	40	12	17	60	35	69
4	48	40	31	61	51	9	28	11	18.5	26.5	43	63.5	65	55	65	67	46	14	21	9	21	57	41	65
5	72	64	40	81	63	41	47	19	23	29	52	69.5	116	59	72	69	55	36	46	25	22	93	65	72

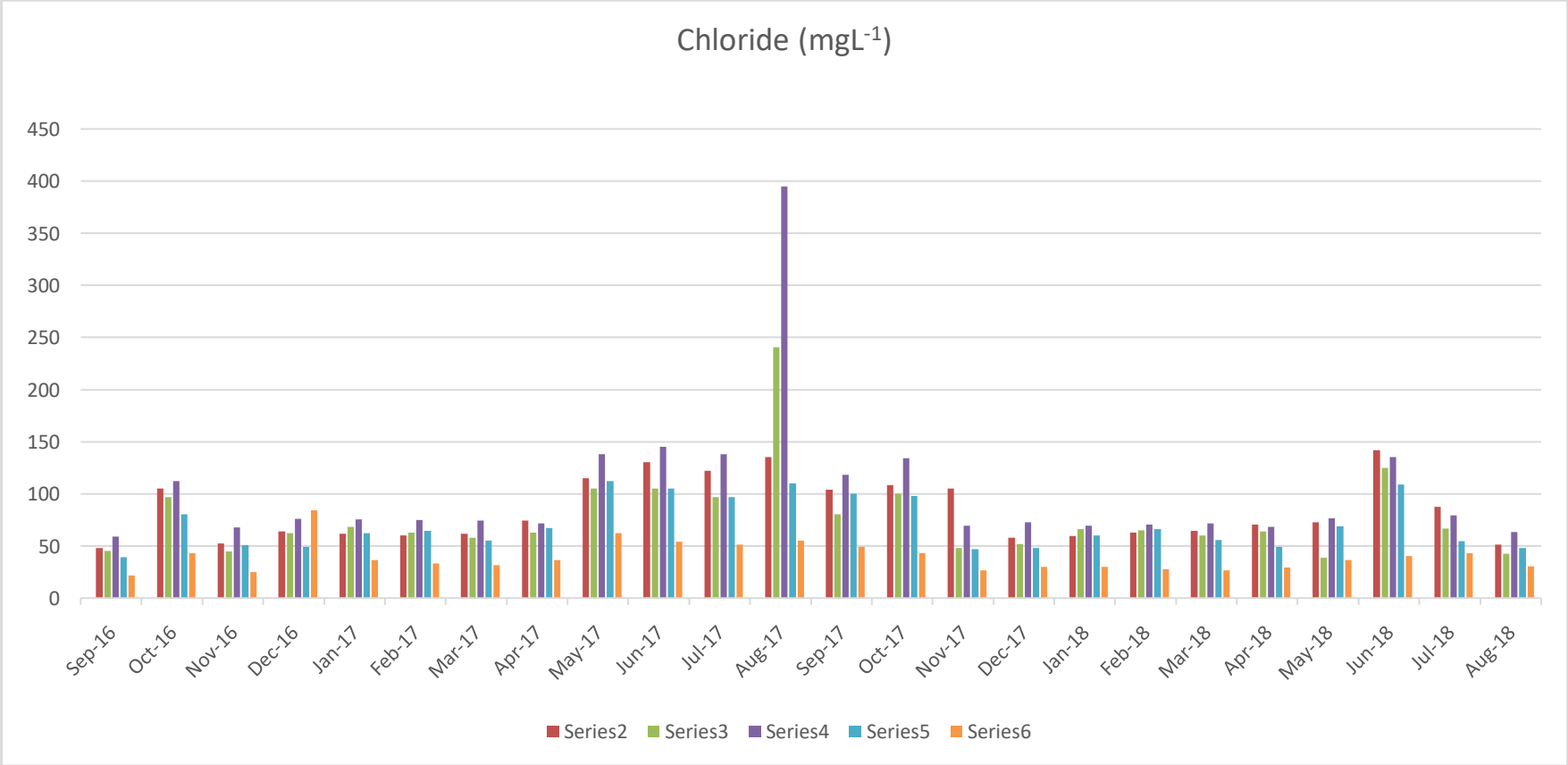
APPENDIX – XXIX : Graph representing monthly variations of acidity.



APPENDIX – XXX : Monthly variations of chloride.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	47.985	104.95	52.23	63.48	61.48	59.98	61.48	73.98	114.96	129.96	121.96	134.96	103.97	107.97	104.96	57.48	59.1	62.5	64.4	70.3	72.49	141.92	87.34	50.98
2	44.986	96.67	44.24	61.98	67.98	62.48	57.48	62.48	104.97	104.97	96.97	240.92	79.97	99.97	47.73	51.48	66.2	64.8	59.9	63.5	38.49	124.98	66.21	42.49
3	58.982	111.96	67.5	75.98	75.48	74.98	74.23	71.48	137.96	144.95	137.96	394.88	117.96	133.96	68.98	72.48	69.4	70.4	71.2	67.9	76.49	134.97	79.32	62.98
4	38.988	79.97	50.48	48.98	61.98	64.48	54.73	66.98	111.96	104.95	96.97	109.96	99.96	97.97	46.48	47.98	60.1	66.1	55.6	49.1	68.49	108.89	54.67	47.98
5	21.493	42.99	24.74	83.97	36.49	32.98	31.49	36.49	61.98	53.98	50.98	54.98	48.98	42.99	26.24	29.49	29.8	27.2	26.5	29.3	36.49	39.91	42.61	29.99

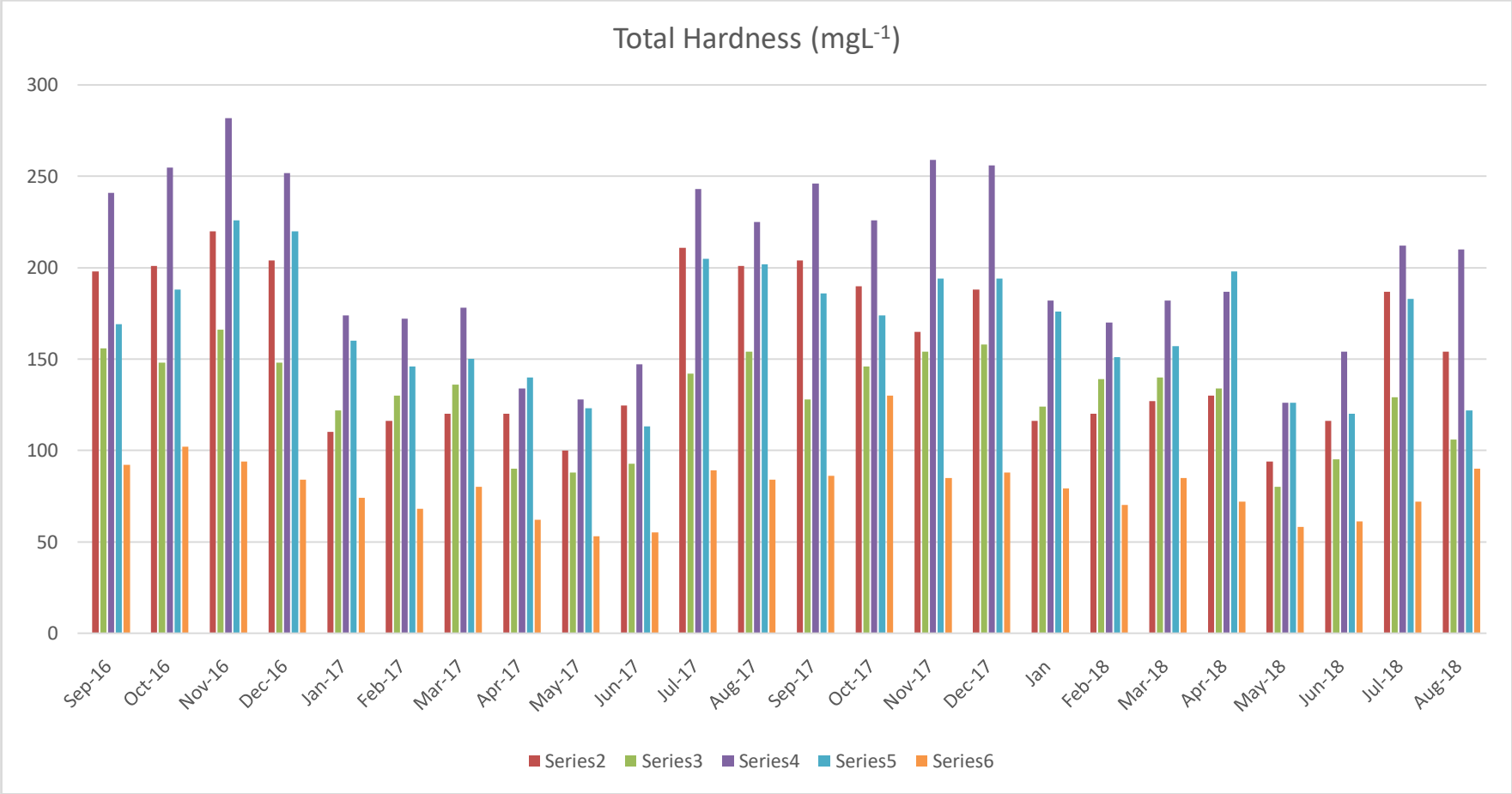
APPENDIX – XXXI : Graph representing monthly variations of chloride.



APPENDIX – XXXII : Monthly variations of total hardness.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	198	201	220	204	110	116	120	120	100	124.6	211	201	204	190	165	188	116	120	127	130	94	116	187	154
2	156	148	166	148	122	130	136	90	88	92.6	142	154	128	146	154	158	124	139	140	134	80	95	129	106
3	241	255	282	252	174	172	178	134	128	147.2	243	225	246	226	259	256	182	170	182	187	126	154	212	210
4	169	188	226	220	160	146	150	140	123	113.2	205	202	186	174	194	194	176	151	157	198	126	120	183	122
5	92	102	94	84	74	68	80	62	53	55.2	89	84	86	130	85	88	79	70	85	72	58	61	72	90

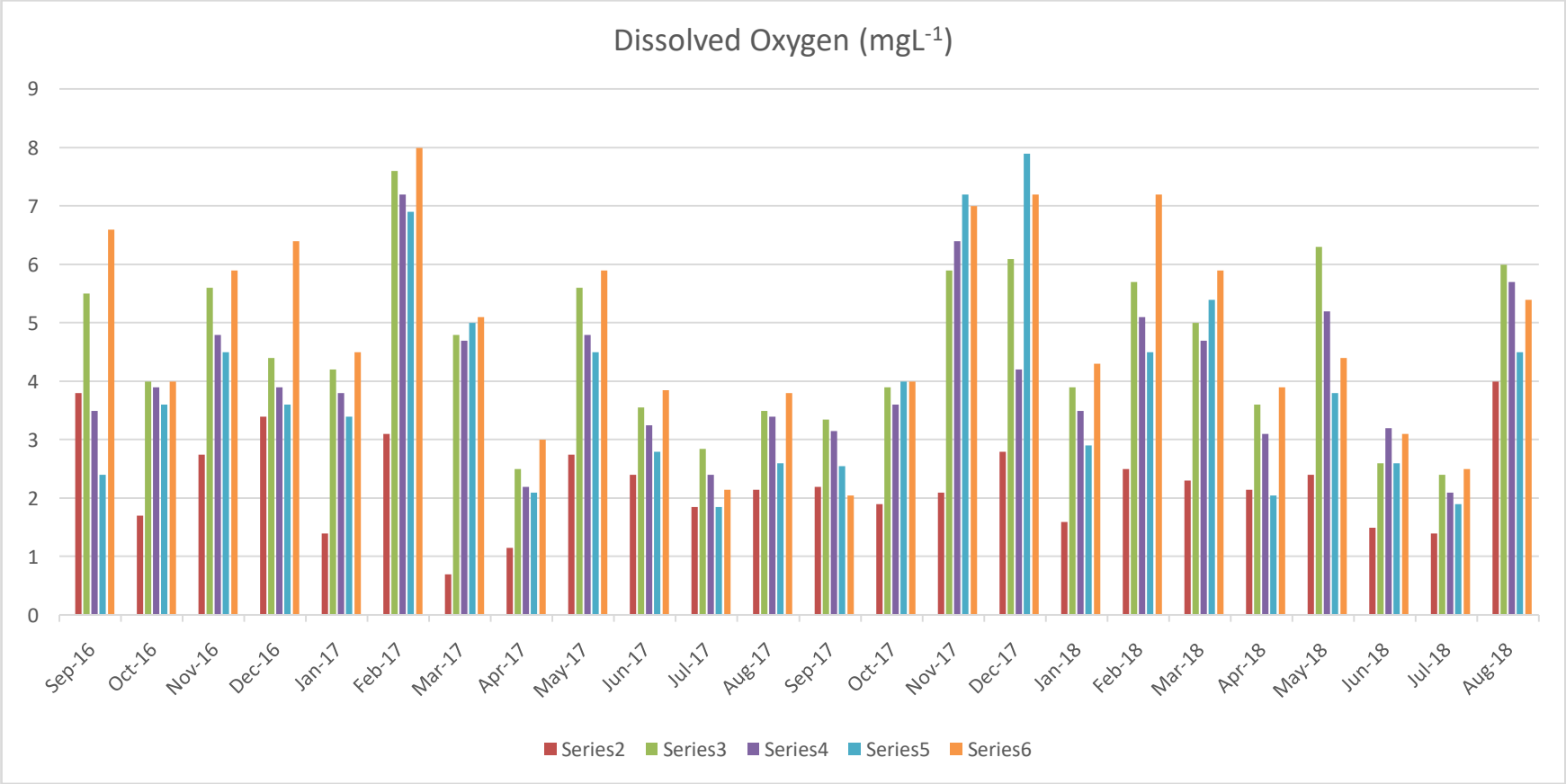
APPENDIX – XXXIII : Graph representing monthly variations of total hardness .



