ASSESSMENT OF EFFICIENCY OF WATER TREATMENT PLANT IN CHAMPHAI TOWN, MIZORAM: FORMULATION OF WATER MANAGEMENT STRATEGIES

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ASSESSMENT OF EFFICIENCY OF WATER TREATMENT PLANT IN CHAMPHAI TOWN, MIZORAM: FORMULATION OF WATER MANAGEMENT STRATEGIES

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DECLARATION

I, **Vanlalhruaitluanga Bochung**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did 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 for any research degree in any other University/Institute.

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

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CHAPTER – 1

INTRODUCTION

INTRODUCTION

1.1 Basic Concept

Water is the basis of life on the earth surface, and is the most abundant chemical component within our biosphere and perhaps the most important. Water covers about 71% of the earth's surface. Water resources in the world may be classified as surface water sources (lakes, rivers, artificial catchments and storage reservoirs) and groundwater sources (natural springs, deep and shallow wells, artesian wells and horizontal galleries). (Raven *et al.,* 2010).

Since the dawn of civilization, water has been the most important resource to human society. Ancient cities were developed near the water sources because of the ease of providing water for different purposes. The low-cost supply of large amount of water is one of the foundations of modern society (Henry and Heinke, 1996). However, due to the rapid rise of human population and the accelerated growth of industrialization during the last few decades, there has been a great increase in the demand for fresh and wholesome water (Ramakrishnaiah *et al*., 2009).

1.2 Chemical Properties of Water

Water is so common and so abundant in the biosphere that we take it for granted. However, it is not like any other liquid and in fact, nearly all physical and chemical properties of water are unusual as compared to other liquids. The two hydrogen-to-oxygen chemical bonds in water molecule form a 105° angle with each other which resulting in a slightly positive charge at one end and slightly negative charge at the other end. This dipolar characteristic of water causes the water molecules to attract each other which results in high temperature of boiling point of water and requires a large amount of energy to vaporize it. The dipolar nature of water also helps in explaining the high surface tension. The dipolar nature of water molecules help them to easily adhere on to surfaces and in combination with surface tension, capillary action is possible. Capillary action plays a crucial role to life science as it causes sap to rise in trees, water to rise in soil and movement of food and fluids inside body of organisms. The universal solvent property of water is also possible because of the dipolar nature of the water molecules which tends to surround charged ions and effectively neutralize them (Masters and Ela, 2008).

Including human, almost all kind of life on earth depends on water as the basic medium of metabolic functioning. The removal and dilution of most man-made and natural wastes are accomplished and taken care of by water. Water also possesses unique physical and chemical properties for the evolution of our environment and functioning of life (Henry and Heinke, 1996).

The thermal conductivity and heat capacity of water are unparalleled by any other substances. Water has an extremely high heat of evaporation. While it takes only 0.239 J (1 calorie) of energy to rise the temperature of 1g of water to 1°C, it takes 540 times as much to evaporate the water. The sun’s heat radiation removes around 1230 km^3 of water from seas, lakes, rivers and soil through evaporation and from plants through transpiration everyday (Miller, 1992).

1.3 Water Cycle

Water is constantly being recycled in a system known as the *hydrologic cycle*. The various earths’ water sources get their supply of water from precipitation, while precipitation itself is the evaporation from the sources. The water lost in the atmosphere as vapor then precipitated back in the form of rain, snow, hail, dew. This precipitation and evaporation continue forever in the hydrologic cycle (Garg, 2021).

Evapotranspiration removes an amount of water equivalent to about a layer of 1m thickness around the earth each year, about 88% of that is evaporation from the oceans while the remaining 12% is evapotranspiration from the land. There is more evaporation than precipitation in the oceans while there is more precipitation than evapotranspiration over the land. The difference between the amount of precipitation and evapotranspiration on land resulted in runoff of water where the water returned to the oceans through both streams and groundwater flow (Masters and Ela, 2008).

1.4 Distribution of Water

Shiklomanov (1992) argued that 60% of precipitation from the land is eventually returned to the atmosphere as evapotranspiration. Of the remaining 40% that does not evaporate, most of them are collected on the surface, flows into streams and rivers and then eventually emptied into the oceans, while some seeps into the soil and become ground water that slowly moves toward the seas. The combined ground water and surface water run-off is estimated to be 47,000 km3/yr. and is a renewable supply of freshwater that has a great potential for reuse for years after years without depletion.

It is of paramount importance to distinguish between consumptive and non-consumptive use of water. Consumptive use of water is that which renders the water unavailable for further use, either because of evapotranspiration, pollution or seepage in the underground until the hydrologic cycle returns it as precipitation. The non-consumptive use of water leaves the water for reuse, after treatment, without going through the hydrologic cycle. On this basis, agricultural use of water, because of evaporation and percolation of water used on crops, results in almost 90% of the water unavailable for reuse (Viessman and Hammer, 1993).

About 97.2% of the global surface water is in form of oceans and the remaining 2.8% is fresh water. But over 75% of freshwater is locked in the Polar Regions, soil and rock formations, and the atmosphere which leaves less than 25% available as surface water and ground water. Still, unfortunately, over 99% of this fresh water (surface and groundwater) is not easily accessible, and thus, we rely on the approximately 0.6% available (0.004% of the original quantity) for our water supply. It is rather difficult to estimate how much of the total water resource is available on a continuous basis and if we consider only the water participating in the hydrologic cycle annually, the precipitation (and equal amount of evaporation) is estimated at 4,20,000 km3/yr., of which 25% falls on the land (van der Leeden *et. al.*, 1990).

1.5 Water Shortages

In many parts of the world today, more water is being withdrawn for use than it is being replaced by precipitation. For the next decade or so to come, many countries of the world, developed and developing countries will face a chronic water shortages as well (Miller, 1992). This is a serious problem since many developing countries are still in the process of improving their living standards. The reasons for shortage of water are fundamentally different in developed and developing countries. In developed countries, the water withdrawal is becoming so high that even their technology, and water management facilities cannot keep up with the demand. Whereas, in developing countries, lack of proper technology and water management facilities for treatment and distribution of water along with the high population growth led to a severe water shortages (Henry and Heinke, 1996).

1.6 Contamination of Water and Epidemic

Water derives from precipitation in the form of rain, snow, hail, or sleet which, as they precipitate, collect dust form the air. Because of the filtering action of the soil, ground water is normally free of organisms. But, in some rocky areas, surface water can reach the ground water system through cracks and tunnels and cause contamination of the groundwater.

Surface water mixed together with different kind of substances during its travel over agricultural lands and industrial areas. Agricultural run-off contains nitrates, phosphates, other nutrients and microorganisms. Organic material such as leaves, grass, birds and animal excrements and other wastes with their associated microorganisms can enter in to the surface water.

Many forms of microbial life and activities can exist in water if there is an appropriate physical and nutritional requirement for growth are met. Dissolved oxygen is necessary for the growth of aquatic life including bacteria and protozoa. Nitrogen, phosphorus and light are essential for proper growth of green plants and algae. The quantity and types of microorganisms present in water give an indication of the water quality (Henry and Heinke, 1996).

Contaminated water is responsible for the spread of different types of contagious diseases. Disease causing microorganisms, also called pathogens, can grow and multiply inside the host which resulting in an infection. Pathogens associated with water include bacteria (causing dysentery, cholera, typhoid), viruses (causing hepatitis and poliomyelitis), protozoa (causing amebic dysentery, giardiasis) and Helminthes or parasitic worms (causing schistosomiasis and dracunculiasis).

Among the different sources of pathogens in water, the most important is the contamination by human feces. The human feces of an infected individual may contain billions of pathogens. If they enter into the water supply, leads to severe epidemic (Hammer and Hammer, 1996).

An epidemic of infectious diseases tends to emerge from areas of crowded and poor sanitation condition, which enables the microbes to spread at a rapid rate. Now a day, due to ease of transportation around the globe, local epidemics can easily become a global pandemic. The cholera pandemic outbreak that began in 1961 spread around the globe for two decades. It finally jumped to Peru in 1991, where almost 4,000 people died. And around 4,00,000 new cases of cholera were reported within a year in South America, where there had been almost none before (UNEP, 1993).

Nutrients as well as other pollutants can enter into the water bodies either from point sources such as discharge pipes from industries and wastewater treatment plants, waste disposal sites, mines, animal feedlots, and non-point sources such as run-off from agricultural lands, pastures and ranges, urban areas. Point sources are easier to treat and monitor because they are more continuous and centralized and focus on remedial effort has been put into it for the past decades. (Carpenters, 1998; U.S. EPA, 2002).

1.7 Water Demand for Different Aspects

The demand for water increased enormously as civilization and development move forward. In ancient times, human required water mainly for drinking, bathing, cooking and irrigation, but with the advancement of civilization the utility of water has been increased. There are many factors involved in the demand of water. Certain empirical formula and thumb rules are employed in determining the water demand (Birdie and Birdie, 2015). Water demand for irrigation, public water supply and industrial uses are withdrawn from the source while water used for transportation, recreation and fishing do not require withdrawal from the source.

Irrigation is by far the largest water demand which makes agriculture possible in many areas and fields where there are scarcities of water. Industries (factories, paper mills, cotton mills, breweries, sugar refineries) also rely heavily on the adequate supply of water. Public water supply points to the safe and clean water for use in homes, schools, hospitals etc. Water for drinking, hygiene and sanitary purposes is of great importance to the health and well-being of the society (Birdie and Birdie, 2015; Henry and Heinke, 1996).

The water demand of a community or a municipal area (domestic water demand, industrial water demand, institutional and commercial water demand, demand for public uses, fire demand) required to compensate losses in thefts and wastes (Garg, 2021). The water demand in a particular community is specified in terms of average daily demand and is expressed as liters per person (capita) per day (Lpcd). For a single home, bathing and flushing of toilet accounts for almost 80% of the total domestic use. While drinking and kitchen use account for 10% and the remaining 10% for washing, cleaning, garden watering etc. Water consumption is higher in developed countries than in underdeveloped countries. The amount of water consumption depends on the public water system, delivery system, plumbing, whether water is piped, trucked or hand carried and socio-economic conditions (Henry and Heinke, 1996).

On a survey conducted by World Bank in 1976, water use in rural areas of Southeast Asian countries ranged from 30 Lpcd to 70 Lpcd and African countries from 15 Lpcd to 35 Lpcd. However, in cities of developing countries, some areas where there are business and wealthier residential areas, the water consumption is closer to that of the cities in developed countries.

The demand of water varies from year to year and also from season to season. The seasonal variation occurs due to larger use of water in the summer season and lesser use in the winter, and much less in rainy season. The per capita demand of water can also be affected by the size of the city.

Climatic conditions may also affect the water demand because in a hotter and dry place, consumption of water is high. Industrial and commercial activities lead to sharp increase in water consumption. (Garg, 2021; Viessman and Hammer, 1993).

1.8 Constituents of Water

Water contains a variety of chemicals, physical and biological substances either in dissolved form or suspended form. From the moment it condenses as rain, it flows over the surface of the earth picking up or dissolves particles of soil, garbage, sewage, pesticides and other human, animal or chemical wastes. Some impurities in water at low concentration may sometimes be more useful and potable for public uses. Certain minerals like iron, calcium, magnesium, fluorine etc. in low concentration may be beneficial for health of the people but increase in concentration may be harmful and unfit for consumption.

Water also contains living organisms that react with the physical and chemical substances in it. Sometimes water may contain toxic and poisonous substances which may be harmful for public health and sometimes presence of high quantity of salts may also render the water undrinkable. To ensure the safety of the public and to improve the health and well-being of the community, raw water must be thoroughly treated before supply (Garg, 2021; Henry and Heinke, 1996).

1.9 Water Policies

Following the Stockholm conference on Human Environment in June, 1972, the Government of India had set up the Water (Prevention and Control of Pollution) Act, 1974, for addressing the need for appropriate measures and law regarding environmental problems that are endangering the health and safety of the people, as well as the flora and fauna on land. According to the Water (Prevention and Control of Pollution) Act, water pollution is defined as “the contamination of water, alteration of the physical, chemical or biological properties of water, discharge of any sewage or trade effluent or any other liquid, gaseous or solid substance into water (whether directly or indirectly), which may, or is likely to, create a nuisance or render such water harmful or injurious to 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.”

This Act also aims at the establishment of Central and State Pollution Control Board to monitor water quality and to look into pollution control measures. The Water Act prohibits pollutants discharge in the water bodies with penalties if they are non-compliant with the given standard of water quality. Some other important legislation regarding the maintenance and control of pollution of water include the Environmental Protection Act, 1986 which provides for the improvement and protection of the environment. Under this Act, the government is empowered to take necessary action to protect and improve the quality by setting standards for emissions and discharge of pollution in the atmosphere. The Hazardous Wastes (Management, Handling and Trans boundary) Rules, 2008 provides guidelines for manufacture, storage, and import of hazardous chemicals and management of hazardous wastes. The Biomedical Wastes (Management and Handling Rules), 1998 provides proper guidelines for the disposal, segregation, and transportation of infectious wastes materials. The Municipal Solid Wastes (Management and Handling) Rules, 2000 aims to enable the municipalities to dispose solid wastes in a more environment friendly and scientific manner (Vaish and Mehta, 2017).

1.10 Environmental Challenges and Water Resources

Industrial revolution and technological revolution are quite a big leap in moving forward to advance society but the cost of this is rather high. Climate change is one of the biggest threat that mankind is facing today. The fast growing industrial revolution and other human activities such as developmental projects, industries, vehicular traffic, and burning of fossil fuels etc., lead to the production of large amount of greenhouse gases that is more than the desired amount to cover up the earth surface. This leads to our planet getting warmer over a period of time and bought about a lot of changes in the climate and is known as climate change.

According to the experts, global warming is speeding up the hydrologic cycle between the ocean, atmosphere, and land resulting in more intense rainfall and droughts. The impact of climate change on the precipitation is more than that of temperature. The rainfall in Northern and Central Asian countries is witnessing an increase. The pattern of rainfall would be further changed in some areas getting more rainfall and some areas receiving less rainfall leading to droughts.

Rainwater is the lifeline of Indian economy and around 60% cultivated land depends solely on the monsoon rain. The Indian agriculture is likely to suffer from crop yield losses due to the rise in temperature and changes in rainfall pattern. Delayed onset of monsoon, midseason failure of rain and heavy rainfall at the end season has also been observed.

Since our fresh water resources depend heavily on precipitation, mountain runoff and snow melt, the changes in rainfall pattern and climate change lead to water crisis in different areas of the world, and India is also on the brink of water crisis. Due to drought and water salinity, supply of water for public and agricultural uses has been decreased drastically. It is widely accepted that in the near future, fighting over water resources will be the biggest war among countries and states (Henry and Heinke, 1996; Khullar and Rao, 2016).

To counter effects of climate change, there is an ample scope of certain steps in mitigation of the changes. Planting more trees, protection of our forests, use of water resources carefully, and recycling of our waste water for other uses will eventually meet the water demand to a desired pace.

1.11 Water Resources in Northeast India

The North-East states of India comprises of eight states namely, Assam, Meghalaya, Arunachal Pradesh, Manipur, Nagaland, Sikkim, Tripura and Mizoram, and covering a total area of 2,62,179 sq. km which about 7.9% of the total geographical area of the country. North-East India has large amount of accessible freshwater sources in the form of rivers, streams, lakes etc.

The surface water resources availability in the North-East Region alone amount to 653 BCM (billion cubic meters), which is about 34% of the country’s total potential. The Brahmaputra basin alone has a potential of about 573 BCM, while the Barak basin has a potential of about 48 BCM. Among the states, Arunachal Pradesh has the highest run-off with an average of 350 BCM, while Mizoram have about 31 BCM (Brahmaputra Board, 2000).

1.12 Water Resources in Mizoram

Mizoram is a hilly area and is under the influence of South-West monsoon and receives heavy rainfall during the months of May to September, and the average rainfall is 255 cm/yr. Surface water is distributed along rivers and streams and flowing through the terrain of the land which is the main source of water. Harvesting ground water is not very common among the people of Mizoram mainly because of their inaccessibility due to the hilly terrain. Climatic disturbances around Bay of Bengal have influenced the rainfall of the state.

Surface water resources of Mizoram include streams, rivers, lakes, ponds, wetlands and man-made reservoirs. Rivers in Mizoram are rain fed and reach its peak volume during the monsoon season. There are a total of 15 major rivers in Mizoram, out Tuivawl, Tuivai, Tuirini, Tlawng, Tut and Teirei flows northward and ultimately confluence with Barak River. Mat, Tuichang, Tuipui, Ṭiau and Chhimtuipui (Kolodyne) flows southward. The remaining rivers namely, Tuichawng, De and Khawthlang-Tuipui flow to the west. The drainage system in Mizoram comprises of Barak (Ganga-Brahmaputra basin), Karnaphuli and Kolodyne basin (RRC, 2019).

1.13 Water Quality

Water quality is generally defined on the basis of its physical, chemical and biological/ bacteriological characteristics. It depends on the season, local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, and overuse. Guidelines for water quality provide basic scientific information regarding the water quality parameters. Assessment of water quality is an important process in the development of water resources and to check if certain parameter exceeds acceptable limits (Ketata Mouna *et al.*, 2011; Tahera *et al.,* 2016).

1.14 Water Quality Index

Water quality index (WQI) expresses the overall water quality of a particular location in a single value, and is based on several water quality parameters. WQI is considered to be one of the simplest methods for assessing the overall water quality. It is also a useful tool to present the information on the water quality to the general public and policy makers (Yogendra and Puttaiah, 2008; Asadi *et al.,* 2007).

The WQI was developed in the early 1970s and since then, it has been used to monitor water quality changes in a particular water supply over time, or to compare quality of supply water with other water supplies in the region. WQI compressed and reduced the vast amount of data obtained from range of physico-chemical and bacteriological/ biological parameters into a single value in a simple reproducible number. WQI has been used for the assessment of water quality around the world (Stoner, 1978; Bordalo *et al.,* 2006; Simoes *et al.*, 2008). Similar to the UV index or the air quality index, WQI can tell us if the overall quality of water bodies contains a potential threat to various uses of water (Kankal *et al.,* 2012).

1.15 Water Treatment Plant

Today’s water treatment plants are designed to provide water continuously that meets drinking water standards at the tap. Screening, coagulation/flocculation, sedimentation, filtration and disinfection are the main operating unit involved in the treatment of surface water. Prior to the water passing to the main treatment processes, the water must first undergo an important preliminary process which is screening. The screens are formed by steel bars which are normally quite substantial which is typically about twenty five millimeter in diameter and are spaced about one hundred millimeter apart (Binnie and Kimber, 2009) .

Next, the water get into a process called aeration. Aeration is a term used in the environmental field to generally refer to the process of bringing air bubbles in contact with a volume of water (Pontius, 1990). Next, coagulation and flocculation process takes place. Earliest water treatments were forced by visible cloudiness of water due to various sources of waters having particles that had an objectionable taste and appearance. Coagulation is the process of clarifying water by making the suspended particles to settle out of water by using chemical alum (Parsons and Jefferson, 2006). Raw water with low turbidity can be treated by plain sedimentation to remove larger particles and then filtration to remove the small particles that failed to settle out. However, if particles in raw water are too small to be removed by sedimentation and filtration alone, chemicals are added to coagulate/flocculate the smaller particles, called colloids, into larger ones, which can then be settled out in sedimentation tanks or removed directly in filters. The commonly used coagulants are alum, $FeCl_3$, $FeSO_4$ and other coagulants such as Polyaluminium chloride (PAC) etc. (Henry & Heinke, 1996; Masters & Ela, 2008).

Further process in water treatment is called sedimentation and filtration. The last process in water treatment before the water can be distributed to household is disinfection. Killing microbial pathogens to prevent the spread of waterborne diseases is the main purpose of disinfecting water supplies (Parsons and Jefferson, 2006).

Objectives

1. To study the water quality of treated supply water in Champhai Town and pre-treated water at source point.
2. To determine pollutant removal efficiency of the water treatment plant.
3. To formulate appropriate management strategies for betterment of supply water.

CHAPTER – 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 International

Increase in rate of population, rapid rate of urbanization and industrialization led to the decreased water resources and increase in pollutant discharge in water (Pruss *et al*., 2002). Meanwhile, millions of people in under developed countries are lacking the most basic sanitation facility (Anonymous, 2012). The importance of adequate amount of water for human health has been a concern for many years and there are number of debates about the importance of water quality, water quantity, sanitation and hygiene with due consideration of health (Caircross, 1990; Esrey *et al.,* 1991).

Efe *et. al.* (2005) studied the seasonal variation in physico-chemical characteristics of three water resources in Western Niger Delta Region, Nigeria, and reported that the maximum and minimum concentrations of the priority water quality parameters were above the target water quality range for domestic use. Based on overall observation they recommended for urgent management strategies to be implemented so that the health risk could be minimized. Benito et. al. (2016), carried out a research on physico-chemical and bacteriological characteristics Kebena river in Addis Abbas, and argued that there could be changes in water quality due to alteration in climatic conditions. Agbaire and Obi (2009) reported impact of rainfall on physico-chemical properties of the river Ethiope in Abraka, Nigeria.

Kara *et al*., (2007) reported presence of coliform bacteria in the municipal supplied water from the province of Niğde, Turkey. They suggested proper chlorination of supply water to remove coliform bacteria. Klavins *et al*. (1996) found that the well water in Latvia possessed high content of organic substances which renders the water quality unsatisfactory.

Fares *et al*. (2021) studied groundwater and supply water in Relizana, Algeria. They found that ground water quality was within the water quality standards, whereas supply water did not meet the standards for drinking water and can pose a potential source of water borne diseases. Khan *et al*. (2013) studied drinking water quality in the district Peshawar, Pakistan. They reported fecal coliform bacteria, E. coli, Salmonella, Shigella and Staphylococcus aureus. This could be attributed due to flood during monsoon season.

Sunday *et. al.* (2014) studied water quality of domestic supply water in Okada town, Edo state, Nigeria, and reported coliform organisms greater than the WHO standards for domestic water.

Ajayi and Adejumo (2011) assessed the quality of water sources such as boreholes, wells and streams in Akungba-Akoko, in the state of Ondo in Nigeria, and found that all the sources were contaminated by pathogens which can be harmful for human health. The total coliform count was exceedingly high as compared to the EPA recommendations. They reported that most of domestic water sources were prone to health risks

Yadav *et al*. (2015) studied the physico-chemical and bacteriological parameters of domestic water sources in Dhankuta Municipality in Nepal, and found that the total coliform count for all samples was exceedingly high which may be due to the fecal contamination on the water sources. Evidently, most of the water borne diseases area was due to improper disposal of fecal wastes and contamination of water by sewage and surface runoff.

Sila (2019) studied the water quality in the rural areas of Kenya, Africa, and found that most water sources do not meet the potable water standards according to WHO water quality standards. Total coliform was detected with and exceeding level with the presence of *E. coli*, Vibrio cholera, *Shigella sp*., *Salmonella sp*., *Klebsiella sp.*, *Streptococcus faecalis* and *Clostridium perfringens*. Of all the pathogenic bacteria, *Shigella sp*. was the most abundant at study sites.

Jiang *et. al.*, (2002) developed an electro-coagulation-floatation process for water treatment. This treatment method was found to be superior to the conventional coagulation with aluminium sulphates for treating model coloured water, with 20% more dissolved organic carbon removed from the same Al (III) dose. Yan *et. al*., (2008) found that water with high alkalinity; the conventional coagulation method is not effective to remove natural organic matters (NOM). A novel coagulant, composite poly-aluminium chloride (PAC) and the additive coagulant aids HPAC inhibited 30% more efficiency than alum and ferric salts for removal of dissolved organic carbon and reduction of turbidity effectively.

To enhance the efficiency of water softening along with the coagulation process in the treatment of Ghrib Dam water, Ghernaout *et. al*. (2018) introduced the concept of replacement of alum by lime and sodium hydroxide. They reported that the partial substitution of alum with lime and NaOH in coagulation process resulted in the reduction of 50% of the total hardness.

In a study of water sources form Turkey and Italy, Selcuk *et. al*. (2007) reported that the process of coagulation and subsequent chlorination cause reaction between chlorine and natural organic matter (NOM) which forms disinfection by-products (DBPs). DBPs especially chloroform and trihalomethanes (THMs) may cause adverse health effects to human. They also argued that pre-ozonation in combination with coagulants enhanced the removal of total organic carbon and reduction of total trihalomethanes formation potential.

Presence of algae in raw water may lead to nuisance during treatment process in terms of unpleasant tastes and odours, formation of disinfection by-products (DBPs) and formation of toxins from cyanobacteria (Pan *et. al.*, 2006). In a study conducted by Wu *et. al.,* (2011), the combination of PAC with diatomite enhanced the coagulation process, resulting in sharp decrease in turbidity and algae cells (96%). This method of combining PAC and diatomite seems to be more effective and feasible than traditional coagulation for treatment of slightly polluted algae-combining surface water.

There can be deposition of high molecular weight natural polymers called humic substances, resultant from the decomposition of organic substances. They are stable and resistant to microbial breakdown. Presence of humic substances (HSs) in water can be characterized by a yellowish to brown colour. HSs can form toxic disinfection by-products (DBPs) such as chlorinated organic compounds which includes trihalomethanes (THMs). DBPs can exhibit mutagenic properties during the disinfection stages in water treatment (Stevenson, 1994; Whitehead *et. al.,* 1963; Rook *et. al.,* 1982; Schnitzer *et. al.,* 1972). Sudoh *et. al.,* (2005) has done an investigation on the effectiveness of coagulant and alkaline chemicals for removal of humic acids from the water. Their study suggested that PAC is an effective coagulant for the removal of humic acids from the water. With the addition of $CaCO_3$ as a coagulant aid, the removal of HA was enhanced which was caused by three important processes such as the reduction of EDL in HA colloids by Ca^{2+}, adsorption onto $CaCO_3$, and formation of flocks with $CaCO_3$. This process is cost-effective as well as efficient.

2.2 National

Trivedi *et al*. (2009) conducted an extensive investigation on seasonal variation in physico-chemical characteristics of Ganga river water at Kanpur, Uttar Pradesh. They reported very high turbidity due to presence of suspended particles, however other water quality attributes were within the permissible limit as given by WHO (World Health Organization).

Venkatesharaju *et al*. (2010) carried out research on physico-chemical and bacteriological characteristics on the river Cauvery of Kollegal stretch in Karnataka, and reported deterioration of water quality, as river had been subjected to human interference over the years. The seasonal and yearly trends were discussed to comprehend anthropogenic interference on the river. They argued that the major anthropogenic activities practiced in and around the river stretch were agriculture, washing, and irrigation, discharge of sewage, boating, fishing, open defecation and religious activities on river bank. Mohanty *et al*. (2016) has done an investigation on the potable water quality in Berhampur town, Odisha and observed that most of the parameters were beyond the permissible limit of the WHO guidelines in the deep bore well and the old bore wells. In their assessment of supply drinking water in Jaipur city, Chandra *et al*. (2016) have detected pathogenic bacteria using polymerase chain reaction based assays.

Momin *et al*. (2019) reported water quality attributes of supply water of GM Momin Women’s College, Maharastra within the permissible limit given by various scientific agencies. Pawar *et al.* (2006) in a study on the bore well and dug well water samples from an industrial area of Nacharam, reported high values for most of the water quality attributes beyond the drinking water standards.

Dey Kallol *et al*. (2005) in a study on various physico-chemical characteristics of Koel River water at Shankha and Brahmani, reported a decrease in the metal concentration level at a considerable extent during the rainy season. In addition to this, the contamination by these metals through bio-magnification and bioaccumulation in edible components produced from the water was found to produce a remarkable effect on the water of river Brahmani. Due to the increase of population, booming industries and use of fertilizers and pesticides, water got highly polluted (Shukla *et al*., 2017).

Pandey *et al*. (2014) has studied the physico-chemical parameters of different pond water of Bilaspur district, Chhattisgarh. They reported very high turbidity and BOD values of the different samples.

Discharge of wastewater from domestic and industrial sewage is one of the major sources of water pollution. They contributed to the nutrient loading of the water bodies, promoting algal blooms and increasing the BOD (Morrison *et al*., 2001). Gupta *et al*. (2014) have done an assessment on the physico-chemical parameters of wastewater collected from different areas of Sagar (M.P), India. They argued that the dumping of waste materials in different drainage systems led to adverse effects on aquatic life.

Bhanu (2016) has done an analysis of water samples from river Bhavani for various physico-chemical characteristics. From the study, it was concluded that the water possess high BOD, COD, TDS and Ph. It was argued that the discharge of pollutants into the river greatly affected the quality of the water. Billions of gallons of waste water from the city areas, housing, industries and agricultural areas eventually ended up into the water courses. Rastogi and Jayaraj, (1987) estimated about 70% of streams and river of India contains polluted water from anthropogenic sources.

On the analysis of water samples from Bibi Lake, Ahmedabad, Gujarat, Umerfaruq and Solanki (2015) reported high level of turbidity, TDS, Ph, hardness, alkalinity and phosphate in Bibi Lake, Ahmedabad, and Gujarat. The water quality was above the upper threshold of the WHO recommended guidelines. This may seriously affect the aquatic and terrestrial ecosystem and the significant pollutants emerging from the domestic sections poses an additional threat to the quality of the water.

Choudhury *et al*. (2021) has done a study on the drinking water sources of Goalpara district in the state of Assam, India. In their study, of 194 water samples, 52 samples were found positive for MPN test. E.coli was isolated and it is the primary organism found in the water samples. Other microorganisms such as Klebsiella, Enterococcus and Streptococcus were also found in some samples. A case study on the pollution caused by the industrial effluents on the Indian rivers was conducted by Bharti *et al*. (2020). From their assessment of the water quality of Krishni River, it was found that the river contains high pollution load in almost all the physico-chemical as well as heavy metals. This high pollution was mainly caused due to the discharge of industrial and domestic waste directly or indirectly.

A study on the impact of coal industries on the water quality of Damodar River was conducted by George *et al*. (2010), the contents of TDS, TSS, TH and COD were reported higher due to the disposal of effluents from different industries.

Mishra and Tripathi (2007) has conducted a study on the various physico-chemical and bacteriological characteristics of the river Ganga in Varanasi. Their study has shown that the downstream contain high pollution load and high bacterial density. Some pathogenic bacteria were found which indicate the high level of fecal contamination in water. Shukla *et al*. (1992) also performed a similar kind of research for river Ganga at Ghazipur. They reported sharp depletion in DO content and increase in ECE, BOD, COD, Ph, nitrate-N, phosphate-P, sodium, potassium and calcium content which were likely due to direct discharge of sewage and industrial effluents. Nayak *et al*. (2012) has done an extensive study on the characteristics of drinking water of Berhampur city in Orissa, India. They observed that the BOD values of the water samples were beyond the permissible limit which could be attributed due to presence of biodegradable pollutants in the water.

2.3 Regional

Samson (2011) carried out a comparative study on quality of surface water and groundwater in southern part of Aizawl city and he reported that the water quality attributes met the standards given by various scientific agencies for potable water.

Lalchhingpuii (2011) studied status of water quality of Tlawng River along with tributary in the vicinity of Aizawl city, Mizoram and reported that the intensity of pollutants was maximum in tributary water, indicating direct discharge of huge amount of wastes into water from the settlement. Tlawng river water near upstream was least polluted, and intensity of pollutants was increased from upstream to downstream of river due course of travel of river, and more pollution stress was observed at the sites after meeting point with tributaries. Lalchhingpuii *et. al*. (2011)

also studied the phosphate, nitrate and sulphates contents in river Tlawng water in vicinity of Aizawl city.

The researchers also paid attention on assessment of physical and chemical characteristics of public supply water in Aizawl city, Mizoram (Thasangzuala and Mishra, 2014; Thasangzuala *et. al.*, 2014); assessment of seasonal variations in physical and chemical properties of Tamdil lake, Mizoram, Northeast India (Chenkual and Mishra, 2016; Chenkual et. al., 2016); impact of hydroelectric power plant on water quality of Tuirial and Serlui river (Lalparmawii and Mishra, 2012; Sunar and Mishra, 2016).

CHAPTER – 3

METHODOLOGY

METHODOLOGY

3.1 Description of study site:

3.1.1 Mizoram: Locations and Geographical Features

Mizoram is a state of India that is situated in the extreme south of the North-East and is located between 92˚15’ E to 93˚29’ E longitudes and 21˚58’ N to 24˚35’ N latitudes. The total geographical area of Mizoram is about 21,081 square kilometers with a dimension measuring 277 km from North to South, and 121 km from East to West. It borders with Myanmar on the east and Bangladesh on the west.

Mizoram is divided into eleven districts namely, Aizawl, Lunglei, Siaha, Champhai, Kolasib, Serchhip, Lawngtlai, Mamit, Saitual, Khawzawl and Hnahthial. Aizawl is the state capital of Mizoram and is located at the northern part of the state with a geographical area of about 3576.31 sq. km. (Statistical Handbook, 2020; Census, 2011)

The physiology of Mizoram is mainly characterized by north to south trending parallel hill ranges, valleys and numerous rivers. Water supply for domestic, agricultural, and irrigation purposes depends heavily on the perennial and ephemeral rivers (Imchen *et. al.,* 2020). Mizoram has generally a moderate climate despite being in tropical regions. As it is directly influenced by the south-west monsoon, the state received an adequate amount of rainfall during the month of May to September with an annual rainfall ranges between 2100 mm to 3500 mm (Forest Survey of India, 2019).

The soil of Mizoram is generally young and sandy, and is dominated by loose sedimentary formations. The soil has high acidic content and low potash and phosphorus content. In areas where there is no erosion of soil, nitrogen content is high. According to Sarkar and Nandy (1977), the soil of Mizoram can be categorized in to three soil taxonomy orders namely, Entisols, Inceptisols and Ultisols.

3.2 Description of Study Site

Champhai District is situated in the NE part of the state of Mizoram, India and it lays between 24° 05’ 03.99” and 23° 00’ 03.25” N latitudes and 93° 00’ 31.29” and 93° 26’ 17.66” E longitudes. It has a climate ranging from moist tropical to moist sub-tropical with an annual rainfall of 2908.40mm. Temperature ranges from 10-20ºC in winter to 15-30ºC in summer (Lalzarliana, 2014; Lalbiaknungi and Lalbiakmawia, 2017). According to the 2011 census the population of Champhai district is 1.26 lakhs out of which 38.59% lives in urban area and 61.41% in rural areas.

The supply of water in Champhai town is undertaken by the Public Health Engineering Department, Champhai under the Greater Champhai Water Supply Scheme. The details of the scheme are Greater Champhai Water Supply are as follows:

- Location of the scheme: Champhai
- Nature of the scheme: Pumping (Electric/ Diesel engine).
- Source: Tuipui river
- Total Head: 710m
- Present rate of supply: 70 lpcd (liter per capita per day).
- Maximum design supply capacity: 49420 persons.
- Maximum design water quantity in a day: 3.40 million liters.