APPENDIX – XXXIV: Monthly variations of DO.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17
1	3.8	1.7	2.75	3.4	1.4	3.1	0.7	1.15	2.75	2.4	1.85	2.15	2.2	1.9	2.1	2.8	1.6	2.5	3.8	1.7	2.75	3.4	1.4	3.1
2	5.5	4	5.6	4.4	4.2	7.6	4.8	2.5	5.6	3.55	2.85	3.5	3.35	3.9	5.9	6.1	3.9	5.7	5.5	4	5.6	4.4	4.2	7.6
3	3.5	3.9	4.8	3.9	3.8	7.2	4.7	2.2	4.8	3.25	2.4	3.4	3.15	3.6	6.4	4.2	3.5	5.1	3.5	3.9	4.8	3.9	3.8	7.2
4	2.4	3.6	4.5	3.6	3.4	6.9	5	2.1	4.5	2.8	1.85	2.6	2.55	4	7.2	7.9	2.9	4.5	2.4	3.6	4.5	3.6	3.4	6.9
5	6.6	4	5.9	6.4	4.5	8	5.1	3	**5.9**	3.85	2.15	3.8	2.05	4	7	7.2	4.3	7.2	6.6	4	5.9	6.4	4.5	8

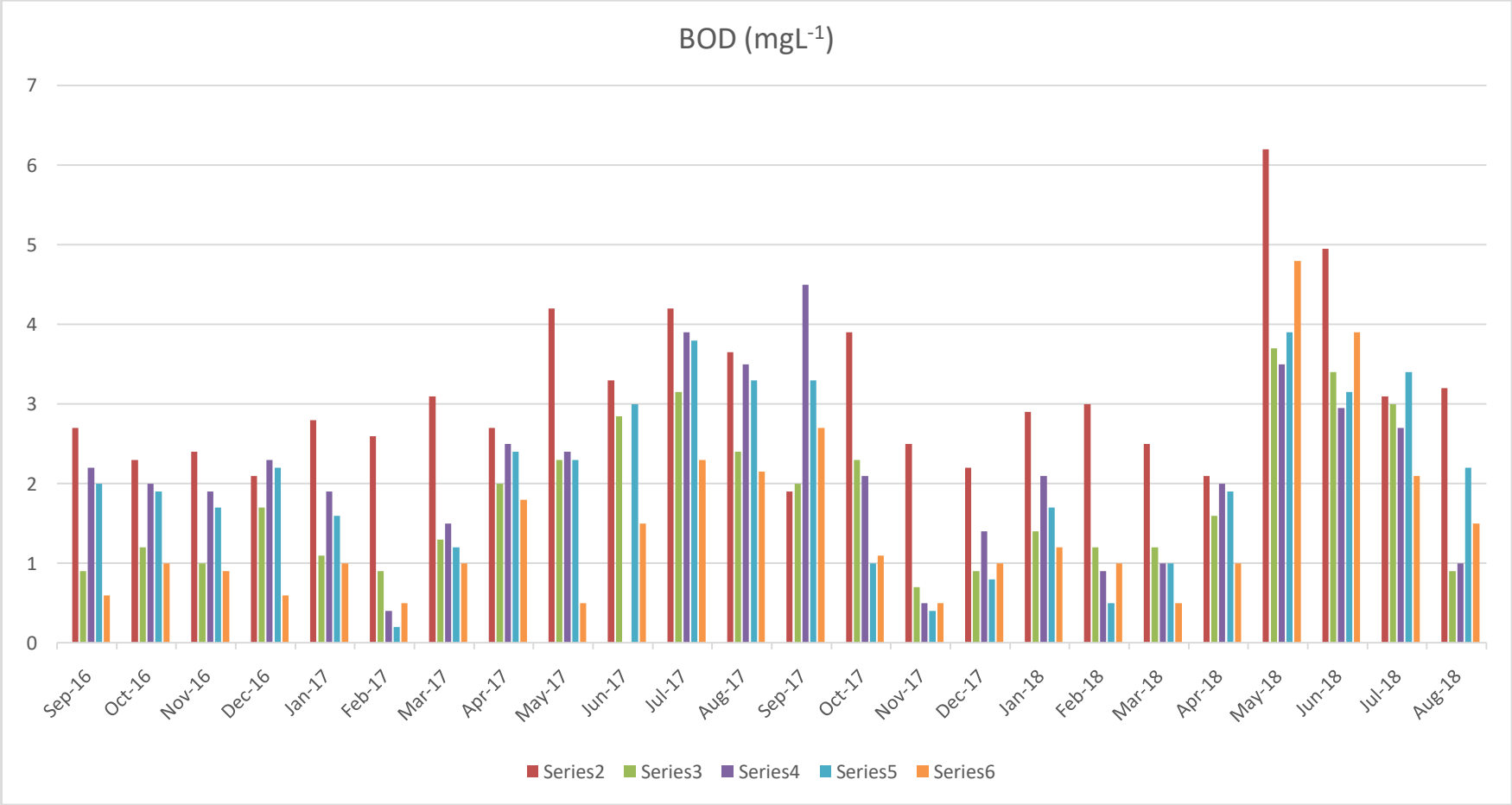
APPENDIX – XXXV: Graph representing monthly variations of DO.



APPENDIX – XXXVI : Monthly variations of BOD.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	2.7	2.3	2.4	2.1	2.8	2.6	3.1	2.7	4.2	3.3	4.2	3.65	1.9	3.9	2.5	2.2	2.9	3	2.5	2.1	6.2	4.95	3.1	3.2
2	0.9	1.2	1	1.7	1.1	0.9	1.3	2	2.3	2.85	3.15	2.4	2	2.3	0.7	0.9	1.4	1.2	1.2	1.6	3.7	3.4	3	0.9
3	2.2	2	1.9	2.3	1.9	0.4	1.5	2.5	2.4	3.05	3.9	3.5	4.5	2.1	0.5	1.4	2.1	0.9	1	2	3.5	2.95	2.7	1
4	2	1.9	1.7	2.2	1.6	0.2	1.2	2.4	2.3	3	3.8	3.3	3.3	1	0.4	0.8	1.7	0.5	1	1.9	3.9	3.15	3.4	2.2
5	0.6	1	0.9	0.6	1	0.5	1	1.8	0.5	1.5	2.3	2.15	2.7	1.1	0.5	1	1.2	1	0.5	1	4.8	3.9	2.1	1.5

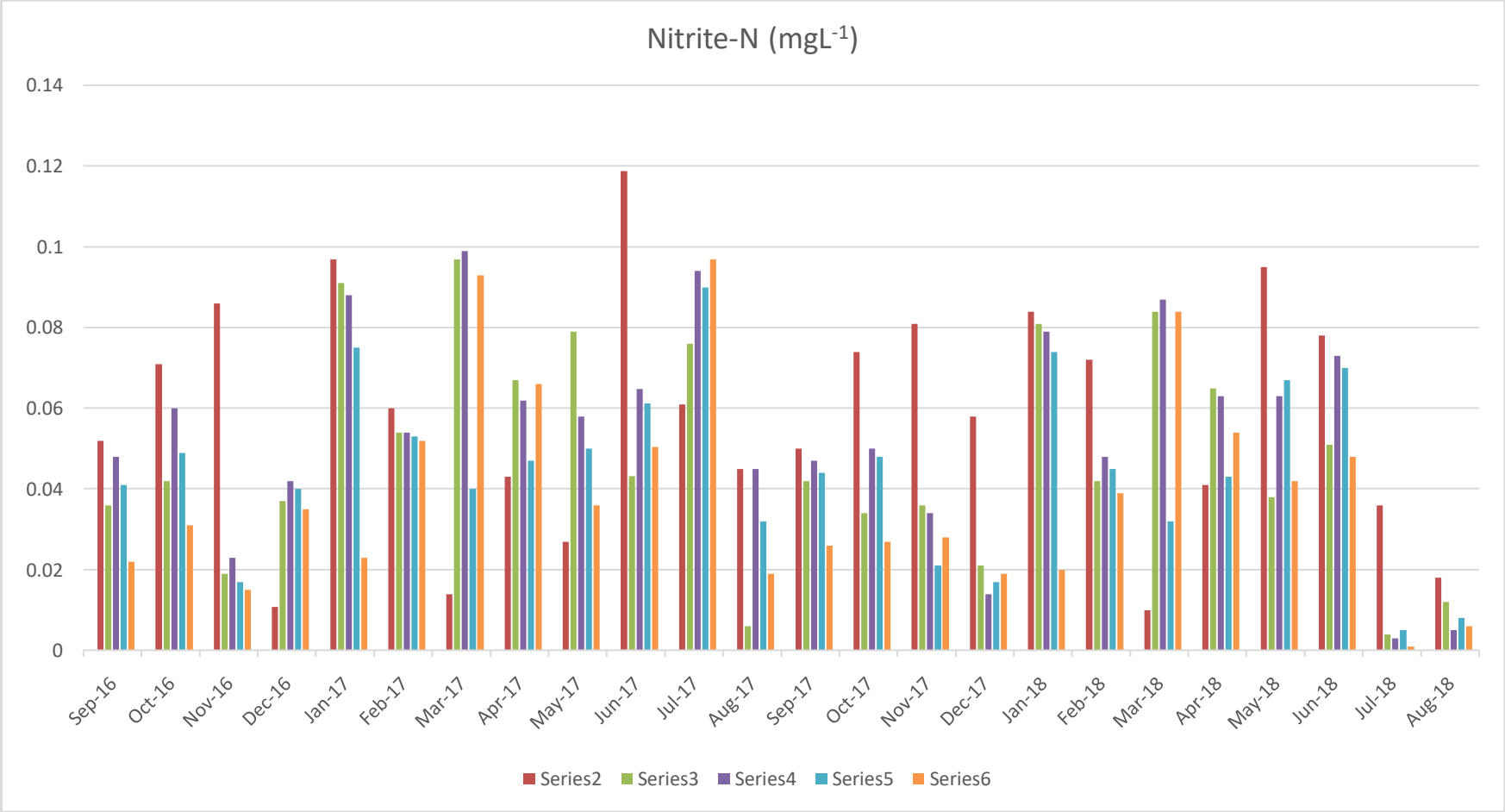
APPENDIX – XXXVII : Graph representing monthly variations of BOD.



APPENDIX – XXXVIII : Monthly variations of Nitrite-N.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	0.052	0.071	0.086	0.0108	0.097	0.06	0.014	0.043	0.027	0.1188	0.061	0.045	0.05	0.074	0.081	0.058	0.084	0.072	0.01	0.041	0.095	0.078	0.036	0.018
2	0.036	0.042	0.019	0.037	0.091	0.054	0.097	0.067	0.079	0.0432	0.076	0.006	0.042	0.034	0.036	0.021	0.081	0.042	0.084	0.065	0.038	0.051	0.04	0.012
3	0.048	0.06	0.023	0.042	0.088	0.054	0.099	0.062	0.058	0.0648	0.094	0.045	0.047	0.05	0.034	0.014	0.079	0.048	0.087	0.063	0.063	0.073	0.03	0.005
4	0.041	0.049	0.017	0.04	0.075	0.053	0.04	0.047	0.05	0.0612	0.09	0.032	0.044	0.048	0.021	0.017	0.074	0.045	0.032	0.043	0.067	0.07	0.05	0.008
5	0.022	0.031	0.015	0.035	0.023	0.052	0.093	0.066	0.036	0.0504	0.097	0.019	0.026	0.027	0.028	0.019	0.02	0.039	0.084	0.054	0.042	0.048	0.01	0.006

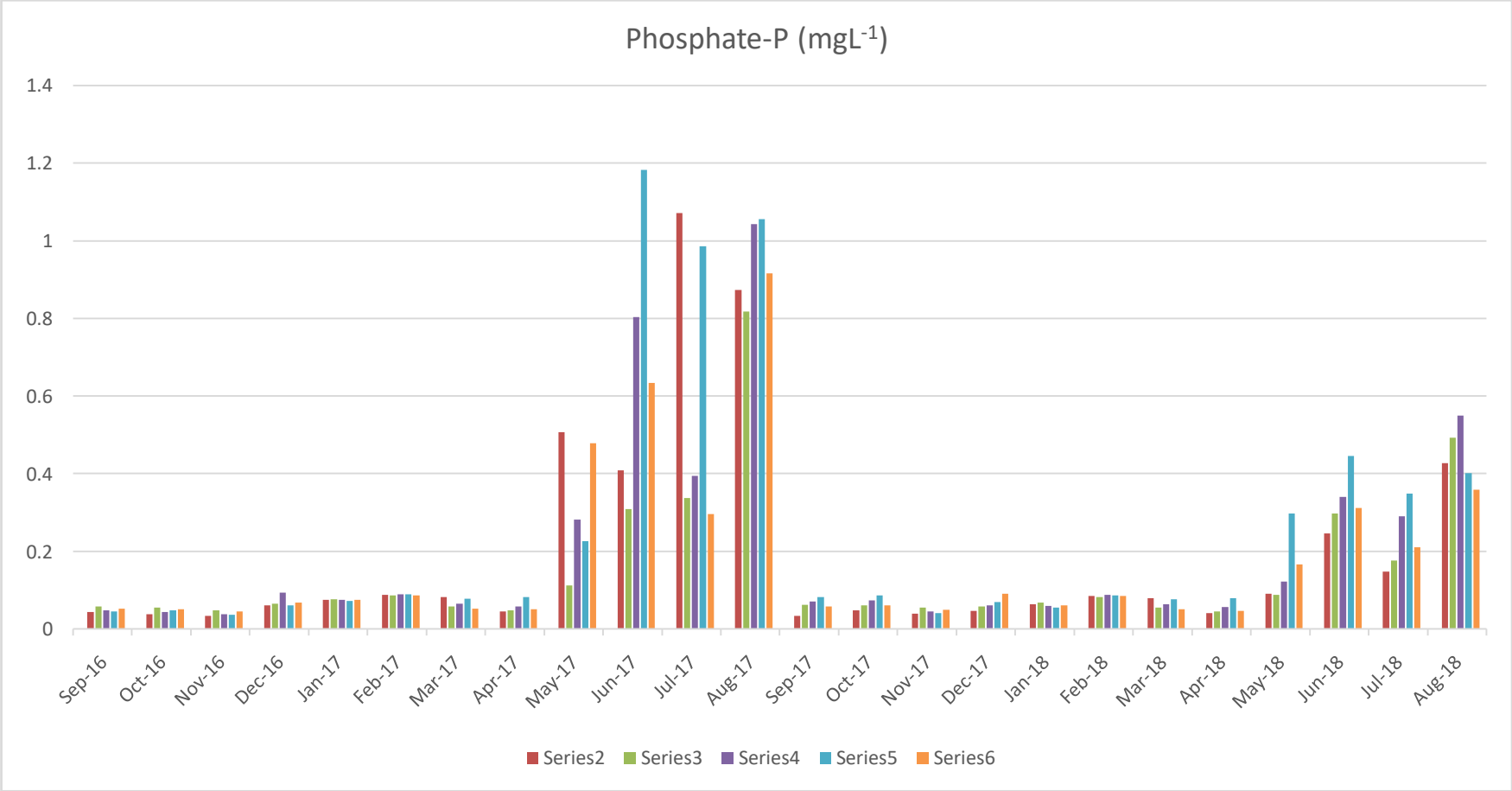
APPENDIX – XXXIX : Graph representing monthly variations of Nitrite-N.



APPENDIX – XL : Monthly variations of Phosphate-P.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	0.044	0.039	0.034	0.061	0.076	0.089	0.082	0.045	0.508	0.409	1.072	0.874	0.034	0.049	0.04	0.047	0.064	0.085	0.08	0.042	0.091	0.246	0.148	0.427
2	0.059	0.055	0.049	0.066	0.077	0.087	0.059	0.049	0.113	0.31	0.338	0.818	0.063	0.061	0.056	0.059	0.069	0.082	0.055	0.045	0.089	0.298	0.177	0.493
3	0.049	0.044	0.039	0.094	0.075	0.09	0.065	0.059	0.282	0.804	0.395	1.043	0.071	0.074	0.045	0.061	0.06	0.089	0.064	0.057	0.122	0.341	0.291	0.55
4	0.046	0.048	0.037	0.061	0.072	0.09	0.079	0.082	0.226	1.184	0.987	1.057	0.083	0.087	0.042	0.07	0.056	0.087	0.077	0.08	0.298	0.446	0.35	0.402
5	0.053	0.052	0.045	0.068	0.075	0.087	0.053	0.052	0.479	0.634	0.296	0.916	0.059	0.062	0.05	0.091	0.062	0.085	0.051	0.047	0.167	0.312	0.211	0.359

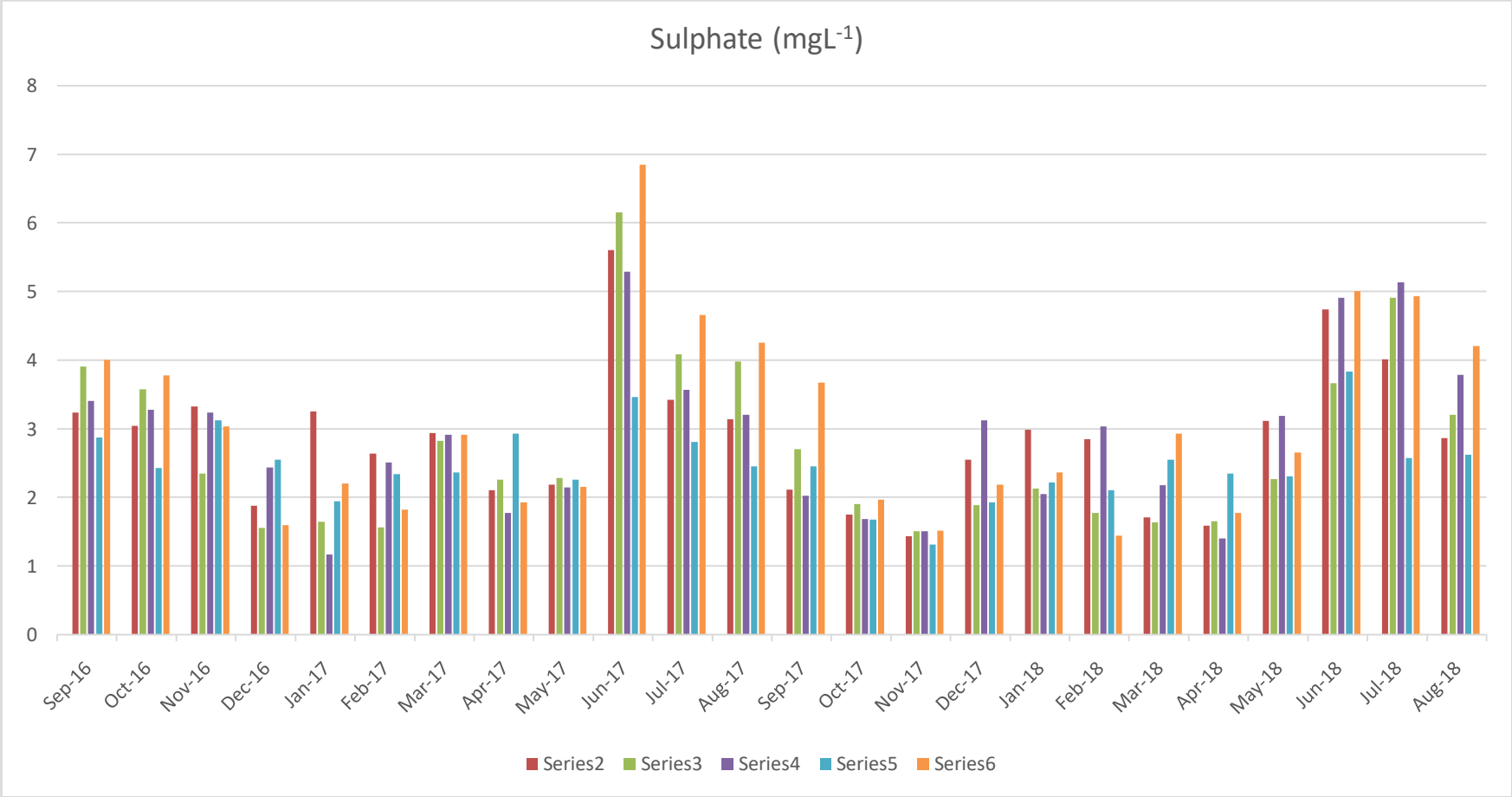
APPENDIX – XLI : Graph representing monthly variations of Phosphate-P.



APPENDIX – XLII : Monthly variations of sulphate.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	3.24	3.05	3.33	1.88	3.26	2.64	2.94	2.11	2.19	5.61	3.43	3.14	2.12	1.75	1.44	2.55	2.99	2.85	1.71	1.59	3.12	4.74	4.02	2.87
2	3.91	3.58	2.35	1.56	1.65	1.57	2.83	2.26	2.29	6.16	4.09	3.98	2.71	1.91	1.51	1.89	2.13	1.78	1.64	1.66	2.27	3.67	4.91	3.21
3	3.41	3.28	3.24	2.44	1.17	2.51	2.92	1.78	2.15	5.29	3.57	3.21	2.03	1.69	1.51	3.13	2.05	3.04	2.18	1.41	3.19	4.91	5.14	3.79
4	2.88	2.43	3.13	2.55	1.95	2.34	2.37	2.93	2.26	3.47	2.81	2.46	2.46	1.68	1.32	1.93	2.22	2.11	2.55	2.35	2.31	3.84	2.58	2.63
5	4.01	3.78	3.04	1.6	2.21	1.83	2.92	1.93	2.16	6.85	4.66	4.26	3.68	1.97	1.52	2.19	2.37	1.45	2.93	1.78	2.66	5.01	4.94	4.21

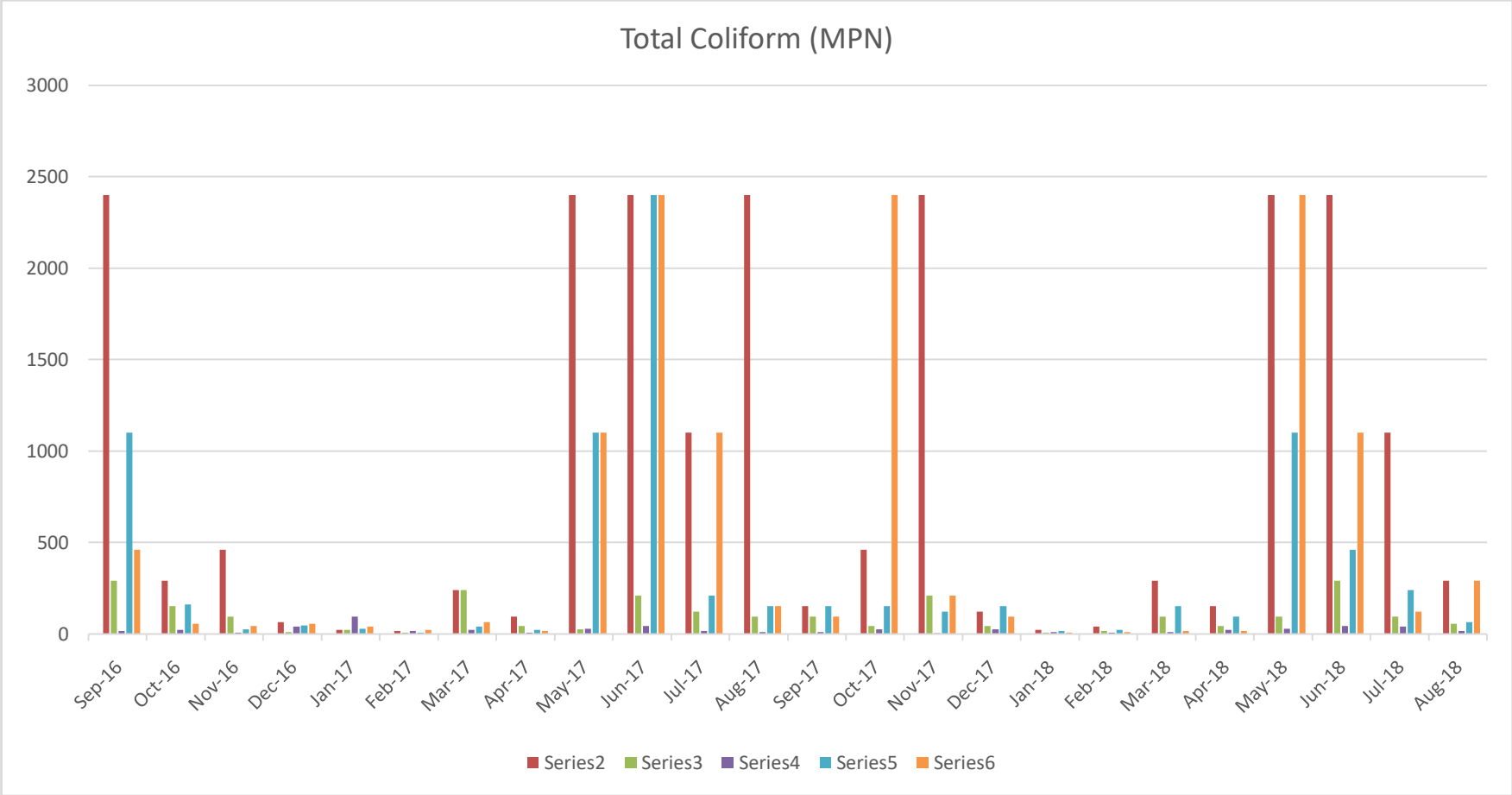
APPENDIX – XLIII : Graph representing monthly variations of sulphate.