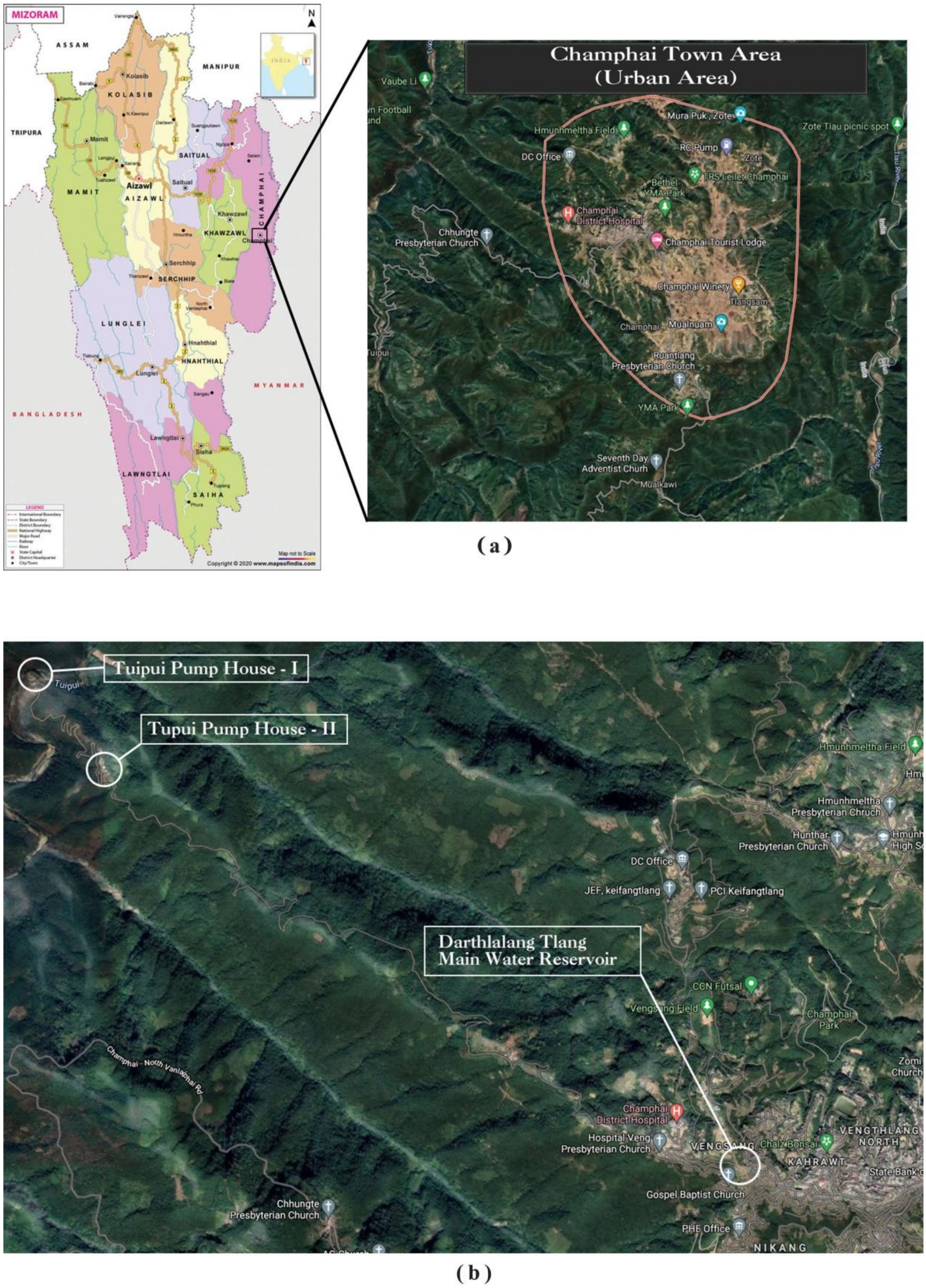
Treated water is supplied to every household in Champhai town (urban area) and as of January, 2017 there are 4143 numbers of HWC (Household water connection) in Champhai town. Apart from town area, treated water is supplied to North Khawbung, Kelkang and Mualkawi villages.

Pre-treated water is collected from Tuipui river at Tuipui Pump House – I, located beside the river, where large suspended solids are removed. Then, water is pumped up to Tuipui Pump House – II, located 220m above sea level where it undergoes treatment such as sedimentation and filtration processes. The filtered water is then pumped up to Darthlalang tlang main water reservoir, located at 830m above sea level. Disinfection process is also done here at the main reservoir. From the main reservoir, water is supplied to different zonal tank located at 18 places in Champhai town. Laboratory for water quality testing is also located at Darthlalang tlang.

3.2.1 Selection of Sampling Sites

To fulfill the objectives of the present study, two sample sites were selected for collection of water samples and analysis of water quality characteristics.

1. **Site 1**: River Tuipui, the source river from where pre-treated water is collected for treatment.
2. **Site 2**: Darthlalang tlang main water reservoir, where treated water is collected for domestic supply.



Map 3.1: Location map of **(a)** Mizoram, India showing Champhai town area (urban area) and **(b)** Pump Houses and Main Water Reservior.

Photo plate 3.1: Site 1- Water collection point at Tuipui river during Pre-Monsoon season.

Photo plate 3.2: Site 1- Water collection point at Tuipui river during Monsoon season.

Photo plate 3.3: Site 1- Water collection point at Tuipui river during Post-Monsoon Season.

Photo plate 3.4: Site 1- Tuipui Pump House-I located near the bank of Tuipui river

Photo plate 3.5: Sedimentation Tank at Water Treatment Plant near Tuipui Pump House-II.

Photo plate 3.6: Filtration Tank at Water Treatment Plant near Tuipui Pump House-II.

Photo plate 3.7: Water pumping unit located at Tuipui Pump House-II.

Photo plate 3.8: Darthlalang tlang, the main water reservoir (Site 2).

Photo plate 3.9: Site 2- Inlet of filter water at Darthlalang tlang main water reservoir.

Photo plate 3.10: Site 2- Chlorinator unit for disinfection of water at Darthlalang tlang.

3.3 Collection of Water Sample

The water samples were collected (in triplicate) from the river Tuipui source point before treatment (pre-treated water) and PHE water (treated water) on a monthly interval for two successive years ie, from February 2018 to January 2019, and February 2019 to January 2020. The various physicochemical characteristics viz., Turbidity, Total Dissolved Solids, Total Hardness, Total Alkalinity, Acidity, Chloride, Phosphate-P, Nitrogen-N, Dissolved Oxygen, and Biochemical Oxygen Demand were analyzed. Temperature and pH the water samples were recorded at the sampling sites and samples were fixed at site for estimation of DO of water. The bacteriological analysis was performed for Total Coliform count. The monthly observations have been presented on seasonal basis i.e., Pre-monsoon season (February to May), Monsoon season (June to September) and Post-monsoon season (October to January).

3.4 Analytical Methods:

Analysis of physical, chemical and bacteriological characteristics of water was carried out using the methods as outlined in the “Standard Methods for Examination of Water and Wastewater” as prescribed by APHA (2005).

3.4.1 Physical parameters

3.4.1.1 Temperature

Temperature of water was measured by using digital thermometer and the value was expressed in ºC.

3.4.1.2 Turbidity

Turbidity was measured by using Nephalometer/ Turbidity meter and the value was expressed in NTU (Nephalometric Turbidity Unit).

3.4.1.3 Total Dissolved Solids (TDS)

Measurement of TDS of water was done by evaporation and filtration method and the value was expressed in mg/L. TDS was calculated as follows:

$$\text{TDS} = \frac{(W_2 - W_1)\times 1000}{V}$$

where, W_1 *= Final weight of residue + dish.*

W_2*= Initial weight of dish.*

V = Volume of the sample taken in ml.

3.4.2 Chemical parameters

3.4.2.1 pH

Measurement of pH was done by using Electronic pH meter.

3.4.2.2 Total Hardness

Measurement of total hardness was done using EDTA titration method and the value was expressed in mg/L of $CaCO_3$. Total hardness value was calculated as follows:

$$\text{Total Hardness} = \frac{C\times D\times 1000}{Volume\ of\ Sample\ taken(ml)}$$

where, C = Volume of EDTA required by sample

D = mg $CaCO_3$ *equivalent to 1 ml EDTA titrant*

3.4.2.3 Total Alkalinity

The total alkalinity was determined by potentiometric titration method and the value was expressed in mg/L of $CaCO_3$. Standardised Sulphuric acid (0.02N) was used as a titrant to bring the pH of sample at 8.3 (phenolphthalein alkalinity) and to pH of 3.7 (methyl orange alkalinity). Total alkalinity was calculated as follows:

$$\text{Total alkalinity} = \frac{(A-B)\times 1000}{Volume\ of\ water\ sample\ used(ml)}$$

where, A = Alkalinity due to Phenolphthalein,

B = Alkalinity due to Methyl Orange

3.4.2.4 Acidity

The acidity of the water was measured by potentiometric titration method and the value was expressed in mg/L of $CaCO_3$. Standardised Sodium hydroxide (0.02N) was used as a titrant. Acidity was calculated as follows:

$$\text{Acidity} = \frac{Volume\ of\ titrant\ used\ (0.02N\ NaOH)\times 1000}{Volume\ of\ water\ sample\ used(ml)}$$

3.4.2.5 Chloride

The chloride content of water was measured using argentometric titration method (Mohr's method) and the value was expressed in mg/L. Standardised Silver nitrate (0.0141N) solution was used as a titrant. Chloride content was calculated as follows:

$$\text{Chloride content} = \frac{A\times N\times 34.45\times 1000}{Volume\ of\ water\ sample\ used(ml)}$$

where, A = Volume of titrant used

N = Normality of titrant

3.4.2.6 Phosphate – P

The Phosphate–P content of water was analyzed using the Stannous Chloride colorimetric method and the value was expressed in mg/L. Phosphate–P content was calculated as follows:

Phosphate–P content = R x mf

where, R = Absorbance reading of sample

mf = absorbance/conc.

3.4.2.7 Nitrate – N

The Nitrate–N content of water was measured using Phenol disulphonic acid (PDA) method and the value was expressed in mg/L. Nitrate – N content was calculated as follows:

Nitrate – N content = R x mf

where, R = Absorbance reading of sample

mf = absorbance/conc.

3.4.2.8 Dissolved Oxygen (DO)

DO content of water was determined using the modified Winkler's Azide method and the value was expressed in mg/L. DO content was calculated as follows:

$$\text{DO content} = \frac{V \times N \times 8 \times 1000}{Volume\ of\ water\ sample\ used\ (ml)}$$

where, V = Volume of titrant used

N = normality of titrant

3.4.2.9 Biochemical Oxygen Demand (BOD)

The BOD content of the water was determined by measuring the intitial and final DO content of water after 5-days incubation period at 20ºC. The value was expressed in mg/L. BOD content was calculated as follows:

$$\text{BOD content} = \frac{DO_i - DO_f}{Dilution\ factor\ for\ water\ sample, ml\ (if\ any)}$$

where, DO_i *= initial DO*

DO_f *= final (5 days) DO*

3.4.3 Bacteriological Parameters

3.4.3.1 Total Coliform

The total coliform of the sample was determined using the Multiple-tube fermentation technique. MPN index table was used to calculate the most probable number of coliform bacteria in 100 mL of water sample (**Appendix I**).

3.5 Water Quality Index (WQI)

Weighted arithmetic index method (Brown *et al.*, 1972) has been used for calculating the water quality index of the water body. Calculation steps are as follows:

$$\text{Sub-index of quality rating } (q_n) = \frac{(V_n - V_{id})}{(S_n - V_{id})} \times 100$$

where, q_n *= quality rating for the* n^{th} *water quality parameter.*

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

S_n *= Standard permissible value of the* n^{th} *parameter.*

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

All the ideal values are taken as zero for drinking water except for pH = 7, and DO = 14.6 mg/L (Tripaty and Sahu, 2005). Unit weight (Wn) for various water quality parameters was calculated by:

$$W_n = \frac{k}{S_n}$$

where, W_n *= unit weight of nth parameters.*

S_n *= Standard value for the nth parameters.*

k = constant of proportionality, and is calculated by

$$k = \frac{1}{\sum \frac{1}{S_n}} \quad and\ n = 1,2,3 \ldots n$$

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

$$\text{WQI} = \frac{\sum W_n q_n}{\sum W_n}$$

3.6 Statistical Analysis

To check the validity and significance of the data, statistical analyses such as correlation coefficient and analysis of variance (ANOVA) were computed using SPSS ver. 26 and MS Excel 2010.

CHAPTER – 4

RESULTS

RESULTS

The results of the research on the various physical, chemical and bacteriological parameters of the water and its impact on the quality of water bodies can be presented as follows:

4.1 Water Quality Parameters

4.1.1 Temperature

The minimum and maximum temperature value for pre-treated and treated water in both the years was recorded in post-monsoon season and monsoon season respectively. For pre-treated water, the temperature ranged from 16.95°C to 24.05°C during 2018-19, and 18.8°C to 24.59°C during 2019-20. Similarly, the temperature of treated water ranged from 18.0°C to 23.83°C during 2018-19, and 19.2°C to 24.62°C during 2019-20 (**Fig. 4.1 & Fig. 4.2**).

Statistically, two-way ANOVA showed a significant ($p<0.05$) variation between the seasons ($F = 166.81$) (**Table 4.1**). Correlation coefficient showed a significant ($p<0.05$) and positive correlation of temperature with acidity ($r = 0.664$ for pre-treated and $r = 0.654$ for treated) and nitrate-N ($r = 0.748$ for pre-treated and $r = 0.780$ for treated). Temperature of water showed a negative relationship with dissolved oxygen (DO). The Pearson correlation coefficient between different water quality parameters for pre-treated and treated water has been computed in **Appendix-II & III**.

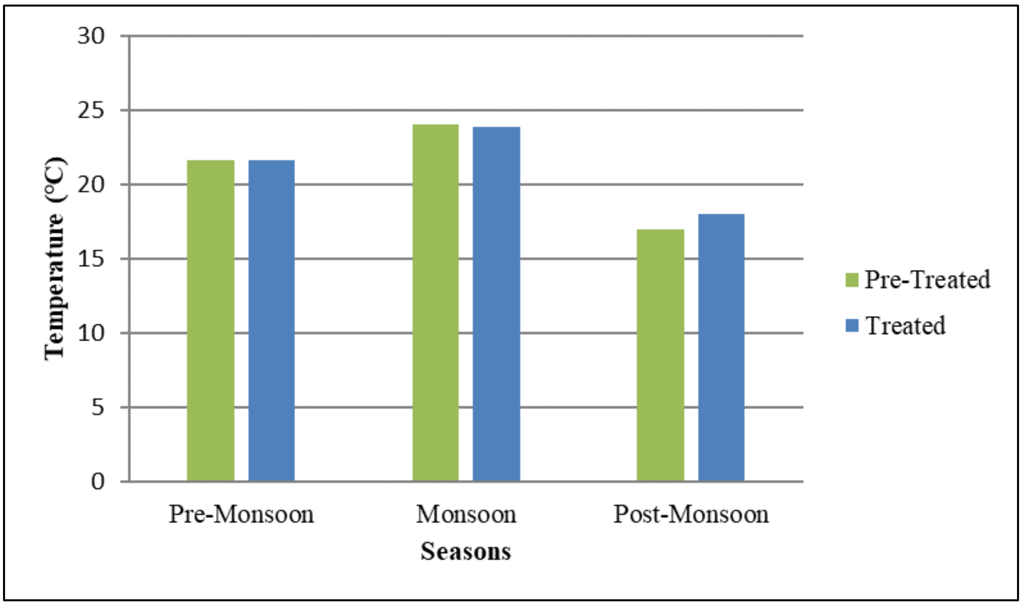


Fig. 4.1 Temperature of the water during 2018-19.

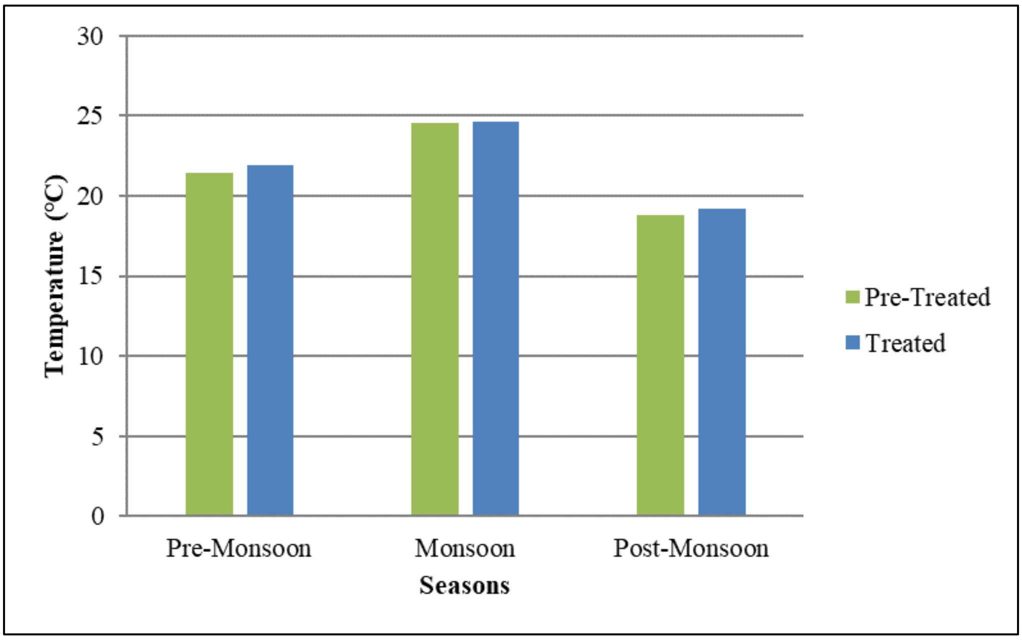


Fig. 4.2 Temperature of the water during 2019-20.

Table 4.1 Two-way analysis of variance for the temperature.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	277.73	11	25.24812074	166.81	0.00	2.81793047
Water Sample Type	0.4662	1	0.466209375	3.08	0.11	4.84433567
Error	1.665	11	0.151361648			
Total	279.86	23				

4.1.2 Turbidity

The minimum and maximum turbidity value for pre-treated and treated water in both the years was observed in the pre-monsoon season and monsoon season respectively. For pre-treated water, the values ranged from 2.13 NTU to 34.89 NTU during 2018-19, and 2.1 NTU to 29.57 NTU during 2019-20. Similarly, turbidity of treated water ranged from 0.8 NTU to 11.87 NTU during 2018-19, and 0.6 NTU to 11.35 NTU during 2019-20 (**Fig. 4.3 & Fig. 4.4**).

Statistically, two-way ANOVA has shown a significant ($p<0.05$) variation between the seasons ($F = 2.896$) and the water sample type ($F = 7.114$) i.e., pre-treated water and treated water (**Table 4.2**). Turbidity has shown a significant ($p<0.05$) and positive correlation with nitrate-N ($r = 0.625$ for pre-treated and $r = 0.647$ for treated) and BOD ($r = 0.939$ for pre-treated and $r = 0.937$ for treated), and a negative relationship with TDS, total hardness and total alkalinity. The Pearson correlation coefficient between different water quality attributes has been calculated in **Appendix-II & III**.

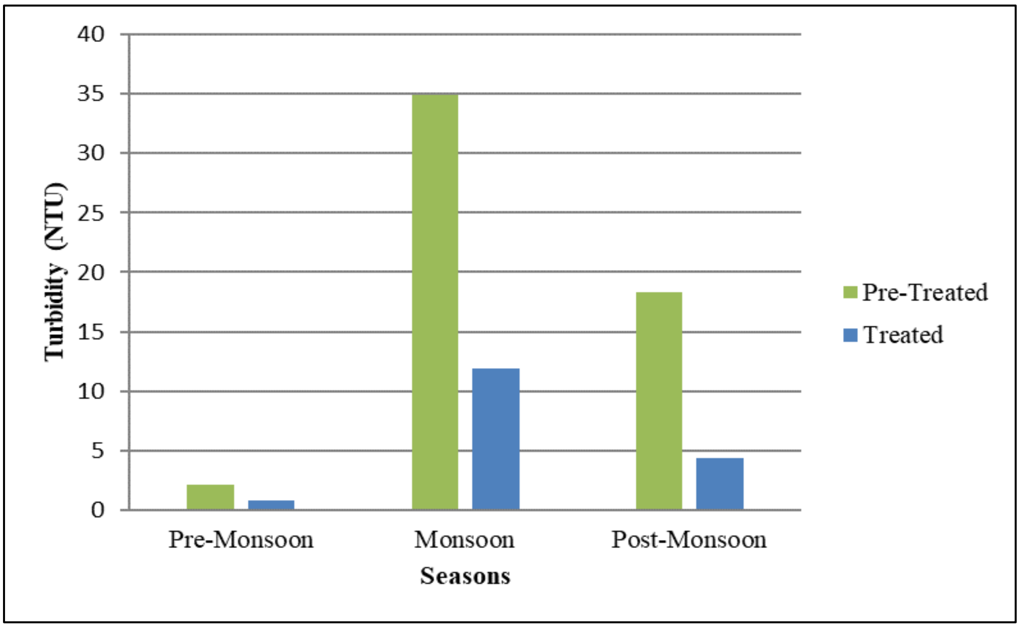


Fig. 4.3 Turbidity of the water during 2018-19.

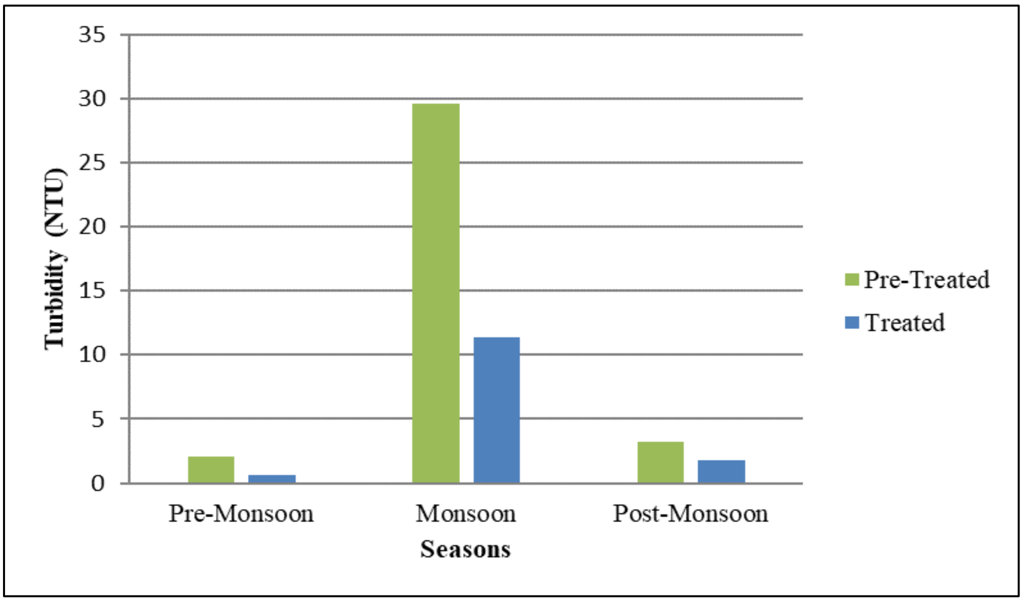


Fig. 4.4 Turbidity of the water during 2019-20.

Table 4.2 Two-way analysis of variance for turbidity of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	2637.66	11	239.787566	2.896	0.046	2.81793
Water Sample Type	589.1	1	589.099959	7.114	0.02	4.84434
Error	910.838	11	82.8034662			
Total	4137.6	23				

4.1.3 Total Dissolved Solids (TDS)

The minimum and maximum value for pre-treated and treated water in both the years was obtained in the monsoon season and pre-monsoon season respectively, except pre-treated water during 2019-20 having a minimum value in the post-monsoon season. The TDS values of pre-treated water ranged from 30.03 mg/L to 42.35 mg/L during 2018-19, and 29.48 mg/L to 45.37 mg/L during 2019-20. Similarly, the values for treated water ranged from 28.78 mg/L to 39.89 mg/L during 2018-19, and 31.61 mg/L to 43.45 mg/L during 2019-20 (**Fig. 4.5 & Fig. 4.6**).

The two-way analysis of variance for TDS has shown a significant ($p<0.05$) variation between the seasons ($F = 98.806$) and the water sample type ($F = 9.322$) i.e., pre-treated and treated water (**Table 4.3**). A significant ($p<0.05$) and positive correlation of TDS was observed with total alkalinity ($r = 0.654$ for pre-treated and $r = 0.625$ for treated) and total hardness ($r = 0.619$ for pre-treated and $r = 0.570$ for treated). The Pearson correlation coefficient between different water quality parameters can be observed in **Appendix-II & III**.

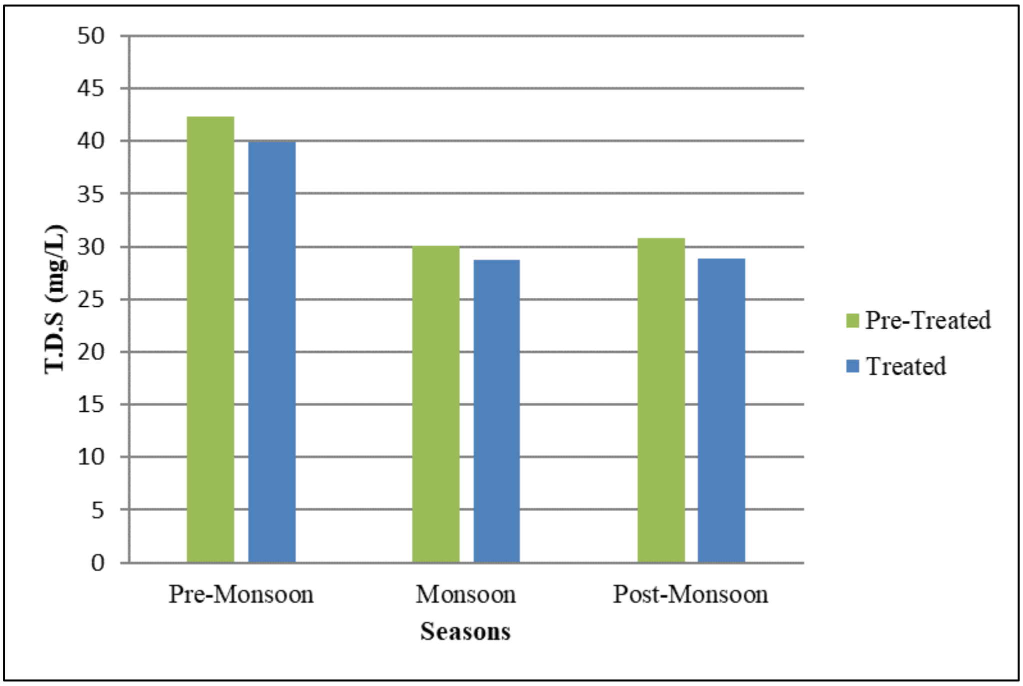


Fig. 4.5 Total Dissolved Solids of water during 2018-19.

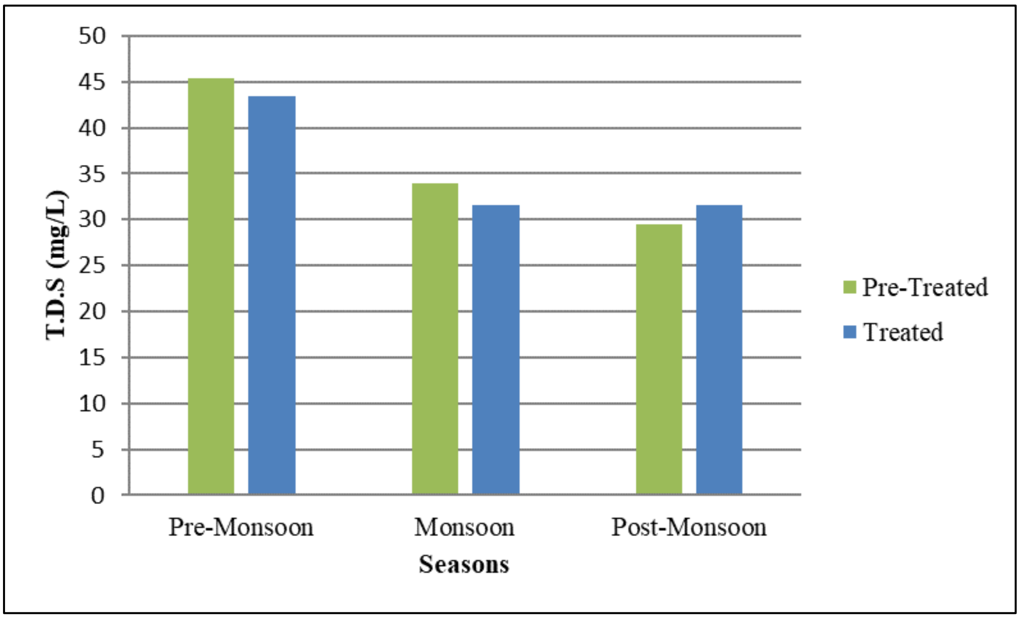


Fig. 4.6 Total Dissolved Solids of water during 2019-20.

Table 4.3 Two-way analysis of variance for total dissolved solids (TDS) of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	1160.34	11	105.486	98.806	0.000	2.81793
Water Sample Type	9.95238	1	9.95238	9.322	0.011	4.84434
Error	11.7437	11	1.06761			
Total	1182.04	23				

4.1.4 pH

The minimum and maximum pH value for pre-treated and treated water in both the years was observed in monsoon season and pre-monsoon season respectively. The values for pre-treated water ranged from 7.1 to 7.2 during 2018-19, and 6.9 to 7.2 during 2019-20. Similarly, the pH of treated water ranged from 7.2 to 7.3 during 2018-19, and 7.1 to 7.3 during 2019-20 (**Fig. 4.7 & Fig. 4.8**).

The two-way analysis of variance on the pH has shown significant ($p<0.05$) variations between the seasons ($F = 3.865$) (**Table 4.4**). The pH values showed a negative correlation with temperature and acidity but there was no significant correlation of pH with other water quality attributes. The Pearson correlation coefficient between different water quality parameters is presented in **Appendix- II & III**.

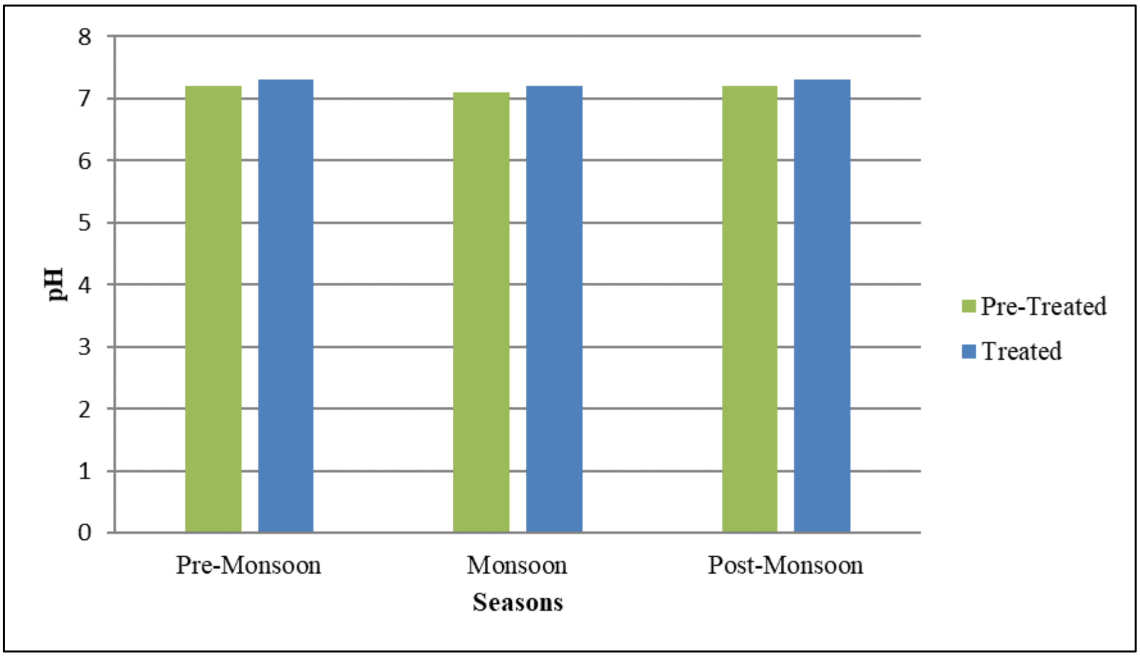


Fig. 4.7 pH of water during 2018-19.

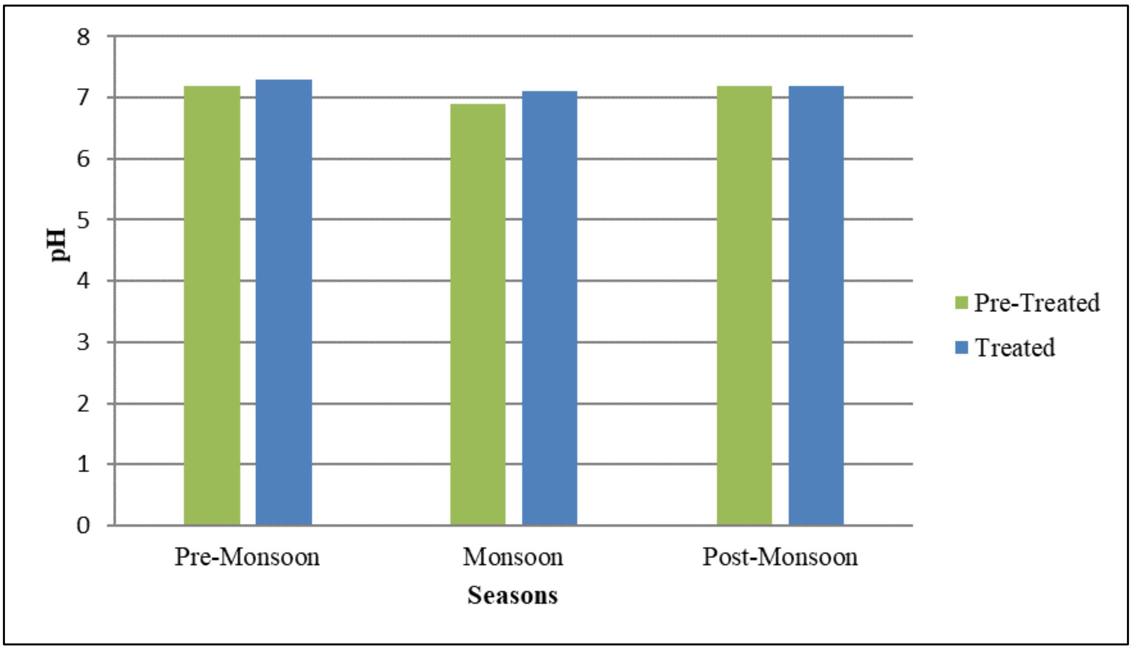


Fig. 4.8 pH of water during 2019-20.

Table 4.4 Two-way analysis of variance for the pH of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	0.2275	11	0.02067983	3.865	0.017	2.81793047
Water Sample Type	0.001	1	0.001001042	0.187	0.674	4.84433567
Error	0.0589	11	0.005351042			
Total	0.2873	23				

4.1.5 Total Hardness (TH)

The minimum and maximum value for pre-treated and treated water in both the years was recorded in post-monsoon season and pre-monsoon season respectively. For pre-treated water , the values ranged from 30.12 mg/L $CaCO_3$ to 43.33 mg/L $CaCO_3$ during 2018-19, and 31.83 mg/L $CaCO_3$ to 47.83 mg/L $CaCO_3$ during 2019-20. Similarly, total hardness for treated water ranged from 27.16 mg/L $CaCO_3$ to 39.16 mg/L $CaCO_3$ during 2018-19, and 29.67 mg/L $CaCO_3$ to 42 mg/L $CaCO_3$ during 2019-20 (**Fig. 4.9 & Fig. 4.10**).

The two-way analysis of variance on the total hardness showed a significant ($p<0.05$) variation between the seasons (F = 31.265) and the water sample type (F = 11.572) i.e., pre-treated and treated water (**Table 4.5**). A significant ($p<0.05$) and positive correlation of total hardness has been observed with total alkalinity ($r = 0.742$ for pre-treated and $r = 0.558$ for treated). The Pearson correlation coefficient between different water quality parameters can be seen in **Appendix- II & III**.

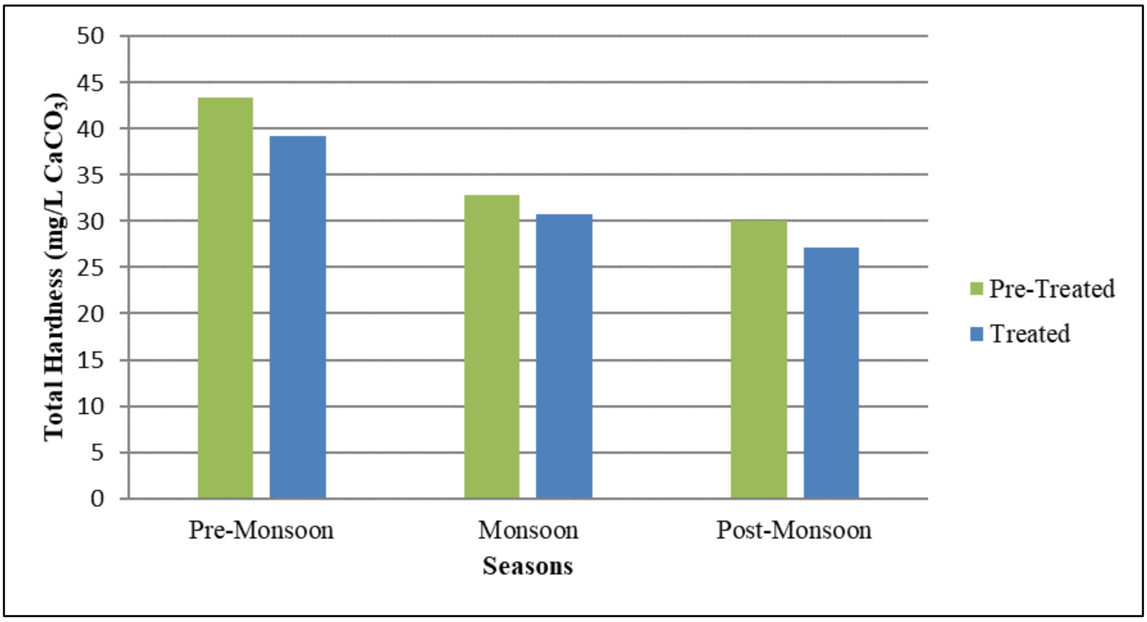


Fig. 4.9 Total Hardness of the water during 2018-19.