APPENDIX – XLIV : Monthly variations of total coliform.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	2400	290	460	64	20	15	240	93	2400	2400	1100	2400	150	460	2400	120	21	39	290	150	2400	2400	1100	290
2	290	150	93	9.1	21	7.3	240	43	23	210	120	93	93	43	210	43	7.3	15	93	42	93	290	93	53
3	15	20	7.3	39	93	15	21	7.3	28	42	15	9.1	9.1	23	3.6	23	9.1	7.3	9.1	21	28	42	39	15
4	1100	160	24	44	28	7.3	39	21	1100	2400	210	150	150	150	120	150	15	20	150	93	1100	460	240	64
5	460	53	42	53	39	20	64	16	1100	2400	1100	150	93	2400	210	93	7.3	9.1	15	15	2400	1100	120	290

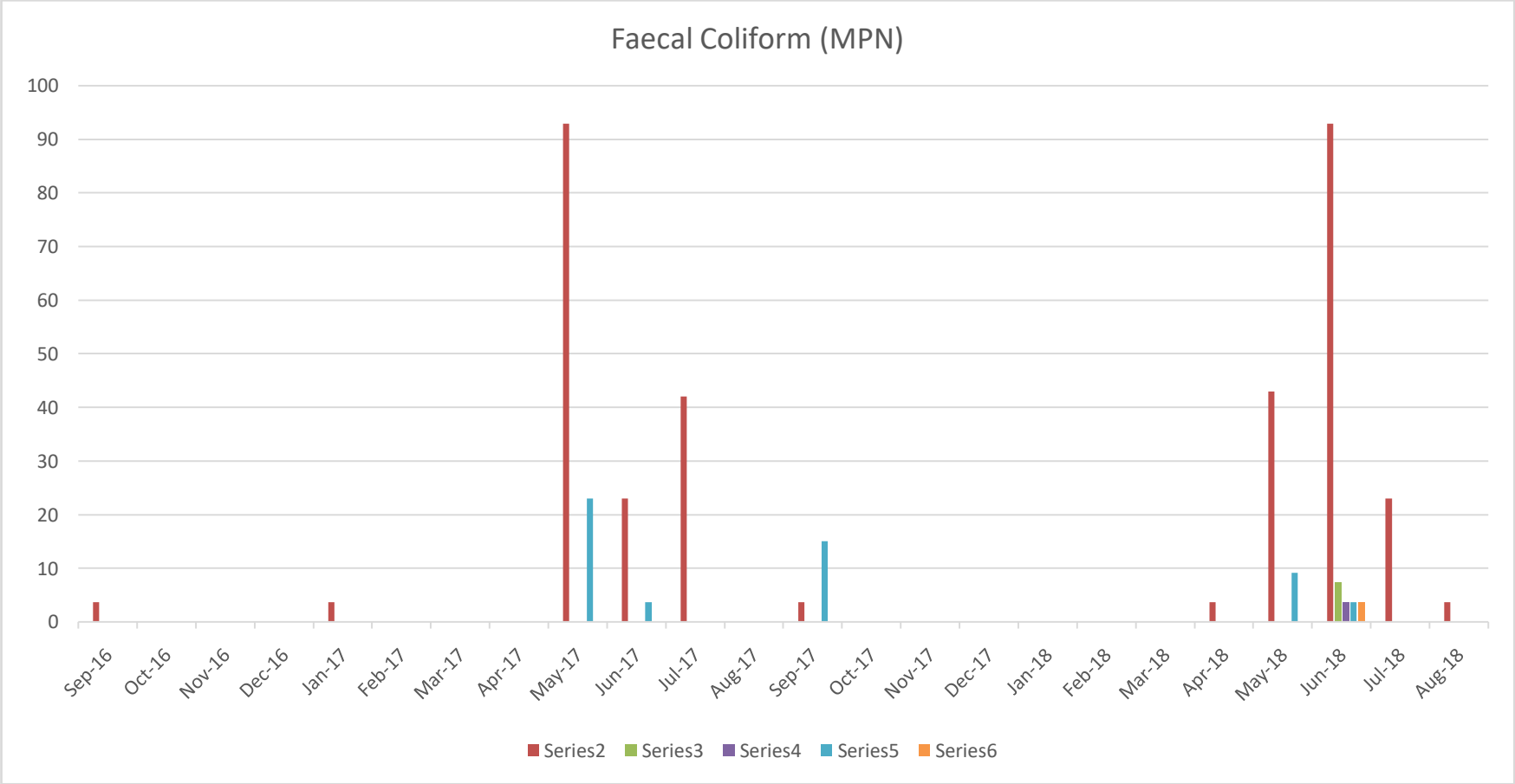
APPENDIX – XLV : Graph representing monthly variations of total coliform.



APPENDIX – XLVI : Monthly variations of faecal coliform.

Samples	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18
1	3.6	0	0	0	3.6	0	0	0	93	23	42	0	3.6	0	0	0	0	0	0	3.6	43	93	23	3.6
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.3	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0
4	0	0	0	0	0	0	0	0	23	3.6	0	0	15	0	0	0	0	0	0	0	9.1	3.6	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0

APPENDIX – XLVII : Graph representing monthly variations of faecal coliform.



BIODATA

NAME : SABRINA LALHMANGAIHZUALI,
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TITLE OF THESIS: "STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM".

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

JOINT SUPERVISOR: PROF. H. LALRAMNGHINGLOVA, DEPARTMENT OF ENVIRONMENTAL SCIENCE, MIZORAM UNIVERSITY

PARTICIPATION IN WORKSHOP/SYMPOSIUM/ SEMINAR/TRAINING :

1) Participated on "One Day Workshop on EIA" jointly organized by State Environmental Impact Assessment Authority and State Environmental Expert Appraisal Committee, Aizawl, Mizoram at Aijal club, Aizawl on the 11th November, 2016.
2) Participated on "International Workshop and training on hydro-meteorological monitoring and watershed management" jointly organized by Mizoram University, University of Minessota and Mississippi Watershed Management Organization during 23rd – 25th October, 2017.
3) Attended and completed certificate course on "Pollution Monitoring: Air and Water Pollution" Under Green Skill Development Programme of the Ministry of Environment, Forest and Climate Change, Govt. Of India, New Delhi at ENVIS Hub during 3rd September – 7th November 2018
4) Attended training on "HYDRO-METEOROLOGICAL AND WATER RESOURCES MONITORING AND WATERSHED MODELLING AND

MANAGEMENT" jointly organized by Irrigation & Water Resources Department, Govt. Of Mizoram and Mizoram University during 19th – 21st March, 2019.

PRESENTED PAPERS:

1) Presented poster presentation entitled "Study on total and faecal coliform in perennial spring water within Aizawl city, Mizoram" and was conferred Best Poster Award in "Regional Seminar on Climate Change: Impact, Adaptation and Response in the Eastern Himalayas" jointly organized by the Department of Environmental Science, Mizoram University and IHCAP- Indian Himalayas Climate Adaptation Programme during 1st – 2nd November, 2018
2) Presented oral presentation entitled "Detailed Assessment of Total and Faecal Coliform in Perennial Spring Water in and around Aizawl City, Mizoram" in the 12th Annual Convention of Association of Biotechnology and Pharmacy(ABAP) and International Conference on Biodiversity, Environment and Human Health: Innovations and Emerging Trends (BEHIET 2018) jointly organized by Shool of Life Sciences, Mizoram University and Association of Biotechnology and Pharmacy (ABAP), India during 12th – 14th November, 2018.
3) Presented a paper entitled "Assessment of Physico-Chemical Properties of Perennial Spring Water in and Around Aizawl City, Mizoram" in "The International Conference on Chemistry & Environmental Sustainability (ICCES- 2019)" organized by the Department of Chemistry, Mizoram University during 19th – 22nd February, 2019.

PAPER PUBLICATIONS:

1) Lalhmangaihzuali, S., Lalramnghinglova, H. And Mishra, B.P. (2019). Assessment of total and faecal coliform in perennial spring water in and around Aizawl city, Mizoram . *Journal of Emerging Technologies and Innovative Research.*,6(6): 677-681.

2) Lalhmangaihzuali, S., Lalramnghinglova, H. And Mishra, B.P. (2019). Detail Assessment of Physico-Chemical Properties of Perennial Spring Water within Aizawl City, Mizoram. *Rsearch Review International Journal of Multidisciplinary.,* 4(10): 51-56.

PERSONAL DETAILS :

i)	Date of birth	: 12th September, 1989
ii)	Father's Name	: Lalnuntluanga
iii)	Mother's Name	: Laltanpuii
iv)	Language	: English, Mizo
v)	Tribe	: Schedule Tribe
vi)	Nationality	: Indian
vii)	Religion	: Christian

DECLARATION:

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

(Sabrina Lalhmangaihzuali)

PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE	: SABRINA LALHMANGAIHZUALI
DEGREE	: Doctor of Philosophy
DEPARTMENT	: ENVIRONMENTAL SCIENCE
TITLE OF THESIS	: "STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM"
DATE OF ADMISSION	: 26th May, 2016

APPROVAL OF RESEARCH PROPOSAL

1) DRC	: 31st March, 2016
2) BOS	: 7th April, 2016
3) SCHOOL BOARD	: 13th April, 2016
MZU REGISTRATION	: 197 of 2013
REGISTRATION NO. & DATE	: MZU/ Ph.D/ 901 of 13.04.2016

Head
Department of Environmental Science
Mizoram University
Aizawl

ASSESSMENT OF TOTAL AND FAECAL COLIFORM IN PERENNIAL SPRING WATER IN AIZAWL CITY, MIZORAM

[1]Sabrina Lalhmangaihzuali, [2]H. Lalramnghinglova and [3]B. P. Mishra
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Department of Environmental Science
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Abstract:

Coliform bacteria have been used to evaluate the general quality of water. Analysis of coliforms in perennial spring water from five areas in Aizawl city (viz., North zone –Bawngkawn Tuikhur, Central zone - Zotui, Electric Veng, East zone –Theihai Tuikhurarmed veng , South zone – SailoTui, Mission Veng, West zone – Vantlang Tuikhur, Govt. Complex) was done to assess the quality of the spring water throughout the year and possible risks from consumption by people living in the nearby locality. Coliform bacteria originate as organisms in soil or vegetation and in the intestinal tract of warm – blooded animals. Bacteria reproduce rapidly if conditions are right for growth. MPN method was used to determine the most probable number of bacteria from the various sites selected in and around Aizawl city. The water samples are incubated separately in a media at a different temperatures and is left for over a night at different temperatures. In north zone maximum MPN of total coliform was found in the month may whereas the minimum was found in the month of December. In central zone maximum MPN was found in the month of October and minimum was found in May. In east zone maximum was found in jan and minimum in November and april. In south zone maximum was found in June whereas minimum was found in February. In west zone maximum was found in july and minimum was found in month of april. Faecal coliform was absent in most of the months accept in May, September and October in all sites.

Keywords: Total coliform, faecal coliform, perennial spring water, Aizawl City.

I. INTRODUCTION:

Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material. The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply. A. Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. B. Faecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and faeces of warm-blooded animals. Because the origins of faecal coliforms are more specific than the origins of the more general total coliform group of bacteria, faecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms. The presence of *E. coli* in water indicates that the water was contaminated by faecal pollution of human or other warm-blooded animals. (An *et al.,* 2002). Total coliforms and *E.* coli, the most common member of faecal coliform bacteria, are the important microbiological parameters of water quality (Dufour, 1977) Testing for bacteria is the only reliable way to know if your water is safe. You cannot tell by the look, taste, or smell of the water if disease-causing organisms are in it. The New York State Department of Health recommends that well owners test their water for coliform bacteria at least once a year.