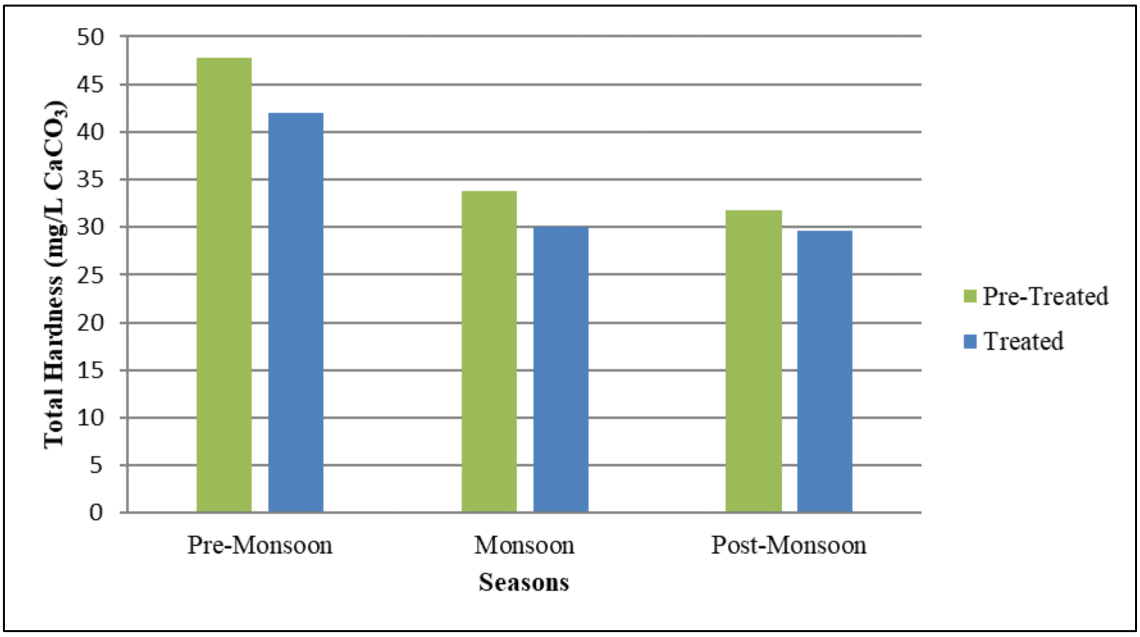


Fig. 4.10 Total Hardness of the water during 2019-20.

Table 4.5 Two-way analysis of variance for the total hardness of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	1369.092496	11	124.4629542	31.265	0.000	2.81793
Water Sample Type	46.06510417	1	46.06510417	11.572	0.006	4.84434
Error	43.78964583	11	3.980876894			
Total	1458.947246	23				

4.1.6 Total Alkalinity (TA)

The minimum and maximum value for pre-treated and treated water in both the years was recorded in monsoon season and pre-monsoon season respectively. The values for pre-treated water ranged from 45.66 mg/L $CaCO_3$ to 78.83 mg/L $CaCO_3$ during 2018-19, and 47.32 mg/L $CaCO_3$ to 63.66 mg/L $CaCO_3$ during 2019-20. Total alkalinity for treated water ranged from 42.08 mg/L $CaCO_3$ to 74.08 mg/L $CaCO_3$ during 2018-19, and 43.08 mg/L $CaCO_3$ to 61.15 mg/L $CaCO_3$ during 2019-20 (**Fig. 4.11 & Fig. 4.12**).

The two-way analysis of variance on the total alkalinity has shown significant ($p<0.05$) variations between the seasons ($F = 66.863$) and the water sample types ($F = 9.055$) i.e., pre-treated and treated water (**Table 4.6**). The correlation coefficient showed a significant ($p<0.05$) and negative correlation of total alkalinity with acidity ($r = -0.665$ for pre-treated and $r = -0.709$ for treated), phosphate-P ($r = -0.718$ for pre-treated and $r = -0.628$ for treated) and BOD ($r = -0.622$ for pre-treated and $r = -0.664$ for treated). Total alkalinity showed a positive relationship with TDS and total hardness. The Pearson correlation coefficient between different water quality attributes has been computed in **Appendix- II & III**.

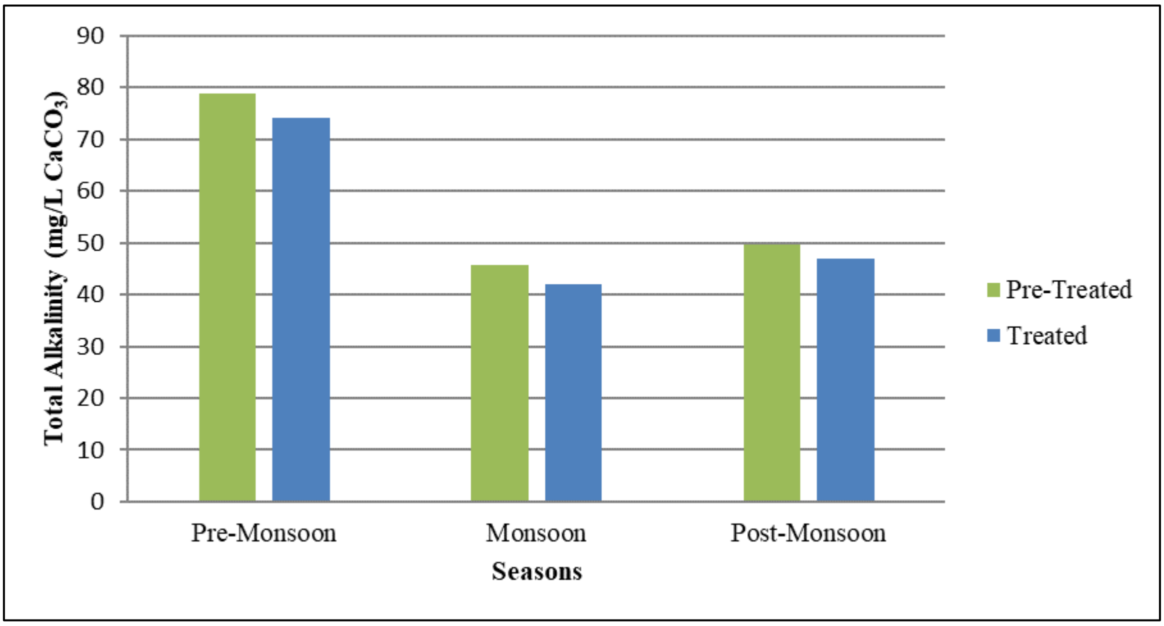


Fig. 4.11 Total Alkalinity of the water during 2018-19.

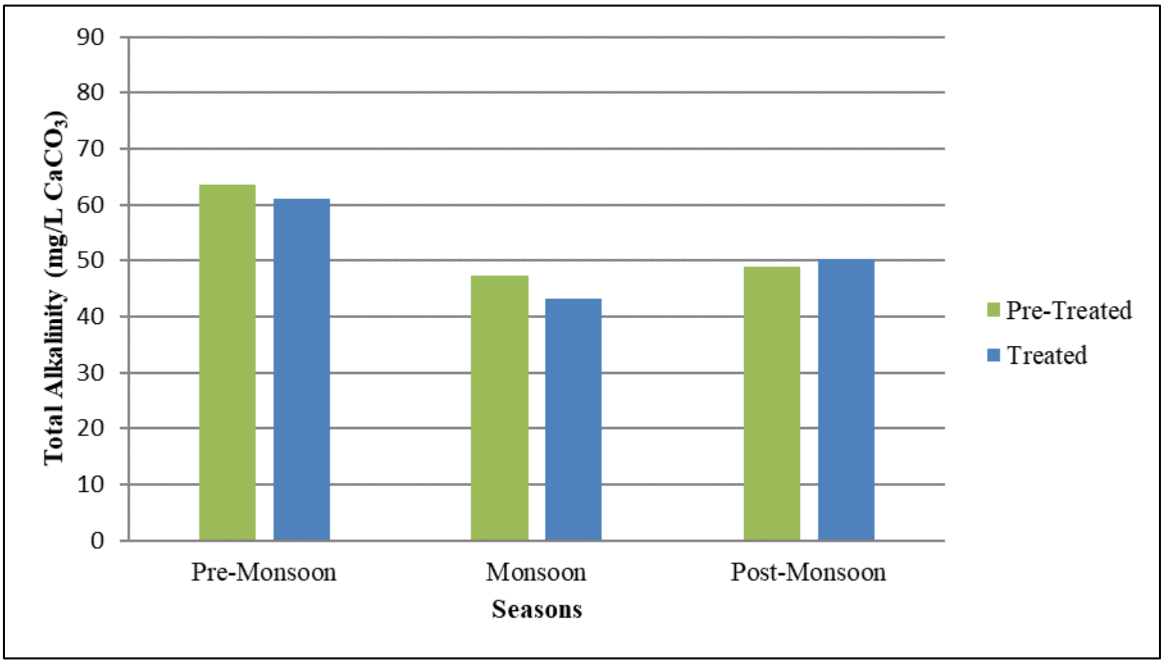


Fig. 4.12 Total Alkalinity of the water during 2019-20.

Table 4.6 Two-way analysis of variance for the total alkalinity of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	3650.103821	11	331.8276201	66.863	0.0000	2.81793
Water Sample Type	44.93606667	1	44.93606667	9.055	0.012	4.84434
Error	54.59070833	11	4.962791667			
Total	3749.630596	23				

4.1.7 Acidity

The minimum and maximum value for pre-treated and treated water in both the years was recorded in pre-monsoon season and monsoon season respectively. The minimum and maximum values for pre-treated water ranged from 16.67 mg/L $CaCO_3$ to 48.67 mg/L $CaCO_3$ during 2018-19, and 18.67 mg/L $CaCO_3$ to 50.33 mg/L $CaCO_3$ during 2019-20. Similarly, the for treated water , the values ranged from 10.33 mg/L $CaCO_3$ to 22.33 mg/L $CaCO_3$ during 2018-19, and 11.67 mg/L $CaCO_3$ to 20.67 mg/L $CaCO_3$ during 2019-20 (**Fig. 4.13 & Fig. 4.14**).

The two-way analysis of variance for the acidity showed significant ($p<0.05$) variations between the seasons ($F = 312.42$) and between the water sample types ($F = 39.776$) i.e., pre-treated and treated water (**Table 4.7**). There was a significant ($p<0.05$) and positive correlation of acidity with temperature ($r = 0.664$ for pre-treated and $r = 0.654$ for treated water), turbidity ($r = 0.865$ for pre-treated and $r = 0.917$ for treated water) and BOD ($r = 0.930$ for pre-treated and $r = 0.980$ for treated water). Acidity showed a negative relationship with total alkalinity and total hardness. The Pearson correlation coefficient between different water quality parameters has been tabulated in **Appendix- II & III**.

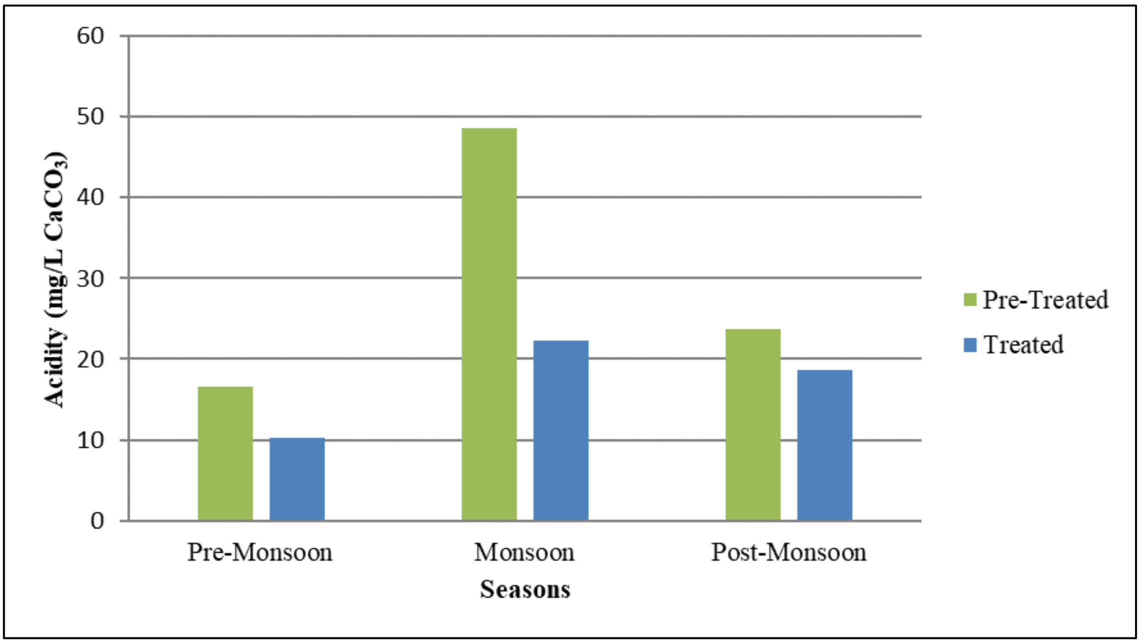


Fig. 4.13 Acidity of the water during 2018-19.

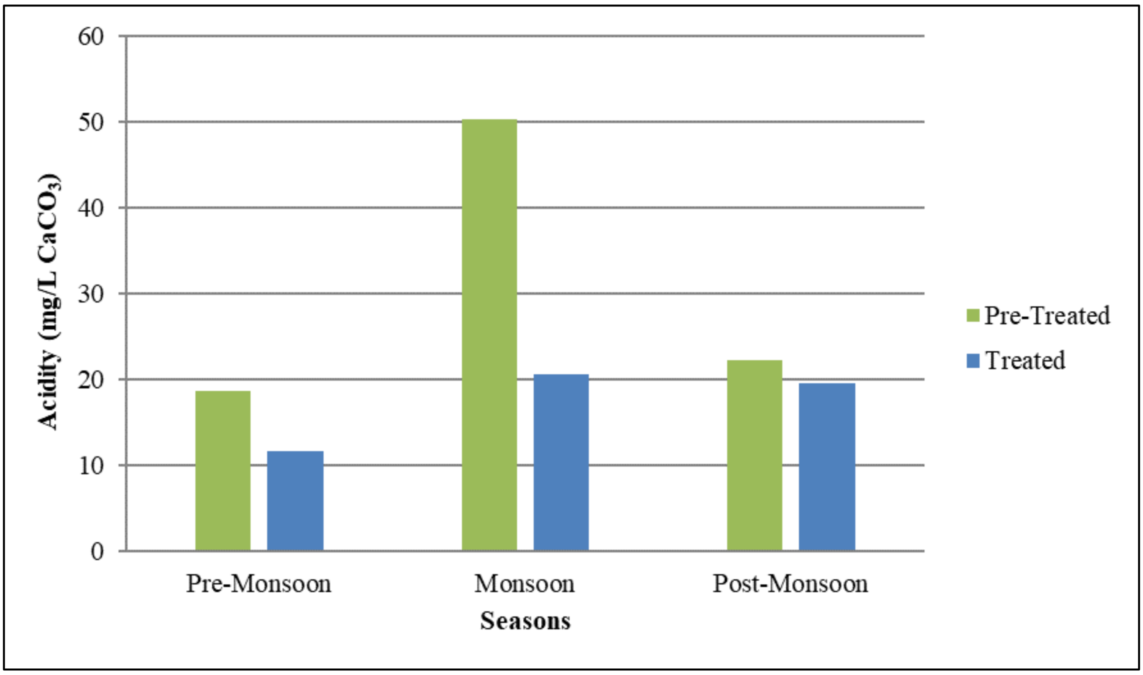


Fig. 4.14 Acidity of the water during 2019-20.

Table 4.7 Two-way analysis of variance for the acidity of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	5198.3	11	472.573	312.420	0.000	2.81793
Water Sample Type	60.1667	1	60.1667	39.776	0.000	4.84434
Error	16.6388	11	1.51262			
Total	5275.1	23				

4.1.8 Chloride

The minimum and maximum value for pre-treated and treated water in both the years was recorded in post-monsoon season and monsoon season respectively. The chloride content for pre-treated water ranged from 0.32 mg/L to 0.57 mg/L during 2018-19, and 0.34 mg/L to 0.45 mg/L during 2019-20. Chloride content for treated water ranged from 4 mg/L to 4.8 mg/L during 2018-19, and 4 mg/L to 4.9 mg/L during 2019-20. The chloride content of treated water was relatively higher than that of pre-treated water (**Fig. 4.15 & Fig. 4.16**).

Statistically, the two-way analysis of variance for chloride content showed a significant ($p<0.05$) variation between the water sample types ($F = 853.227$) i.e., pre-treated water and treated water (**Table 4.8**). Chloride content showed a positive correlation with the temperature while showing a negative correlation with dissolved oxygen (DO). The Pearson correlation coefficient between different water quality characteristics has been presented in **Appendix- II &III**.