Natural spring waters originate from groundwater and are usually rich in minerals such as calcium, magnesium, and potassium (Cabassud *et al.,2001; Leclerc and Moreau, 2002).*

Water pollution caused by faecal contamination is a serious problem due to the potential for contracting diseases from pathogens (disease causing organisms). In waters of the U.S., Canada and other countries, water quality is monitored to protect the health of the general public. Bacteria contamination is one monitored pollutant. In the U.S., faecal coliform testing is one of the nine tests of water quality that form the overall water-quality rating in a process used by U.S. EPA. The faecal coliform assay should only be used to assess the presence of faecal matter in situations where faecal coliforms of non-faecal origin are not commonly encountered (Doyle *et al.,* 2006). EPA has approved a number of different methods to analyse samples for bacteria (USEPA, 2008). Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens. As a result, testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present.

Total coliforms and E. coli are used as indicators to measure the degree of pollution and sanitary quality of well water, because testing for all known pathogens is a complicated and expensive process. (Facts on drinking water). The main source of pathogens in drinking water is through recent contamination from human or animal waste, from improperly treated septic and sewage discharges, leaching of animal manure, storm water runoff and domestic animals or wildlife.

During and after precipitation, bacteria and other harmful microorganisms from any of these sources may be washed into rivers, lakes, or groundwater. Poor well construction or poor maintenance can increase the risk of groundwater contamination Shukla *et.al* 1992.

The presence of E. coli in water indicated that the water was contaminated by faecal material of humans or other warm – blooded animals. The U.S. Environmental Protection Agency (EPA) recommended that E. coli is a better indicator if faecal pollution than faecal coliform for purposes of evaluating ambient fresh water quality (USEPA, 1986. Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available (1). Most probable number (MPN) is a typical test for fecal coliform (Mengesha *et al*., 2004).

II. RESEARCH METHODOLOGY

2.1. Description of study area/sites:

Aizawl is the capital of the state of Mizoram in India. It is the largest city in the state. Aizawl is located north of the Tropic of Cancer in the northern part of Mizoram. It is situated on a ridge 1,132 metres (3715 ft) above sea level, with the Tlawng river valley to its west and the Tuirial river valley to its east. As of 2011 India census, Aizawl had a population of 293,416. Females constitute 50.61% of the population and males made up the remaining 49.39%.

For detailed investigation, a total of 5 strings within the Aizawl city were selected in different locations (i.e., (one site each in North, East,West , South and Central zone).

Site 1: BawngkawnTuikhur (Near Bezalel Workshop) in North zone, with coordinates - N 23˚45'16.7"; E 092˚43'41.0".

Site 2: TheihaiTuikhur, AremdVeng in East zone, with coordinates - N 23˚44'16.0" E 092˚43'14.6"

Site 3: Public Tuikhur, Govt. Complex (Beside Public Step), with coordinates - N 23˚43'50.5"; E 092˚41'39.3"

Site 4: SailoTui, Mission Veng in South zone, with coordinates - N 23˚43'08.6"; E 092˚42'54.6"

Site 5: Central - Zotui, Electric Veng (Near ESRA Drug Store) in central zone, with coordinates - N 23˚44'25.0"; E 092˚43'05.5"

2.2. Materials and method

Collection of water:

The water samples were collected from selected sites at monthly interval (in triplicate), and brought to the laboratory for analysis.

2.3. Preparation of medium:

2.3.1. MacConkey Broth:
a) Single strength: 34.51g of MacConkey Broth was suspended in 1000ml distilled water.
b) Double strength: 69.02g of MacConkey Broth was suspended in 1000ml distilled water.

2.3.2. Brilliant Green Bile Broth: 40.01g of Brilliant Green Bile Broth was suspended in 1000ml distilled water.

2.3.4. EC Broth: 37.0g of EC Broth was suspended in 1000ml of distilled water.

2.4. Presumption Test:

i. Three rows of three tubes each were arranged and labelled in the test tube racks. First row was labelled as F1 and second and third rows was labelled F2 and F3 respectively.
   a) F1 contain 10ml of double strength of MacConkey Broth and inverted Durham's tube.
   b) F2 contain 10ml of single strength of MacConkey Broth and inverted Durham's tube.
   c) F3 contain 10ml of single strength of MacConkey Broth and inverted Durham's tube.
ii. With a sterile pipette 10ml of sample was added to each of the three F1 tube.
iii. With a sterile pipette 1ml of sample was added to each of the three F2 tube.
iv. 1:10 dilution of sample was prepared by adding 1ml of water sample to 9ml of sterile distilled water.
v. With a sterile pipette 10ml of 1:10 diluted sample was added to each of the three F3 tube.
vi. After gently shaking the tubes to mix the inoculum, the rack was incubated for 24hrs. at 35^0C for total coliform and 44^0C for faecal coliform.
vii. After 24hrs of incubation the test tube rack was taken out from the incubator and was left for few minutes to cool down.
viii. Few minutes later the tube was observed for separation. Tube that produced gas was separated from the tube that do not produce gas.
ix. Gas producing tube was taken in separate rack to undergo confirmatory test.

2.5. Confirmative Test:

i. From the gas producing tube, a loop full of broth was transferred to a confirmative broth.
ii. Brilliant Green Bile Broth was the broth used for confirmative test of total coliform and it was then incubated at 35^0C for 24hrs.
iii. EC Broth was used for confirmative test of faecal coliform. After loop transfer was done it was incubated at 44^0C for 24hrs.

iv. After 24hrs of incubation the presence of total and faecal coliform was confirmed if gas was in the confirmation broth.
v. The MPN of coliform was determined from the MPN log table.

III. RESULTS AND DISCUSSION:

The findings on Total Coliform and Faecal coliform counts are presented in Table 1 and 2. The total coliform count ranged between 7.3 MPN (February at site 2, November and April at site 3 and February at Site 4) to 2400 MPN (September, May, June and July at site 1, June at site 4 and June and August at Site 5). And the faecal coliform count if present in the water body ranged between 3(March in site1, October in site 3, April in site 4 and September and October in site 5) to 210 MPN (june at site 1).

At site 1 the maximum MPN of total coliforms count was during the months of May June and September with 2400 MPN and was minimum during the month of December with 14 MPN. And the maximum faecal coliforms was found during the month of june with value 210 MPN and it was minimum with 3MPN during the month of March

At site 2 the maximum MPN of total coliforms counts was found during the months of September and October with 290 MPN and minimum total coliforms count was found at the month of February with value 7.3MPN. And the maximum faecal coliforms was found during the month of june with value 15 MPN and it was minimum with 3.6 MPN during the month of September

At site 3 the maximum total coliforms count was found during the month of January and the value at this month was 93 MPN whereas the minimum value at the site was found in November and April and the value is 7.3 MPN. And the maximum faecal coliforms was found during the month of September and June with value 3.6 MPN and it was minimum with 3MPN during the month of October.

At site 4 the maximum MPN of total coliforms count was during the months of June with 2400 MPN and was minimum during the month of February with value 7.3 MPN. And the maximum faecal coliforms was found during the month of June with value 75 MPN and it was minimum with 3MPN during the month of April

At site site 5 the maximum MPN of total coliforms count was during the months of June and August with 2400 MPN and the minimum MPN was found during the month of April with 16 MPN. And the maximum faecal coliforms was found during the month of june with value 150 MPN and it was minimum with 3MPN during the month of September and October.

The presence of total and fecal coliform was highly accelerated during the month June when there was excessive rainfall. Other than site A all other sites are properly protected or are under constructed areas, but from the observation the protection do not completely prevent the entry of coliform to the water body although the protection and proper maintenance had prevent pollution at some level. Site A water which is located in open area has the highest MPN. Using of water that owes no threat to the consumer's health depends on continuous protection. Because of human frailty associated with protection, priority should be given to selection of the purest source. Polluted source should not be used unless other sources are economically unavailable. Ensuring bacteriological quality of drinking water sources is vital to public health function. On the other hand regular examination of water quality for the presence of organisms remain the most sensitive way of assessing the hygienic conditions of water (World Health Organization 2003).

table 1: monthly variations of total coliform counts in the five study sites.

Sites	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17
1	2400	150	24	14	20	15	240	93	2400	2400	1100	150
2	290	290	93	9.1	21	7.3	240	43	23	210	120	93
3	15	20	7.3	39	93	15	21	7.3	28	42	15	9.1
4	1100	160	460	44	28	7.3	39	21	1100	2400	210	150
5	460	53	42	53	39	20	64	16	1100	2400	1100	2400

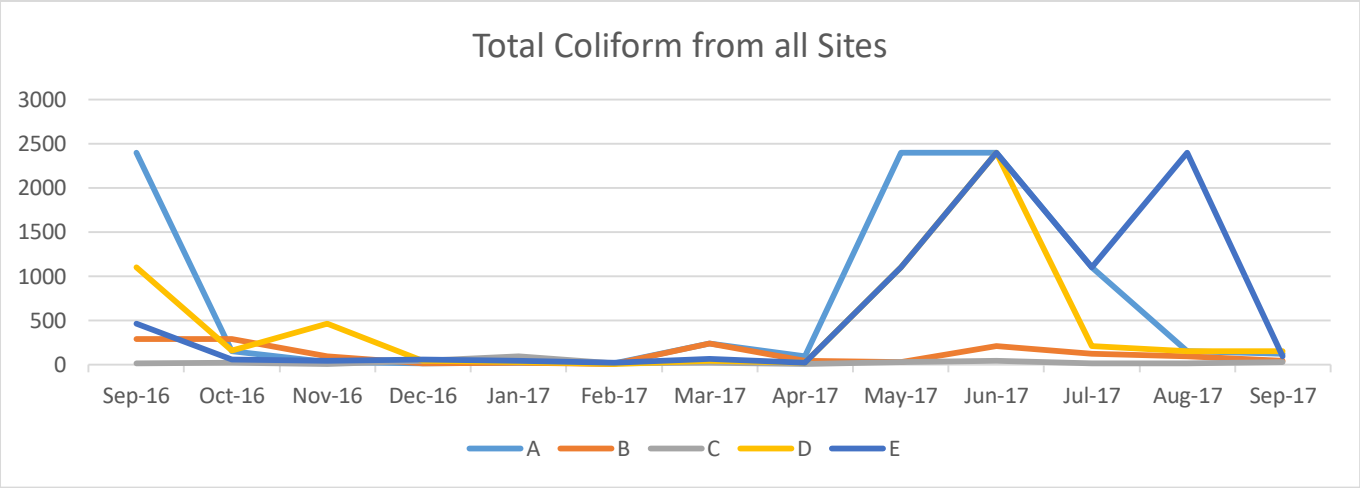

fig. 1: graphical representation of total coliform present from site 1, 2, 3, 4 and 5

table 2: monthly variations of faecal coliform counts in the five study sites.

Sites	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17
1	(6.2) 7	0	0	0	0	0	3	3.6	0	210	3.6	0
2	3.6	0	0	0	0	0	0	0	0	15	0	0
3	3.6	3	0	0	0	0	0	0	0	3.6	0	0
4	0	0	0	0	0	0	0	3	0	75	0	0
5	3	3	0	0	0	0	0	0	0	150	0	0

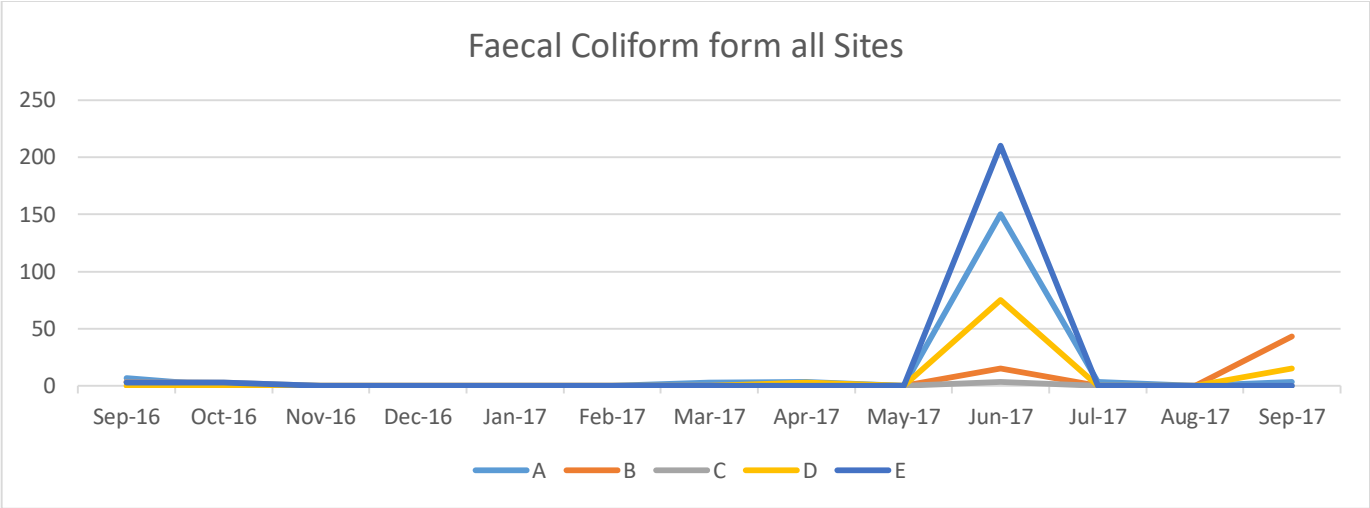

fig. 2: graphical representation of faecal coliform present from site 1, 2, 3, 4 and 5

IV. CONCLUSIONS:

In conclusion, majority of the water resources had unacceptable total coliform counts and faecal contamination during midyear at some study sites and if the water resources were tend to consume for drinking purpose it is highly recommended to treat the water for disinfection and periodic bacteriological appraisal of drinking water sources. The open spring water where there is no protective measures taken in the area the water is highly contaminated comparing to the water under constructed or protected areas. The contamination is also due to the leakage of sewage and improper drainage system of the houses near by the water resources. So in conclusion proper protection of the spring water where it was collected, proper drainage system as well as effluent discharging pipeline from every household could help in maintaining the water quality.