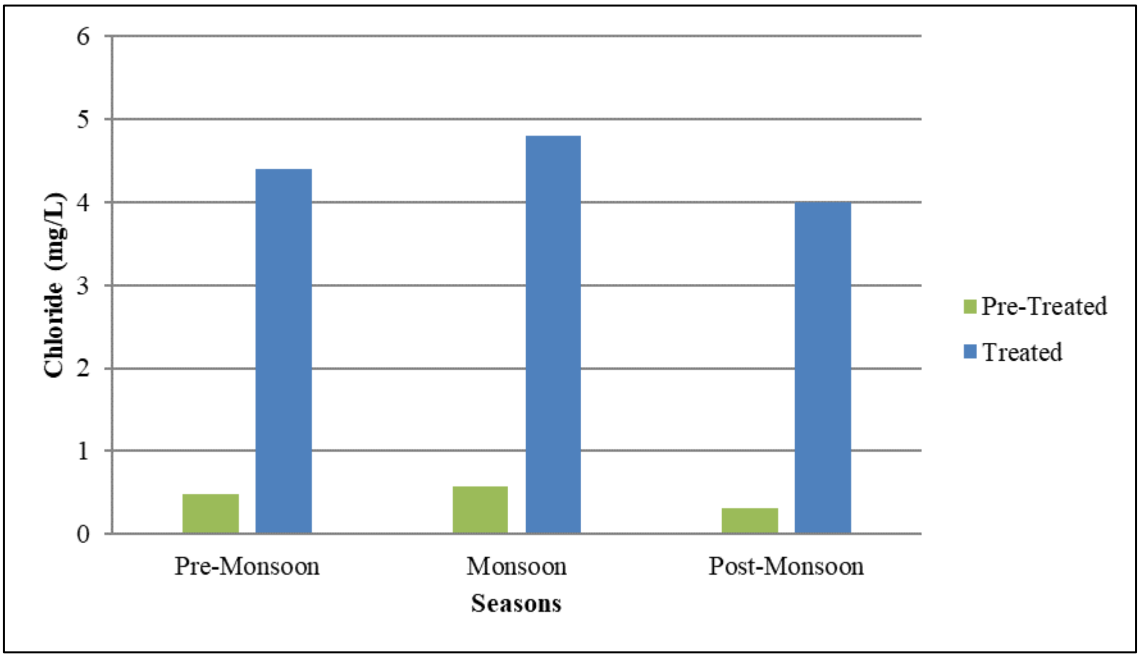


Fig. 4.15 Chloride content of the water during 2018-19.

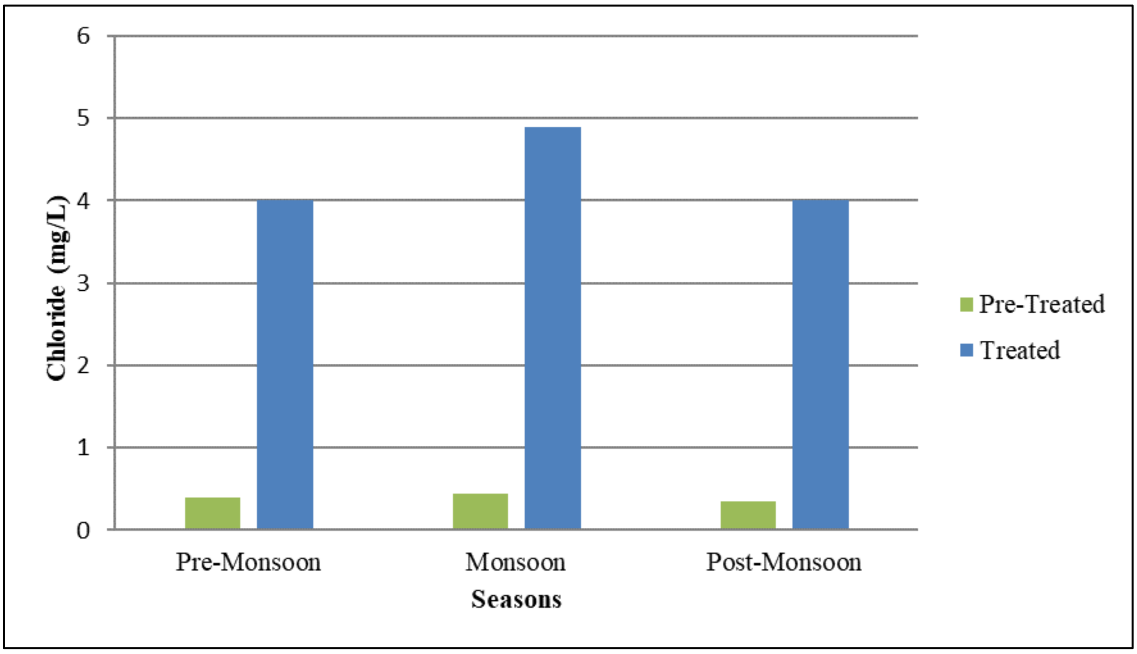


Fig. 4.16 Chloride content of the water during 2019-20.

Table 4.8 Two-way analysis of variance for the chloride content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	0.9591	11	0.087191667	0.825	0.622	2.81793047
Water Sample Type	90.171	1	90.17126667	853.227	0.000	4.84433567
Error	1.1625	11	0.105682576			
Total	92.293	23				

4.1.9 Phosphate – P

The minimum and maximum value for pre-treated and treated water in both the years was recorded in pre-monsoon season and monsoon season respectively. The minimum and maximum values of phosphate for pre-treated water ranged between 0.01 mg/L and 0.02 mg/L during 2018-19, and 0.01 mg/L and 0.02 mg/L during 2019-20. Similarly, the values for treated water ranged between 0.01 mg/L and 0.02 mg/L during 2018-19, and 0.01 mg/L and 0.02 mg/L during 2019-20 (**Fig. 4.17 & Fig. 4.18**).

Statistically, the two-way analysis of variance for the phosphate-P content of showed that the variations in phosphate-P content do not have a significant effect on the seasons and water types (**Table 4.9**). There was a significant ($p<0.05$) and negative correlation of phosphate-P was established with total alkalinity ($r = -0.718$ for pre-treated and $r = -0.628$ for treated water). Phosphate-P showed a positive correlation with nitrate-N, and acidity and a negative correlation with dissolved oxygen (DO). The Pearson correlation coefficient between various water quality parameters can be seen in **Appendix- II & III**.

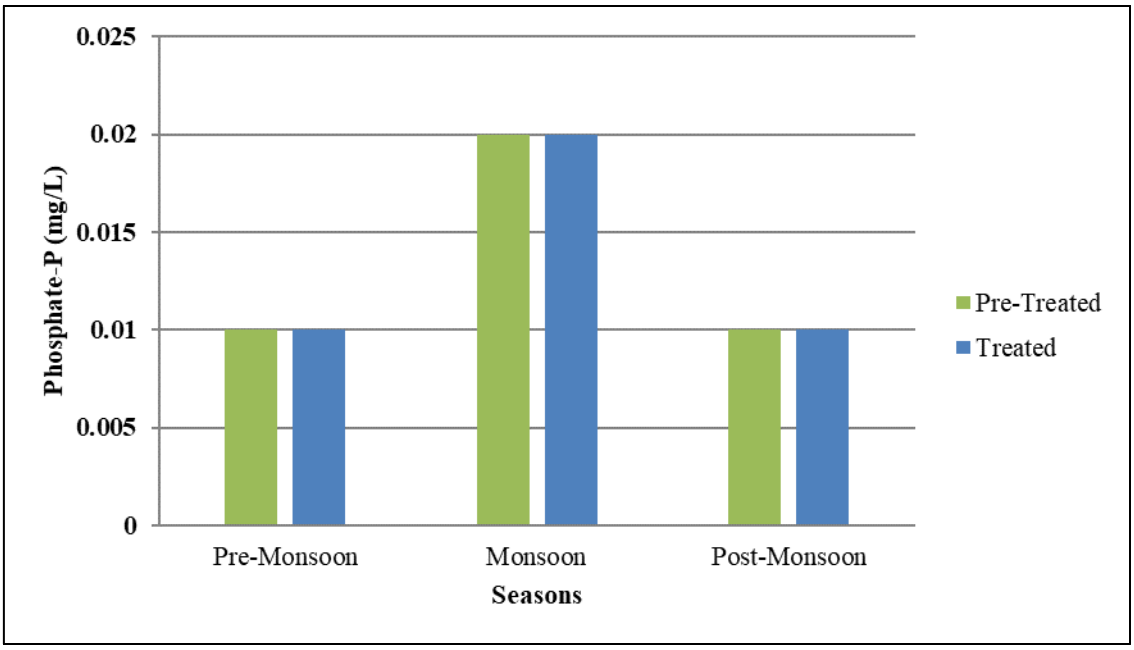


Fig. 4.17 Phosphate-P content of the water during 2018-19.

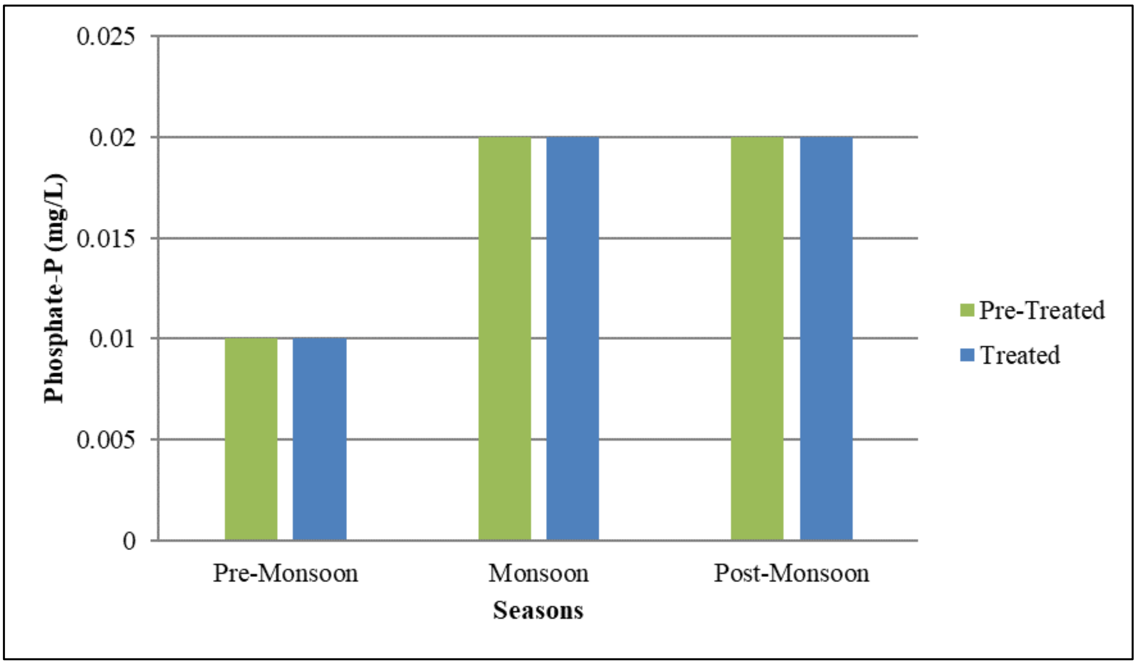


Fig. 4.18 Phosphate-P content of the water during 2019-20.

Table 4.9 Two-way analysis of variance for the phosphate-P content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	0.00035	11	3.18182E-05	2E+15	1E-82	2.81793
Water Sample Type	-1.6263E-19	1	-1.6263E-19	-1E+01	#NUM!	4.84434
Error	1.6263E-19	11	1.47846E-20			
Total	0.00035	23				

4.1.10 Nitrate – N

The minimum and maximum value for pre-treated and treated water in both the years was observed in pre-monsoon season and monsoon season respectively. The minimum and maximum nitrate-N content in pre-treated water ranged between 0.1 mg/L and 0.12 mg/L during 2018-19, and 0.1 mg/L and 0.12 mg/L during 2019-20. The nitrate-N content in treated water ranged between 0.1 mg/L and 0.12 mg/L during 2018-19, and 0.1 mg/L and 0.12 mg/L during 2019-20. (**Fig. 4.19 & Fig. 4.20**).

Statistically, the two-way ANOVA for nitrate-N has shown no significant effect on the seasons and water type (**Table 4.10**). The nitrate-N showed a significant ($p<0.05$) and positive correlation with temperature ($r = 0.748$ for pre-treated and $r = 0.780$ for treated water), turbidity ($r = 0.625$ for pre-treated and $r = 0.647$ for treated water), acidity ($r = 0.723$ for pre-treated and $r = 0.702$ for treated water) and BOD ($r = 0.624$ for pre-treated and $r = 0.603$ for treated water). The Nitrate-N showed a significant ($p<0.05$) and negative correlation with dissolved oxygen (DO) ($r = -0.765$ for pre-treated and $r = -0.862$ for treated water). The Pearson correlation coefficient between various water quality attributes can be seen in **Appendix-II & III**.

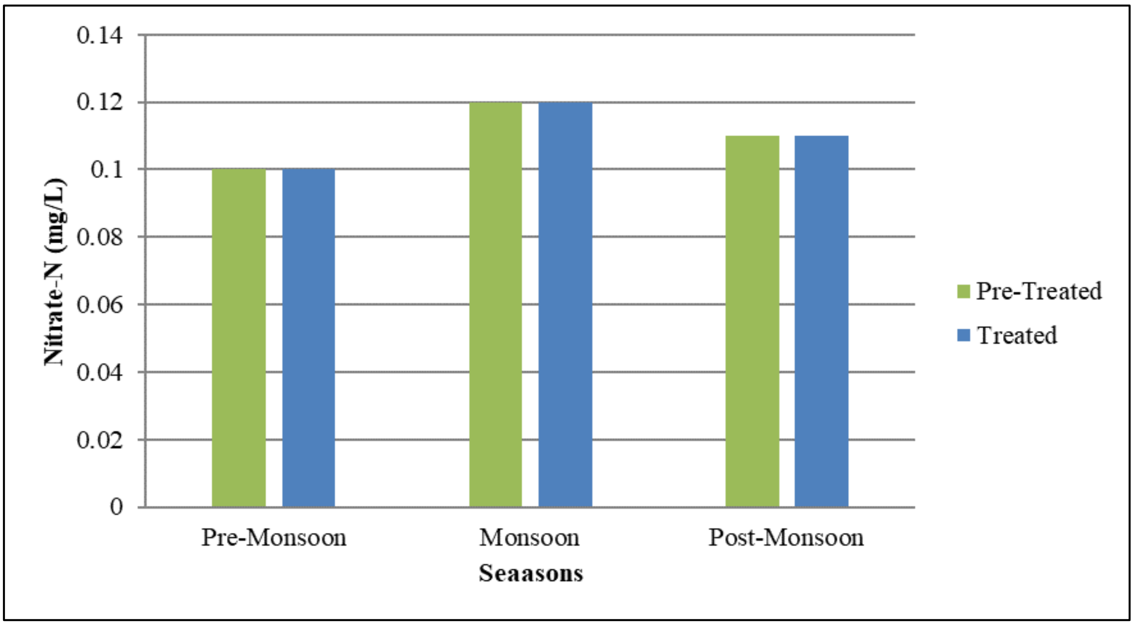


Fig. 4.19 Nitrate-N content of the water during 2018-19.

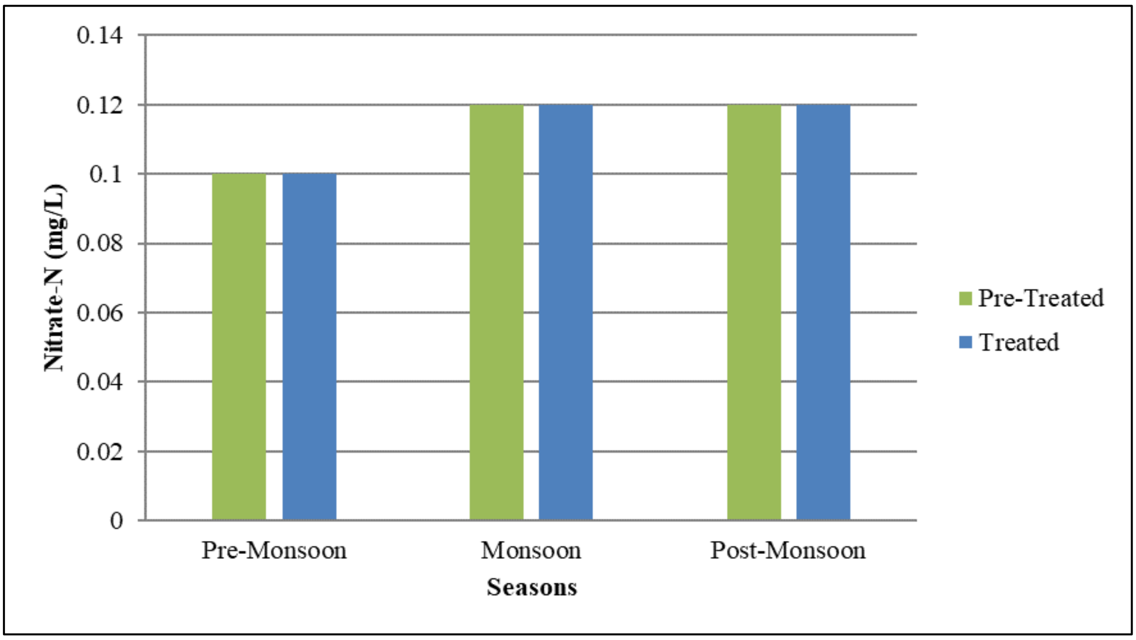


Fig. 4.20 Nitrate-N content of the water during 2019-20.

Table 4.10 Two-way analysis of variance for the nitrate-N content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	0.001383333	11	0.000125758	6E+15	3E-85	2.81793
Water Sample Type	-2.1684E-19	1	-2.1684E-19	-1E+01	#NUM!	4.84434
Error	2.1684E-19	11	1.97128E-20			
Total	0.001383333	23				

4.1.11 Dissolved Oxygen (DO)

The minimum and maximum DO values for pre-treated and treated water in both the years was recorded in the monsoon season and pre-monsoon season respectively. The DO values in pre-treated water ranged between 6.22 mg/L and 6.5 mg/L during 2018-19, and 6.25 mg/L and 6.4 mg/L during 2019-20. The values in treated water ranged between 7.7 mg/L and 8.3 mg/L during 2018-19, and 7.5 mg/L and 8.0 mg/L during 2019-20. (**Fig. 4.21 & Fig. 4.22**).

Statistically, two-way ANOVA for DO of water has shown that there were significant ($p<0.05$) variations between the seasons (F = 3.745) and the water sample types (F = 318.261) i.e., pre-treated water and treated water (**Table 4.11**). There was a significant ($p<0.05$) and negative correlation of DO with nitrate-N (r = -0.765 for pre-treated and r = -0.862 for treated water), temperature (r = -0.753 for pre-treated and r = -0.504 for treated water). The dissolved oxygen (DO) shows a negative relationship with biochemical oxygen demand (BOD). The Pearson correlation coefficient between various water quality characteristics has been presented in **Appendix-II & III**.

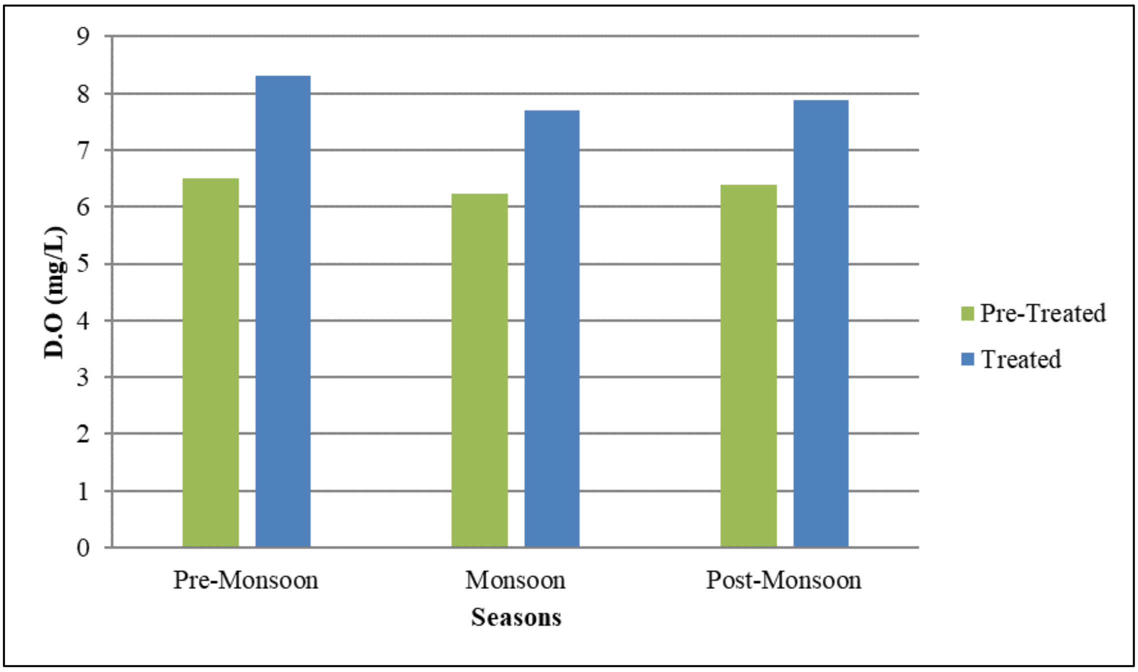


Fig. 4.21 DO content of the water during 2018-19.

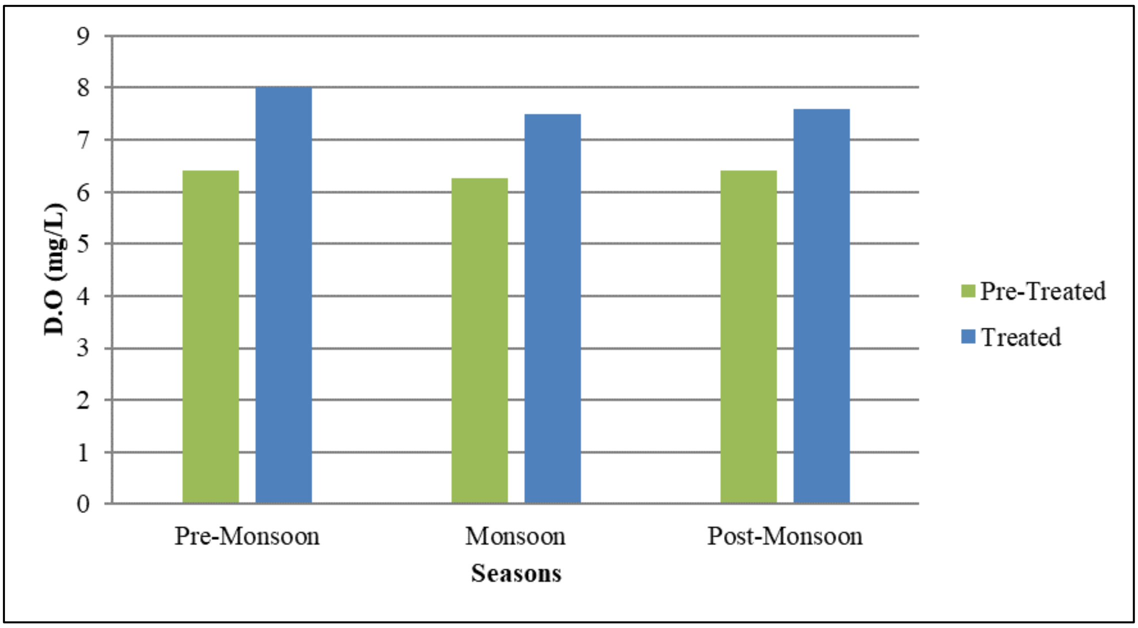


Fig. 4.22 DO content of the water during 2019-20.

Table 4.11 Two-way analysis of variance for the dissolved oxygen (DO) of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	1.56781	11	0.14253	3.745	0.019	2.81793
Water Sample Type	12.1126	1	12.1126	318.261	0.000	4.84434
Error	0.41865	11	0.03806			
Total	14.0991	23				

4.1.12 Biochemical Oxygen Demand (BOD)

The minimum and maximum BOD values were observed in both the years for pre-treated and treated water in pre-monsoon season and monsoon season respectively. The BOD values in pre-treated water ranged between 1.2 mg/L and 1.8 mg/L during 2018-19, and 1.2 mg/L and 1.6 mg/L during 2019-20. On the other hand, the values in treated water ranged between 0.2 mg/L and 0.8 mg/L during 2018-19 and 0.2 mg/L and 0.6 mg/L during 2019-20 (**Fig. 4.23 & Fig. 4.24**).

The two-way analysis of variance for BOD has shown significant ($p<0.05$) variations between the seasons ($F = 40.273$) and the water sample type ($F = 625$) i.e., pre-treated water and treated water (**Table 4.12**). There was a significant ($p<0.05$) and positive correlation of BOD with turbidity ($r = 0.939$ for pre-treated and $r = 0.937$ for treated water), acidity ($r = 0.930$ for pre-treated and $r = 0.980$ for treated water) and nitrate-N ($r = 0.624$ for pre-treated and $r = 0.603$ for treated water). The BOD showed a negative significant ($p<0.05$) correlation with total alkalinity ($r = -0.622$ for pre-treated and $r = -0.664$ for treated water). The Pearson correlation coefficient between different water quality parameters has been tabulated in **Appendix- II & III**.

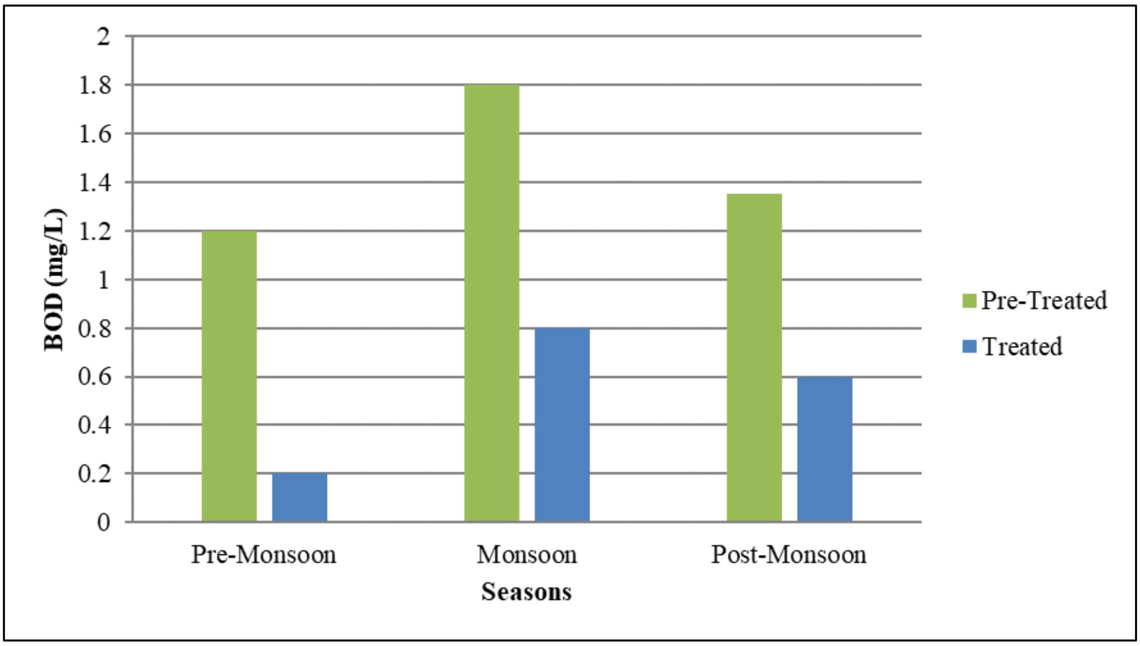


Fig. 4.23 BOD content of the water during 2018-19.

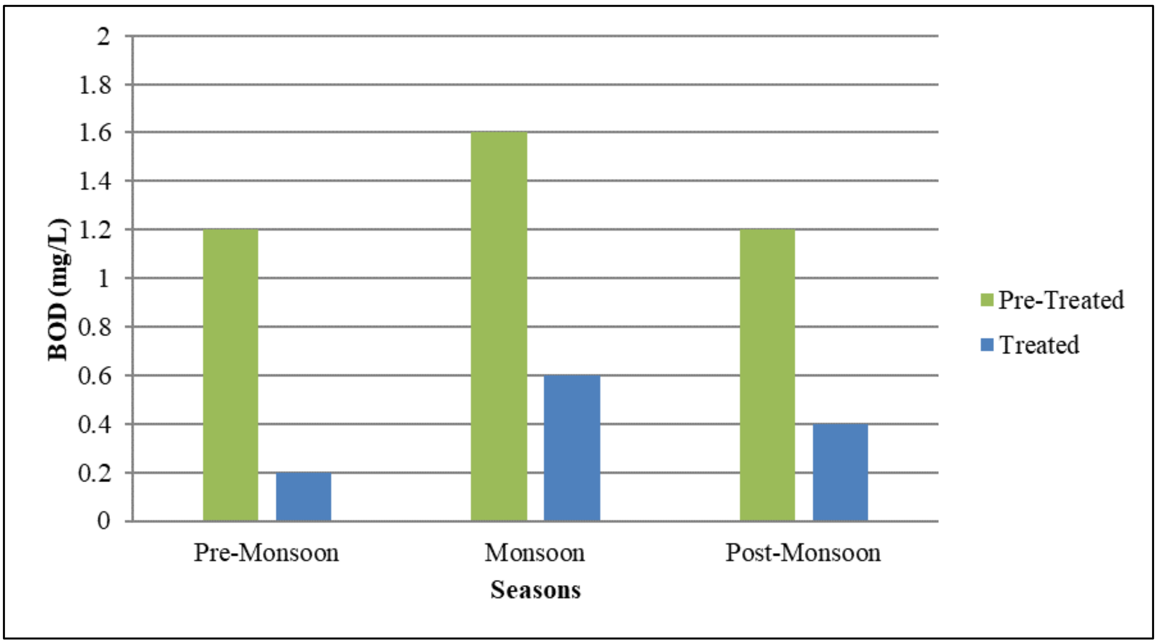


Fig. 4.24 BOD content of the water during 2019-20.

Table 4.12 Two-way analysis of variance for the BOD content of water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	1.6613	11	0.151022727	40.273	0.000	2.81793047
Water Sample Type	2.3438	1	2.34375	625.000	0.000	4.84433567
Error	0.0412	11	0.00375			
Total	4.0463	23				

4.1.13 Total Coliform

The minimum and maximum values were recorded in both the years for pre-monsoon season and monsoon season respectively. The total coliform in pre-treated water ranged between MPN index of 2 and MPN index of 3 during 2018-19, and MPN index of 2 and MPN index of 4 during 2019-20. In treated water, the MPN index of 0 was recorded in both years.

Statistically, the two-way ANOVA for total coliform of water has shown a significant ($p<0.05$) variation between the water type (F = 100) i.e., pre-treated water and treated water (**Table 4.13**). In case of pre-treated water, a positive significant ($p<0.01$) correlation was observed with turbidity (r = 0.909), acidity (r = 0.804) and BOD (r = 0.915). However, total coliform was negatively correlated with the pH, total hardness, and total alkalinity. The Pearson correlation coefficient between various water quality characteristics has been presented in **Appendix- II & III**.

Table 4.13 Two-way analysis of variance for total coliform count in water.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	4.458333333	11	0.40530303	1	0.5	2.81793
Water Sample Type	40.04166667	1	40.04166667	1E+02	8E-07	4.84434
Error	4.458333333	11	0.40530303			
Total	48.95833333	23				

4.2 Pollutant Removal Efficiency of the Water Treatment Plant

The main purpose of a water treatment plant is to provide safe water for human consumption. The pollutants removal efficiency of the water treatment plant (WTP) at Champhai town has been computed. The percentage removal or increase in the concentration of the pollutant in the treated water has been calculated concerning the pre-treated water. The pollutant removal efficiency is as follows:

4.2.1 Turbidity

The turbidity removal efficiency of water treatment plant (WTP) ranged between 62.44% (pre-monsoon) and 75.95% (post-monsoon) during 2018-19, and between 46.15% (post-monsoon) and 71.43% (pre-monsoon) during 2019-20. (**Fig. 4.25**).

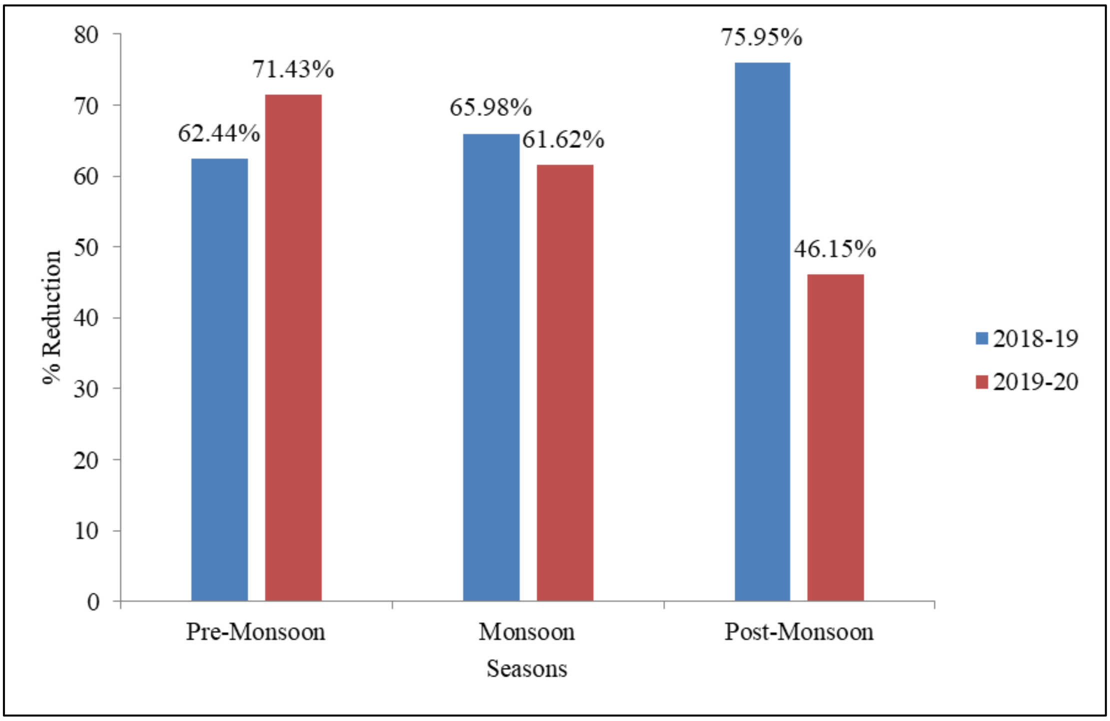


Fig. 4.25 Turbidity removal efficiency during study period.

4.2.2 Total Dissolved Solids (TDS)

The TDS removal efficiency of WTP ranged between 4.16% (monsoon) and 6.08% (post-monsoon) during 2018-19, and between 7.29% (post-monsoon) and 7.00% (monsoon) during 2019-20. (**Fig. 4.26**).

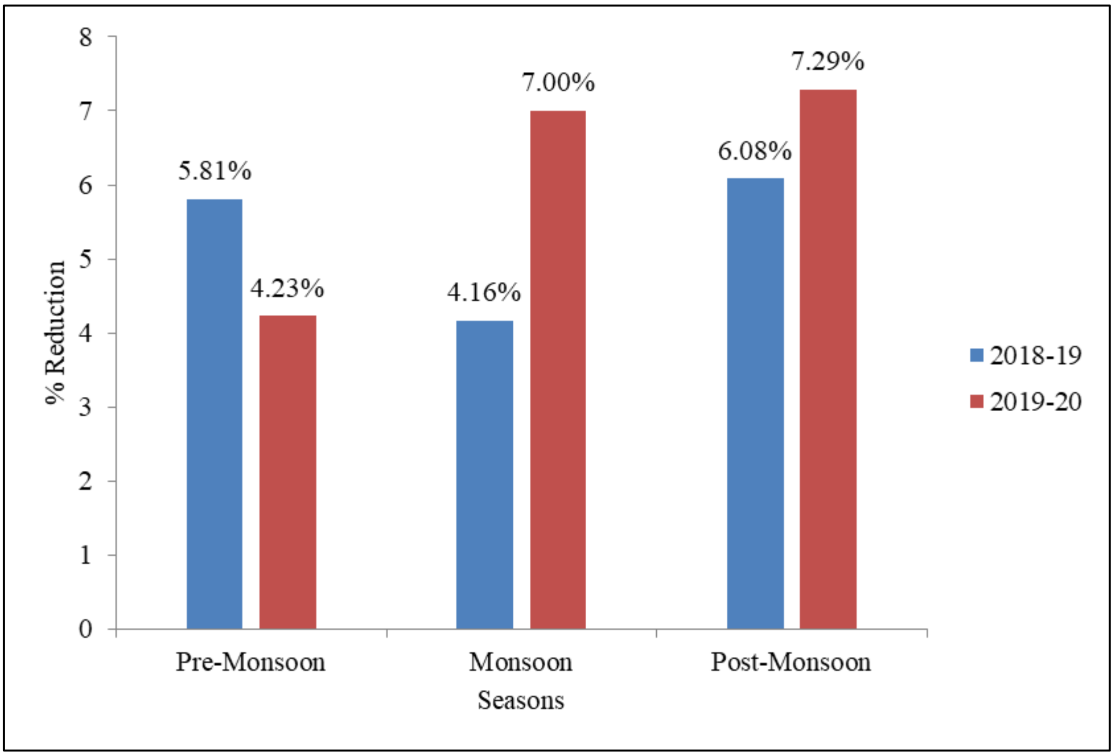


Fig. 4.26 TDS removal efficiency during study period.