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Detail Assessment of Physico-Chemical Properties of Perennial Spring Water within Aizawl City, Mizoram

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ABSTRACT

Water quality is the term used to express the suitability of water to sustain various uses or processes. Earth's water resources, including rivers, lakes, oceans, and underground aquifers, are under stress in many regions. Humans need water for drinking, sanitation, agriculture and industry; and contaminated water can spread illness and disease vectors, so clean water quality is both an environmental and a public health issue. Nowadays fresh water depend solely on letter physico chemical conditions. Analysis of physico chemical parameters of water is therefore essential, as it has great bearing on the explanation of metabolism of the aquatic ecosystem. So five perennial spring water sites were selected for sampling and analysis where most of the local people at the nearby locality consume the water for different household purposes in the north, east, west, south and central zone of Aizawl city. Six physico-chemical properties were selected for determining the quality of the water. Acidity was found highest in west and north zone and was minimum at the central zone of Aizawl. It was observed that water in all sites were highly turbid during the month of July 2017 and was most turbid in the north zone where the spring water in this area remain unprotected. The maximum dissolved oxygen value was found in the west zone on February 2017 throughout the sampling period where Biological Oxygen Demand was found to be highest in the north zone of Aizawl during the month of July 2017.

1. Introduction

Spring is a point where water flows out of the ground or any natural situation where water flows from an aquifer to the earth's surface. It is a component of the hydrosphere. A spring may flow the whole year or only sometimes. This depends on the water getting into the ground all of the time. A spring water may be the result of karst topography where surface water has infiltrated the Earth's surface, becoming part of the area groundwater. Perennial water resources is a water that has continuous presence in its bed all year round during years of normal rainfall. Perennial water body usually refers to mainly liquid fresh water, as opposed to intermittent or periodic water. Most water bodies vary in fullness according to the season, and according to the heaviness of precipitation and other factors during any given year. Also, the water level in many such water bodies as do not actually dry out, may nonetheless drop so drastically that their surface area is greatly reduced. They even may be split into several separate water bodies with dry land between, either arid or covered with vegetation. The internal ecology of such water may differ drastically between periods of drought and deep water(Lake,2011).

The groundwater eventually emerges from below the surface. The forcing of the spring to the surface can be the result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation than that of the outlet. The natural outputs from groundwater are springs and seepage to the oceans. (*Gleeson et al.,2012.)* Safe drinking water is essential to humans and other lifeforms even though it provides no calories or organic nutrients. (United States Geological Survey,2009). The quality of life is linked with the quality of environment,hence the biological components of fresh water depend solely on letters physico-chemical conditions. Analysis of physico-chemical parameters of water is therefore essential, as it has great bearing on the explanation of metabolism of the aquatic ecosystem.

1.1 Literature review:

The sensitivity of a water resource system to climate change is a function of several physical features and, importantly, societal characteristics. There are several indicators of water resource stress, including the amount of water available per person and the ratio of volume of water withdrawn to volume of water potentially available (Falkenmark and Lindh, 1976). It is difficult to draw quantitative conclusions about the impacts of climate change, for several reasons. Our analysis places particular priority on the characterisation of water scarcity in low- income countries of the tropic where the consequences of water scarcity are projected to be most severe (Jimenez-Cisneros et al. 2014) and where most of the global population now live (Gerland et al. 2014).

In countries where freshwater resources are scarce and under pressure, the assessment of freshwater resources is often complemented by an assessment of the available brackish water that can be used for specific purposes (desalination, some types of agricultural production) (Shiklomanov,1997).

The main water resources in Mizoram is the numerous perennial springs and the rivers. The groundwater resource is also utilized wherever possible. As per the census of India 2001, only 5% of the rural households enjoy water supply within their premises and about 75% of the households get water from their near premises. For majority of the households 47% the main source of water is spring water. In the state the

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gravity-based schemes are successful and sustainable. The hand pumps are not working properly and there are instances of excess iron from the hand pump. (Upadhyay and Lalroneiha 2014).

2. Methodology

Site selection: Pre-survey was done within Aizawl city and the list of water resources was short listed to five where one each of perennial spring water from five different zones was selected.

2.1 Description of study area/sites

Aizawl is the capital of the state of Mizoram in India. It is the largest city in the state. Aizawl is located north of the Tropic of Cancer in the northern part of Mizoram. It is situated on a ridge 1,132 metres (3715 ft) above sea level, with the Tlawng river valley to its west and the Tuirial river valley to its east. As of 2011 India census, Aizawl had a population of 293,416. Females constitute 50.61% of the population and males made up the remaining 49.39%.

For detailed investigation, a total of 5 strings within the Aizawl city were selected in different locations (i.e., (one site each in North, East,West , South and Central zone).

Site 1: BawngkawnTuikhur (Near Bezalel Workshop) in North zone, with coordinates - N 23˚45'16.7"; E 092˚43'41.0".
Site 2: TheihaiTuikhur, AremdVeng in East zone, with coordinates - N 23˚44'16.0" E 092˚43'14.6"
Site 3: Public Tuikhur, Govt. Complex (Beside Public Step), with coordinates - N 23˚43'50.5"; E 092˚41'39.3"
Site 4: SailoTui, Mission Veng in South zone, with coordinates - N 23˚43'08.6"; E 092˚42'54.6"
Site 5: Central - Zotui, Electric Veng (Near ESRA Drug Store) in central zone, with coordinates - N 23˚44'25.0"; E 092˚43'05.5" .

2.2 Sampling Method:

Sample was collected every 3rd week of the month between 7:00 AM – 10:00 AM by using sterilized sample glass bottles and were immediately covered and placed in a zip pouch for prevention of any bacterial contamination from outside environment and immediately taken to the laboratory for analysis.

Collection of water : Water collected by using specified sterilized sample bottles. Analysis of water.

2.3 Analytical Method:

2.3.1 Turbidity – for determining turbidity of the various water sample Nephelometer or turbidity meter was used which measures the intensity of light scattered at 90 degrees.

2.3.2 Oxidation reduction potential – Redox potential instruments are used to measure the oxidation reduction potential or the ability of a solution to act as an oxidizing agent, and to quantify the ion activity.

2.3.3 pH – A scientific instrument called pH meter was used to measure the hydrogen ion activity in water-based expressed as pH.

2.3.4 Acidity - Potentiometric titration method was used for determining the acidity of water sample where phenolphthalein was the indicator used and NaOH was the titrant used for analysis.

2.3.5 Alkalinity - Potentiometric titration method was used for determining the alkalinity of water sample. Methyl orange was the indicator used and 0.02N H_2SO_4 was the titrant used for titration method.

2.3.6 Dissolved oxygen - Winkler's iodide azide modified method was used for determining the dissolve oxygen content of water samples. 1ml of $MnSO_4$ followed by 1ml of alkali-iodide-azide reagent upto the brim was added to the water samples and after 30 minutes 2ml of conc. H_2SO_4 was added. 100ml of this solution was taken in a conical flask and 2 – 3 drops of starch indicator was added.The solution will then be titrated against Sodium thiosulphate solution (0.025N) till the blue color turns colourless.

2.3.7 Biological oxygen demand - for determining the biological oxygen demand Winkler's iodide azide modified method was used. The procedure employed for the analysis of biological oxygen demand was exactly the same as that of the procedure in dissolve oxygen determination but after 5 days incubation.

3. Results and conclusion

- A tables and graphical representation of the water samples for each parameters analysed are given in the above figures.
- In oxidation reduction potential the less contamination in the water the higher the value of ORP. The value of ORP was found to be highest in August 2017 at the east site i.e. 106.7 mV and the least value which is 12mV was found during May 2017 in central zone of Aizawl city.
- The samples were most turbid during the month of July 2017 and the highest value was found in the north zone where the water system was left uncovered and makes the water most turbid comparing to the other areas.
- pH was found to be neutral in all the sites. pH value was found maximum during the month of May 2017 and the minimum value was found in Aug. 2017
- The maximum dissolved oxygen value was found in the West zone throughout the sampling period with highest value of 8mg/l, whereas biological oxygen demand was found to be the highest in the north zone comparing to the other four sites and the maximum value was seen in July 2017.
- Alkalinity, which is the capacity of water to resist changes in pH that would make the water more acidic was found highest in January 2017 in the north zone and was lowest in September 2018 in the south site.

Acidity were found to be highest in west and north zone site of Aizawl city and reached the value up to 94 mg/l in December 2016 in the north zone and the minimum value was found in the central zone throughout the year. The least value of acidity was found to be 4mg/l in April 2017.

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Table 1: Oxidation reduction potential

Samples	Sept 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug 2017
A- North	68.4	71.3	60	58	57	65	68	68	35	43.1	67	81.3
B-Central	62.1	59	27	12	14	13	37	33	12	67.3	72	89.8
C-East	78	55	80	87	71	54	84	98	60	79.9	80	106.7
D-South	63.5	49	67	76	70	42	64	88	58	66.5	80	90.4
E-West	66	62.4	40	71	63	55	72	82	41	63.7	80	89

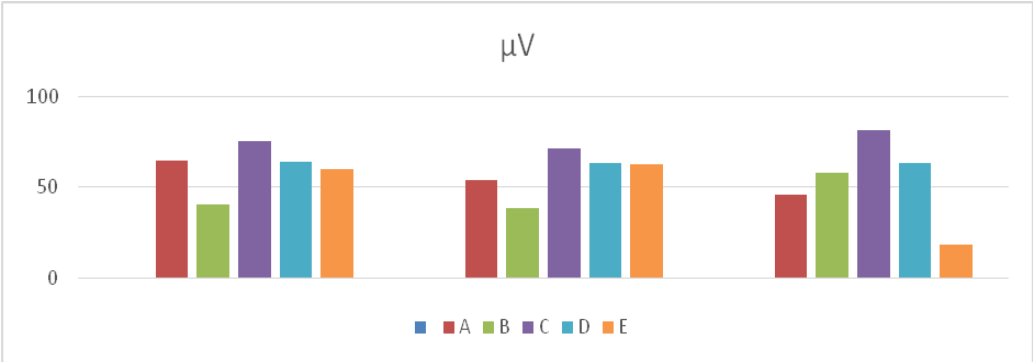

Fig. 1: Graphical representation of Oxidation reduction potential-µV

Table 2: Turbidity

Samples	Sept 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug 2017
A- North	1.3	0.9	0.7	0.6	0.6	0.4	0.3	0.4	0.9	0.9	2.3	0.5
B-Central	0.9	0.7	0.3	0.2	0.3	0.1	0.1	0.1	0.6	0.6	1.3	0.8
C-East	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.0	0.5	0.5	0.3	0.7
D-South	0.1	0.1	0.1	0.1	0.2	0.3	1.0	0.4	0.9	0.9	1.5	0.6
E-West	0.1	0.3	0.6	0.4	0.3	0.2	0.2	0.2	0.6	0.6	0.3	0.6

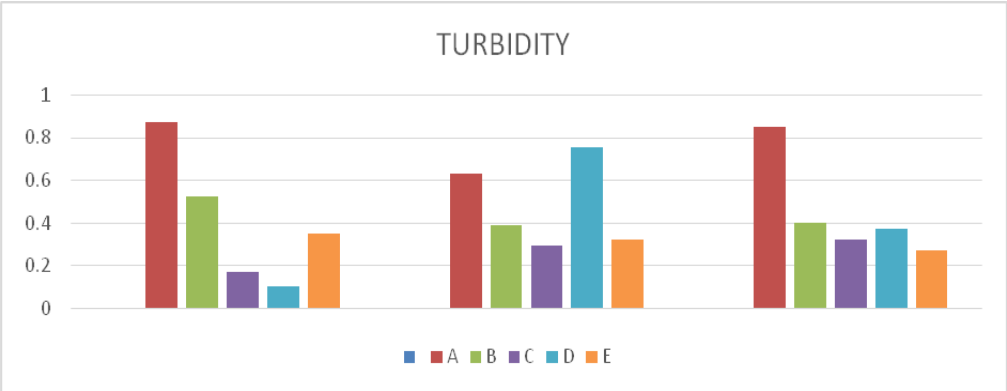

Fig. 2: Graphical representation of Turbidity

Table 3: pH

Samples	Sept 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug 2017
A- North	5.53	5.91	6.02	6.11	6.13	6.32	5.92	5.93	6.4	5.84	6.03	5.64
B-Central	5.82	6.04	6.57	6.87	6.84	6.97	6.45	6.53	**6.9**	5.43	5.99	5.50
C-East	5.11	6.10	5.67	5.64	5.89	6.05	5.63	5.45	6	**5.21**	5.83	**5.21**
D-South	5.50	6.25	5.99	5.82	5.91	6.10	5.85	5.62	6.1	5.44	5.86	5.49
E-West	5.44	5.99	6.17	5.88	6.03	6.33	5.85	5.74	6.2	5.50	5.81	5.51

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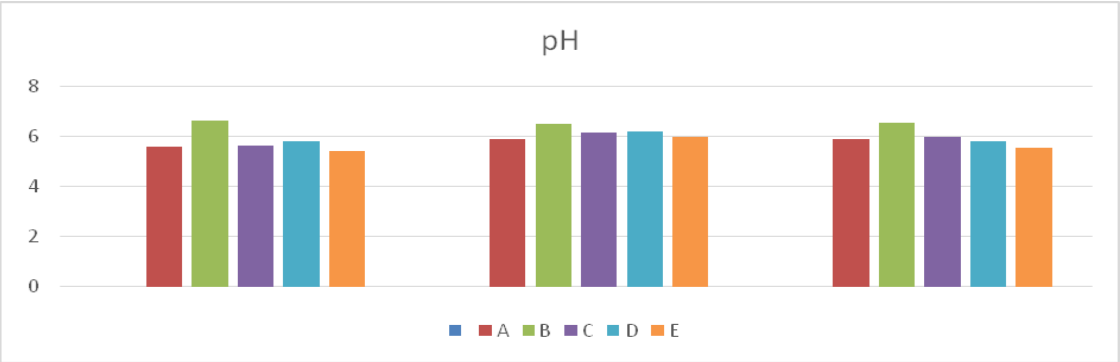

Fig. 3: Graphical representation of pH

Table 4: Dissolve Oxygen

SAMPLE	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug. 2017
A- North	3.8	1.7	2.75	3.4	1.4	3.1	0.7	1.15	2.75	2.4	1.85	2.15
B-Central	5.5	4	5.6	4.4	4.2	7.6	4.8	2.5	5.6	3.55	2.85	3.5
C-East	3.5	3.9	4.8	3.9	3.8	7.2	4.7	2.2	4.8	3.25	2.4	3.4
D-South	2.4	3.6	4.5	3.6	3.4	6.9	5	2.1	4.5	2.8	1.85	2.6
E-West	6.6	4	5.9	6.4	4.5	8.0	5.1	3.0	**5.9**	3.85	2.15	3.8

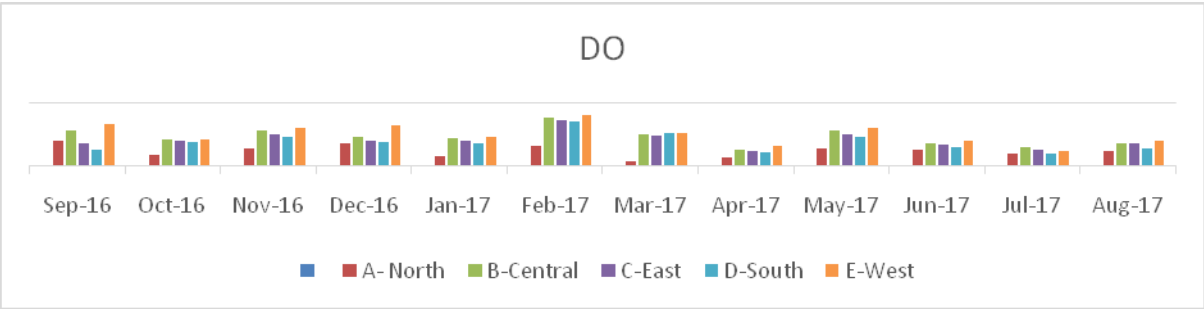

Fig. 4: Graphical representation of Dissolve oxygen

Table 5: Biological Oxygen Demand

Samples	Sept 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug 2017
A- North	2.7	2.3	2.4	2.1	2.8	2.6	3.1	2.7	3.2	3.3	4.2	3.65
B-Central	0.9	1.2	1.0	1.7	1.1	0.9	1.3	2.0	2.3	2.85	3.15	2.4
C-East	2.2	2	1.9	2.3	1.9	0.4	1.5	2.5	2.4	3. 05	3.9	3.5
D-South	2	1.9	1.7	2.2	1.6	0.2	1.2	2.4	2.3	3	3.8	3.3
E-West	0.6	1	0.9	0.6	1.0	0.5	1.0	1.8	0.5	1.5	2.3	2.15

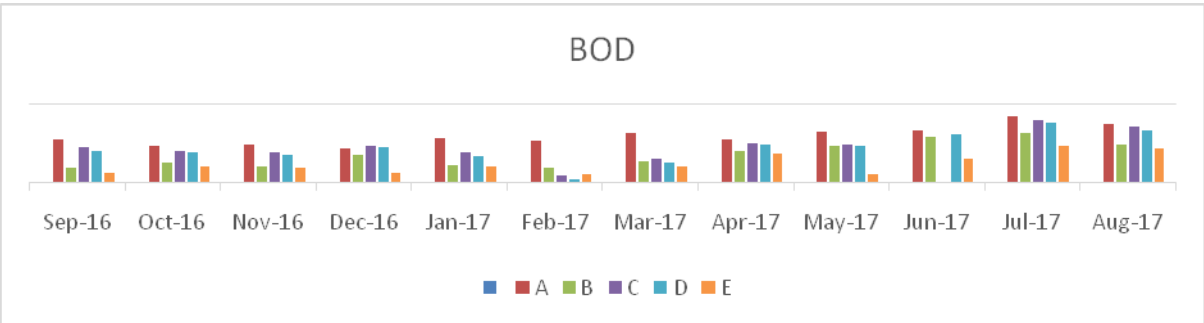

Fig. 5: Graphical representation of Biological oxygen demand

Table 6: Alkalinity

SAMPLE	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug. 2017
A- North	54	44	62	78	99	67	68	40	24	27.6	23	16
B-Central	26	25	16	17	6	12	19	10	13	12.6	10	9.5
C-East	24	33	26	27	21	25	23	18	5	14.3	8.5	9.5
D-South	3	37	40	38	41	32	31	29	10	17	14	11.5
E-West	34	41	48	54	68	54	44	38	12	18	14.5	12

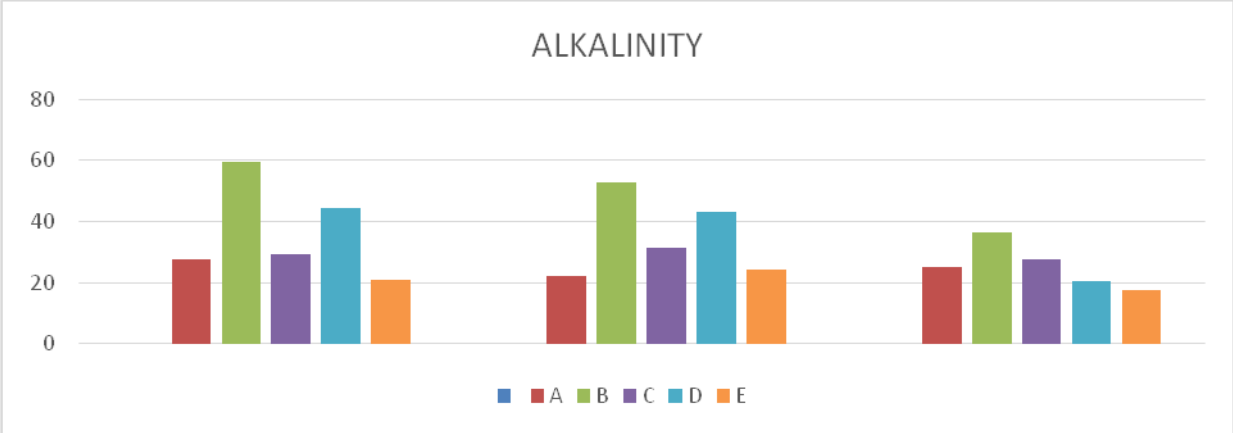

Fig. 6: Graphical representation of Alkalinity

Table 7: Acidity

SAMPLE	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	March 2017	April 2017	May 2017	June 2017	July 2017	Aug. 2017
A- North	63	61	64	94	53	31	92	28	21.5	42	59.5	93.5
B-Central	14	11	5	14	5	3	12	4	5	21	13.5	47
C-East	53	47	35	60	46	12	36	14	16.5	25	34.5	63
D-South	48	40	31	61	51	9	28	11	18.5	26.5	43	63.5
E-West	72	64	40	81	63	41	47	19	23	29	52	69.5

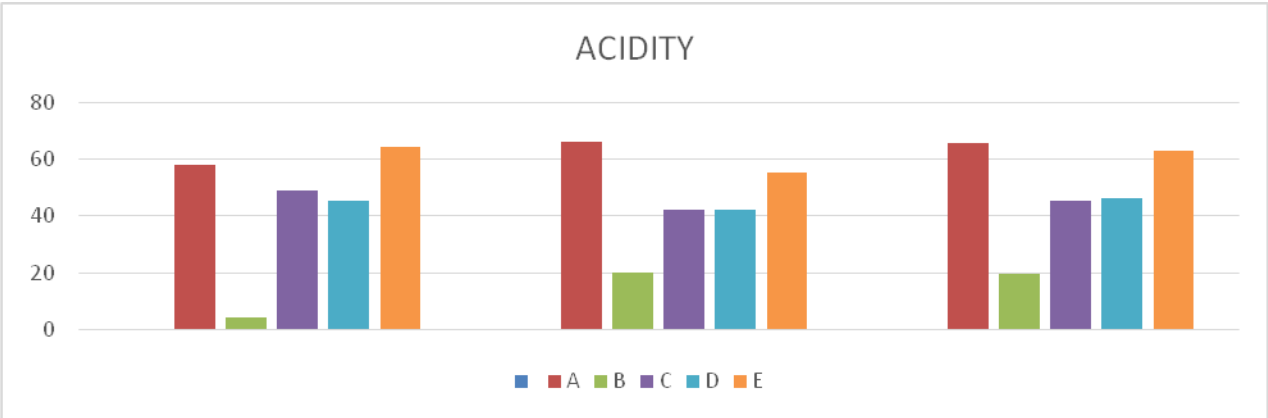

Fig. 7: Graphical representation of Acidity

4. Conclusion

It can be concluded that the water samples that has been studied bears a good water quality and were all remain below their permissible limits for each particular parameters. But for drinking purposes the water required treatment for purification. So we can declare the spring water selected for qualitative analysis was good enough for consumption of household purposes if not for drinking purposes.

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(ABSTRACT)

STUDY OF WATER RESOURCES AND QUALITY ASSESSMENT OF PERENNIAL WATER IN AND AROUND AIZAWL CITY, MIZORAM

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

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ABSTRACT

Water is one of the most precious elements of nature, sustaining the mother Earth and her inhabitants in every form of life. Rivers have proved as supports for nurturing civilization, agricultural activities, and trade and commerce. Water and life are intricately linked, and water is the main constituent of human body making up to 80% of the body weight and is the medium for all metabolic activities. More than half of the world's species of plants and animals live in water, and even our terrestrial-derived food is totally dependent on water and often largely composed of water. Water is needed not only for drinking purpose, but also for production of food. Water is also used to generate electricity, for navigation, and also for leisure.

Water is constantly being recycled in a system known as either the water cycle or more correctly the hydrological cycle (storage, distribution and movement of water). Water may be stored temporarily in the ground, oceans, lakes, rivers, icecaps and glaciers. It evaporates from the earth's surface, condenses in clouds, falls back to the earth as precipitation (rain or snow) and eventually either runs into the seas or re-evaporates into the atmosphere. While the total volume of water in the world remains constant, its quality and availability varies significantly.

Availability of water depends on withdrawal for consumptive and non-consumptive uses. In terms of quality, water bodies get polluted from industrial effluents and municipal wastewater, runoff from chemical fertilizers and pesticides, oil and lube spillages. Water quality also depends on effluent types and discharge quantity from different pollution sources and seasonal water flow and also dilution capacity by the water body system.

The concept of water resources is multidimensional. It is not limited only to its physical measure (hydrological and hydrogeological), the 'flows and stocks', but encompasses other more qualitative, environmental and socio-economic dimensions. Fresh water (both surface and ground water) is the central of three dimensions of sustainable development – social, economic and environmental. Clean water and healthy fresh water ecosystems provide the basic goods and services upon which

many livelihoods depend, from irrigation water to creating fertile floodplains for grazing. According to UN agriculture report on water and livelihoods, about 75% of the world's poorest people live in rural areas across the world and for them, water access can literally mean the difference between life and death. Spring is a point where water flows out of the ground or any natural situation where water flows from an aquifer to the earth's surface. It is a component of the hydrosphere. A spring may flow the whole year or only sometimes. This depends on the water getting into the ground all of the time.

In Mizoram, the major rivers flow either northerly or southerly creating deep gorges between the N-S trending hill ranges. The major drainage pattern of the tributaries and streamlets are angular, sub parallel and dendritic. The main drainage system of the state has a straight flow regime. The main factor influencing Mizoram's water cycle is southwest monsoon. Most of the rivers in Mizoram originate in the central part of the state and flow either towards north or south, directed by the north-south trending ridges.

Water from natural sources invariably contains some ingredients, which are referred to as impurities. The sources of pollutant bearing waste water are:(a) storm and run-off water (b) domestic, institutional and municipal effluents and (c) industrial effluents. Many water bodies have been used for the purpose of disposal of sewage and other wastes. They can assimilate wastes to a certain degree and restore its quality before becoming polluted. However, with the advent of industrialization, urbanization and increased human interference, its self-purification power is diminished, leading to water pollution, a problem of great biological, technological and sociological complexity. Water pollution is one of the most serious environmental problems in India. The main sources of potable water in Mizoram are river water, groundwater and spring water; and also rainwater during monsoon. Most of the water consumed in Mizoram is untreated raw water obtained from one or more sources mentioned above. Treated water is available to the small section of society only, and that also only in the state capital, Aizawl city, and a few other district headquarters. The potential sources of pollutants in Mizoram are:

1. Natural sources (atmospheric, dissolved minerals, decay of vegetation, aquatic growths, storm runoff). 2. Agricultural sources (increased soil erosion,

animal wastes, fertilizers, pesticides). 3. Solid waste and waste waters (municipal sanitary sewage, municipal storm runoff, domestic wastes).

Even though the state of Mizoram is a non-industrialized zone, dissolved minerals and organic wastes, municipal and domestic wastes, agricultural runoff are posing severe threats on the quality, quantity and sustainability to the availability of fresh water in the state. Major portion of municipal, domestic, agricultural and other wastes are directly or indirectly discharged into water bodies situated in the vicinity, as neither proper liquid nor solid waste management system has been developed yet in the state. Because of this, there isan urgent need to determine the status of water quality as well as to develop appropriate and effective water management strategies. For sustainable water resources management, two management actions are needed, namely, the quantitative potential of water resources and the reduction of pollution for restoration of water quality. The scientific and holistic water management depends upon the availability of comprehensive and authentic data on both quantitative and qualitative aspects of water resources, and on the nature and magnitude of anthropogenic activities in the catchment area. Hence, in order to bring out the physical, chemical and biological properties of perennial spring water in Aizawl and to suggest appreciable water management initiatives, the present study has been carried out on five different sites, where one site each was selected from the north, east, west, south and central zone of Aizawl city during the year 2016-2018 .

The major objectives of the study envisage the followings:

1. To survey and describe water resources in and around Aizawl city.
2. To analyze the physical and chemical characteristics of selected perennial spring water.
3. Strategies for better management options and utility.

For detailed investigation, following study sites were selected:

Sampling Sites	Zone of sampling sites	Coordinates	Location
Site-1	North	N23˚45'16.7" E 092˚43'41.0"	BawngkawnTuikhur, Bawngkawn
Site-2	Central	N 23˚44'25.0" E092˚43'05.5"	Zotui, Electric Veng (Near ESRA Drug Store)
Site-3	East	N23˚44'16.0" E092˚43'14.6"	TheihaiTuikhur, AremdVeng
Site-4	South	N 23˚43'08.6" E092˚42'54.6"	SailoTui,MissionVeng
Site-5	West	N 23˚43'50.5" E092˚41'39.3"	Public Tuikhur, Govt. Complex

The methods as outlined in the Standard Methods for the Examination of Water and Wastewater as prescribed by the American Public Health Association (APHA, 2005) were adopted for analysis of water quality attributes. The water samples were collected (in triplicate) from selected study sites at monthly interval for two consecutive years (September, 2016 to August, 2018) for analysis of various physico-chemical and bacteriological characteristics. The study period was divided into three seasons i.e., pre-monsoon, monsoon and post-monsoon. To check the validity and significance of the observed data, operation of statistical data analysis was carried out.

In order to study the water resources in and around Aizawl city, survey method was employed. It was found that there are three types of water resources which are spring water, ground water and river. Zone wise survey was conducted and it was found that there are 27 water resources found so far in the north zone, 10 in the east zone, 34 in west zone and 10 in south zone. Out of total 81 water resources found 16 resources are perennial in nature whereas the rest 65 are seasonal.

To study the water quality of five selected sites, 15 parameters were analyzed. All the data except dissolved oxygen, biological oxygen demand and total coliforms were within the permissible limits given by various scientific agencies. Statistical analysis was done to find correlation between each parameters as well as significant change between different seasons. The observation on the studied water quality parameters were as follows:

1. The value of temperature varied from 19.2 ^{o}C to 23 ^{o}C during the study period. It was high during monsoon and post monsoon season where as lower during pre-monsoon season. Water temperature was mainly depended on the surface temperature. Temperature has great effect on the metabolic activities of aquatic organism. High value of temperature can disrupts the dissolved oxygen of the water body.
2. During the study period the turbidity values range from 0 NTU to 2.3 NTU, maximum value was observed during monsoon season and minimum during pre-monsoon season. The value of turbidity was affected by run-off and sedimentation from the surface during rainy seasons. High turbidity value makes the water unfit for consumption and can eradicate the photosynthetic activity inside the water body by reducing intensity of sunlight.
3. The pH values of the study range from 5.84 to 6.79 during the study period. This shows that the water quality in acidic in nature. Minimum values were found during monsoon season and maximum during pre-monsoon and post-monsoon season. pH of the water body is mainly depend on the surface soil quality. Rain water is acidic which neutralize the alkalinity of the water body.

4. During the study period the oxidation reduction potential varied from 12µV to 97.9 µV. Maximum values were found at monsoon season and minimum at pre-monsoon season. The oxidation reduction potential value was affected by different solids dissolved in water which enters through run-off from the surrounding areas. High oxidation reduction potential may indicate more sediments and minerals in the water body.
5. The value of acidity ranges from 22 mg/l to 116mg/l. the maximum value was during post monsoon season and minimum during pre-monsoon season. The acidity of surface water is mainly due to carbonic acid dissolved in the water body from bicarbonates containing materials and also from free carbon dioxide in the surface and water body. The free carbon dioxide dissolved in the water in the processed of condensation. High acidity in the water may corrode other substances and may also disrupt some aquatic micro and macro organisms.
6. During the study period the value of alkalinity ranges from 2mg/l to 140 mg/l. The value of alkalinity was found to be higher during pre-monsoon season and low during monsoon season. Alkalinity was mainly due to hydroxyl ions and bicarbonates present in the water body, the value of alkalinity lower during monsoon could be due dilution of these ions by rain water in the water bodies which is acidic that neutralize the alkaline molecules.
7. Chloride is the naturally occurring chemical in rocks and soil. The value of chloride in the study sites carried from 21.493 mg/l to 394.88 mg/l chloride value was higher during rainy seasons and there is only little difference compared to different seasons which shows that chloride do not enter to water body from run-off and other sources. High amount of chloride in water body may affect the taste of the water body.
8. The total hardness of the study site during the study period ranges from 53 mg/l to 246 mg/l. the value of alkalinity is more or less constant throughout every season. But there is a great difference in different sites. It is caused mainly due to the presence of calcium and magnesium ions which are naturally present in rocks and soils. Total hardness may not be included in

water pollutants but high hardness in water caused economic hardships and may also results in bad taste of the water.

9. The dissolved oxygen valued varied from 0.7 mg/l to 5.9 mg/l during the study period, most of the sites at different seasons were under permissible limits which are mainly 4-6 mg/l. The amount of dissolved oxygen was found to be higher during pre-monsoon season where water temperature is lower, this may be due to decreased of metabolic reaction of aerobic organisms which lower the rate of respiration. Low level of dissolved oxygen indicates high population of microorganisms in the water body.
10. The biological oxygen demand of the study site values ranges from 0.5 mg/l to 4.95 mg/l during the study period. The value was found to higher during monsoon season where temperature was raised in every site which is due to increased metabolic reaction that intense the rate of respiration. The increased value of biological oxygen demand may indicate high aerobic microbial population. The permissible limits for biological oxygen demand shows that the amount should be always less than 3 mg/l for drinking water.
11. The nitrite value rage from 0.001 mg/l to 0.097 mg/l during the study period. It was higher during pre-monsoon season and lower during monsoon season in most of the study sites. This is due to dilution of nitrite ions by rain water in monsoon seasons and the amount of nitrate ions enters into the water body during rainy seasons get convert into nitrite ions which is concentrated in the water body during pre-monsoon season as a result of fewer water through this period. Consumption of high level of nitrite in water bodies is unfit for drinking purposes as it can affect health especially on infants and children.
12. During the study period the phosphate content of different study sites ranges from 0.034 mg/l to 1.184 mg/l. the value of phosphate was observed to be high during monsoon season and low during pre- monsoon and post-monsoon season. The amount of phosphate in natural water is greatly affected by human activities like consumption of chemical fertilizers in agriculture and decomposition of organic wastes. From the observation it is clear that phosphate ions enter to water bodies from surface through leaching due rainy season.

13. The amount of sulphate in different site varied from 1.32 mg/l to 6.85 mg/l during the study period. The maximum value was observed during monsoon season and minimum during pre-monsoon season. The observation shows that there is only trace amount of sulphate content in all the study site due to absence industrial region near the surrounding areas and it is clear that the sulphate present in water body of the selected sites were formed only from natural oxidation process.
14. The total coliform value of the study sites ranges from 3.6 mg/l to 2400 mg/l during the study period. The maximum value was observed during monsoon and post-monsoon season and lower during pre-monsoon season. From the observation it is clear that the total coliform was affect by domestic waste leaching from the surrounding areas. High amount of total coliform may indicate the presence of pathogenic microorganisms. It is unsafe to consume water having high total coliform values as it can result different water borne diseases.
15. During the study period the fecal coliform value ranges from 0 mg/l to 93 mg/l in the study sites. The value was observed to be high during monsoon season and low during pre-monsoon and post-monsoon season. The fecal coliform was mainly produced from feces of human and animals. The elevated value during monsoon season could be due to leaching of fecal waste from the surrounding areas especially from septic tank and from pigs sty in which their excreta are openly disposed in the surface of the surrounding areas. The amount of feacal coliform should always be zero for drinking water as their presence indicates existence of pathogenic microorganisms harmful for human health.
16. From the observation, it can be concluded that the physico-chemical quality of the selected study sites were under permissible limits except for dissolved oxygen and biological oxygen demand. The bacteriological properties of the study sites exceed permissible limits especially during monsoon seasons. The water from different selected sites needs to be disinfected before consumption. As most of the parameters are higher during monsoon it shows that there were no proper drainage systems and different kind of domestic

waste enters to the water body through run-off and leaching. The water resources needs better management to prevent them from being severely polluted in near future. There is also need of proper waste management and awareness of its importance to the people to save our valuable water sources.

The following recommendations may be taken into consideration for maintaining better potable water quality:

1. As for sewage, trade waste control can be used to minimize the presence of chemical in sewage that could leach down and enters the water body.
2. Proper management and maintenance of sanitary system to avoid leakage.
3. To minimize rearing of pet animal as well as pigs, for they are one of the main contributor for coliform contamination.
4. Increase plantation near the water resource area as well as human settlement, as increasing plantation with increase the water retention.
5. To strictly restrict throwing of garbage from any kind of sources.
6. Regular cleaning of the collection point will also help in maintaining the quality of water.
7. Avoid throwing of detergent waste in the nearby spring water collection point.
8. To make a strict regulation for each water sources, so that the quality will definitely improve the water quality.

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