4.2.3 Total Hardness

The total hardness removal efficiency of WTP ranged between 6.54% (monsoon) and 9.83% (post-monsoon) during 2018-19, and between 6.79% (post-monsoon) and 12.19% (pre-monsoon) during 2019-20 (**Fig. 4.27**).

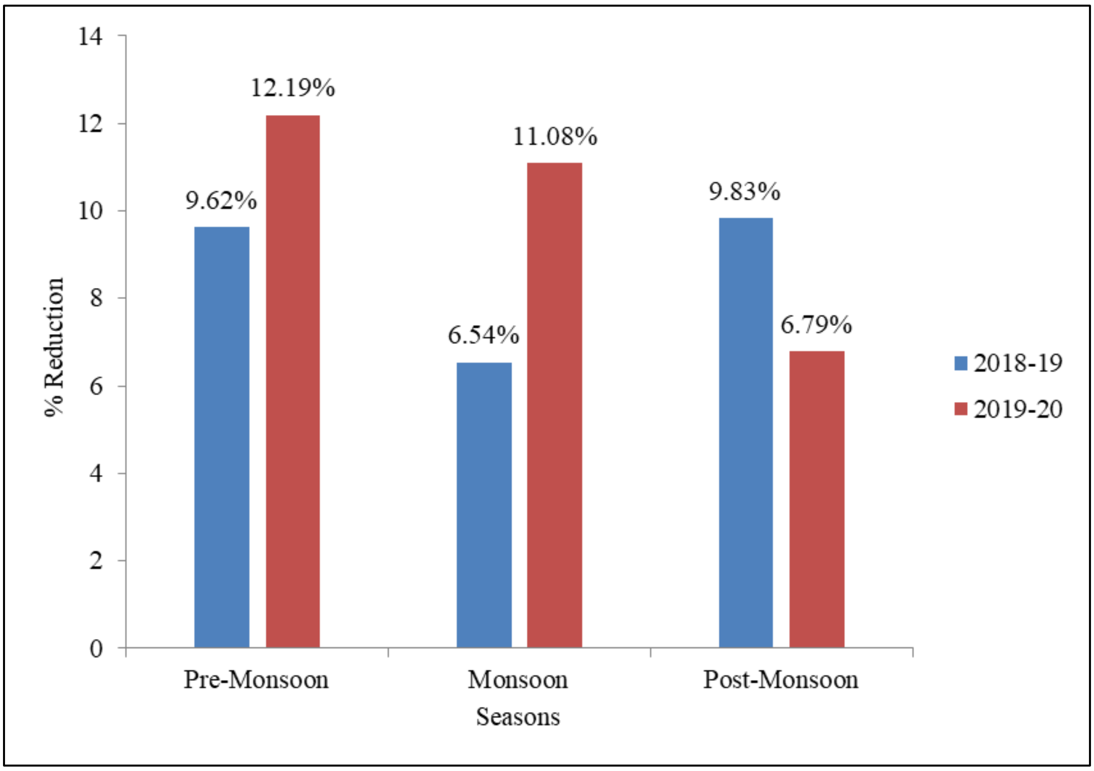


Fig. 4.27 Total Hardness removal efficiency during study period.

4.2.4 Total Alkalinity

The total alkalinity removal efficiency of WTP ranged between 5.54% (post-monsoon) and 7.84% (monsoon) during 2018-19, and between 2.90% (post-monsoon) and 8.96% (pre-monsoon) during 2019-20 (**Fig. 4.28**).

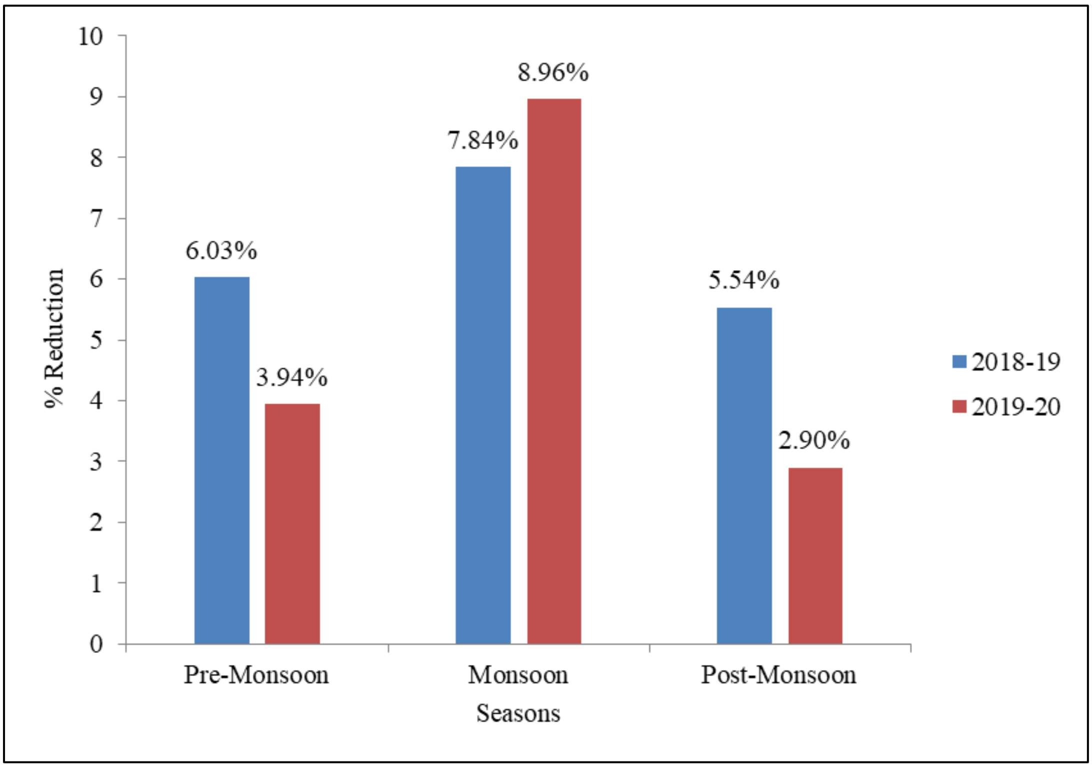


Fig. 4.28 Total Alkalnity removal efficiency during study period.

4.2.5 Acidity

The acidity removal efficiency of WTP ranged between 21.12% (post-monsoon) and 54.12% (monsoon) during 2018-19, and between 11.91% (post-monsoon) and 58.93% (monsoon) during 2019-20 (**Fig. 4.29**).

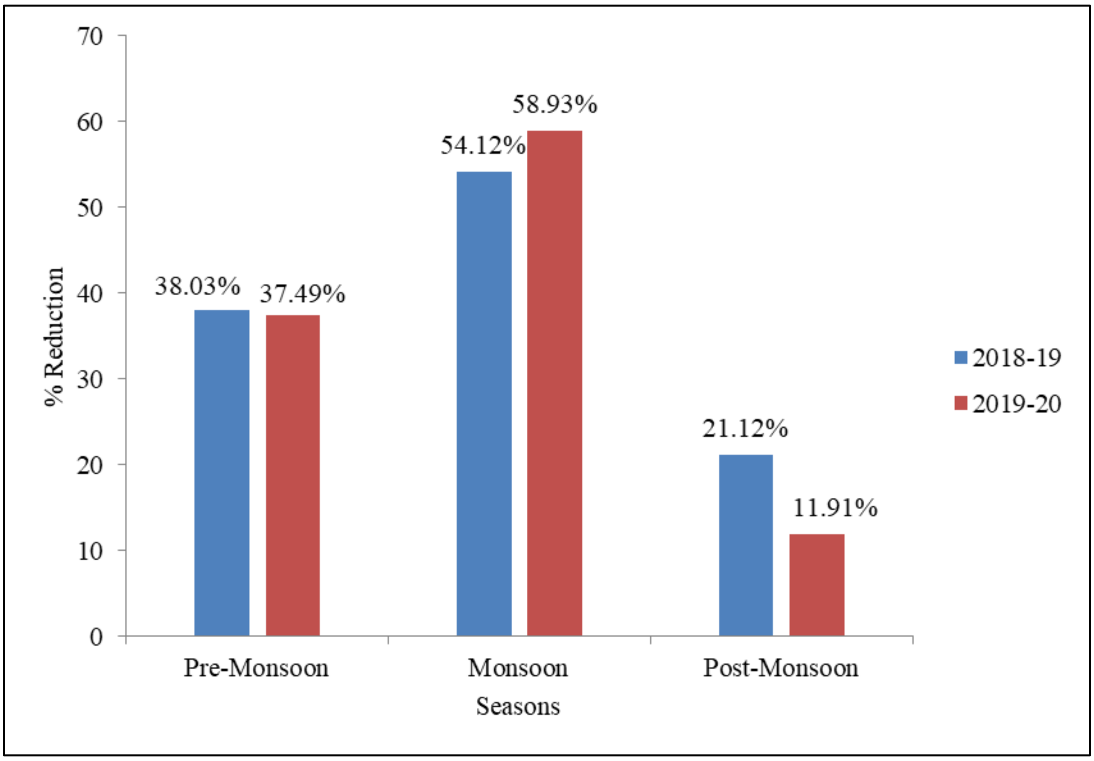


Fig. 4.29 Acidity removal efficiency during study period.

4.2.6 Dissolved Oxygen (DO)

The WTP helped in increase of DO content which ranged between 22.97% (post-monsoon) and 27.69% (pre-monsoon) during 2018-19, and between 18.75% (post-monsoon) and 25.00% (pre-monsoon) during 2019-20 (**Fig. 4.30**).

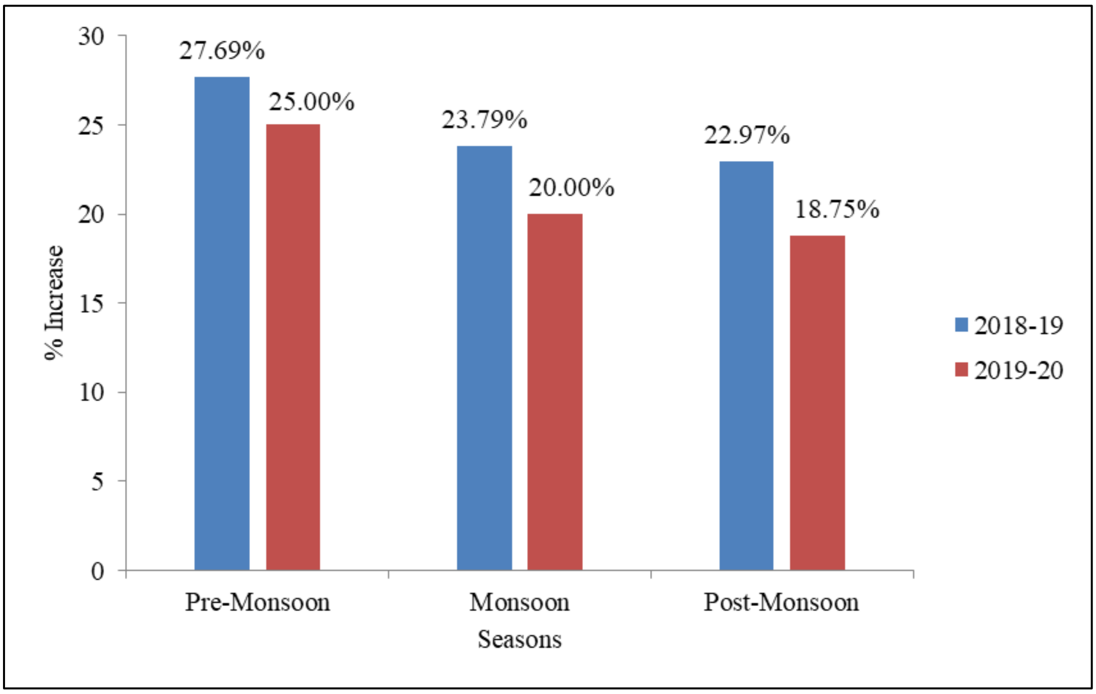


Fig. 4.30 DO increase efficiency during study period.

4.2.7 Biochemical Oxygen Demand (BOD)

In contrary to DO, the WTP leads to decrease in the BOD content which ranged between 55.56% (monsoon) and 83.33% (pre-monsoon) during 2018-19, and between 62.50% (monsoon) and 83.33% (pre-monsoon) during 2019-20 (**Fig. 4.31**).

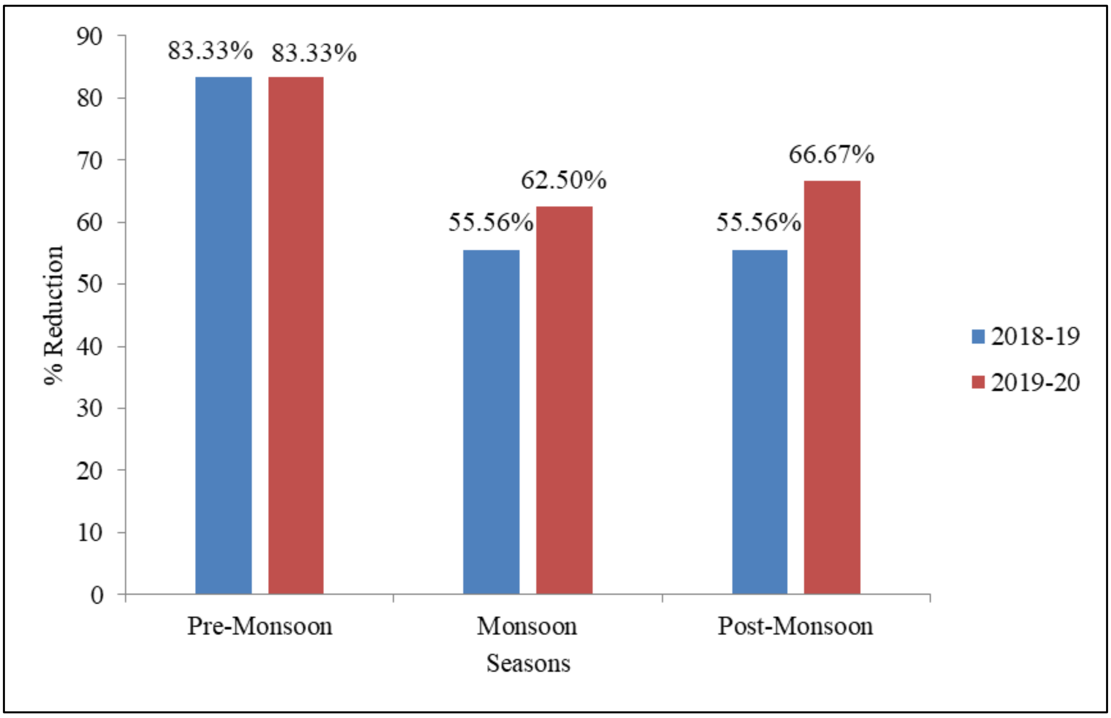


Fig. 4.31 BOD removal efficiency during study period.

4.3 Water Quality Index (WQI)

The water quality index (WQI) of pre-treated and treated water from Tuipui river was computed to work out the impact of impurities and pollutants on the water quality and their acceptance for human consumption. The water quality standard prescribed by various scientific agencies, ideal values and the *k*-value for each water quality attributes are presented in **Table 4.14**. The computation for WQI was done by using the Weighted Arithmetic WQI Method and the findings was campared against the status of water given in **Table 4.17**.

Table 4.14 Water quality standards, ideal values and *k*-value for water quality attributes as prescribed by various scientific agencies for calculating WQI.

S/No	Parameters	Agencies	Standard values (S_n)	Ideal value (V_{id})	*k*-value
1	Turbidity	ICMR	2.5	0	0.0914
2	TDS	BIS	300	0	0.0914
3	pH	BIS	7.5	7	0.0914
4	T. Hardness	BIS/ICMR	300	0	0.0914
5	T. Alkalinity	BIS	200	0	0.0914
6	Chloride	BIS/USPH	250	0	0.0914
7	Phosphate-P	USPH	0.1	0	0.0914
8	Nitrate-N	BIS/USPH	45	0	0.0914
9	DO	USPH	6	14.6	0.0914
10	BOD	WHO	5	0	0.0914

ICMR: Indian Council of Medical Research; BIS: Bureau of Indian Standards;
USPH: United States Public Health; WHO: World Health Organisation.

The WQI for pre-treated water observed to be 42.38 and the quality of the pre-treated water falls under Grade-B (26 – 50), designated as "good quality (slightly polluted)" (**Table 4.15**). The WQI for treated water was observed to be 27.42 and the quality of treated water falls under Grade-B (26 – 50), and designated as "good quality (slightly polluted)" (**Table 4.16**). Monthly values of WQI during the study period and variations of WQI with average rainfall can be found in **Appendix - IV & V**.

Table 4.15 Water Quality Index (WQI) of pre-treated water from Tuipui river.

Parameters	**S_n**	**$1/S_n$**	***k***	**$W_n = (k/S_n)$**	**Ideal value (V_{id})**	**Mean conc. Value (V_n)**	**V_n/S_n**	**$Q_n = V_n/S_n*100$**	**W_nQ_n**
Turbidity	2.5	0.4	0.0914	0.036570128	0	15.05	6.02	602.000	22.01522
TDS	300	0.0033	0.0914	0.000304751	0	35.33	0.118	11.777	0.003589
pH	7.5	0.1333	0.0914	0.012190043	7	7.28	0.187	18.667	0.227547
T.Hardness	300	0.0033	0.0914	0.000304751	0	36.63	0.122	12.210	0.003721
T.Alkalinity	200	0.005	0.0914	0.000457127	0	55.68	0.278	27.840	0.012726
Chloride	250	0.004	0.0914	0.000365701	0	0.44	0.002	0.176	6.44E-05
Phosphate-P	0.1	10	0.0914	0.914253208	0	0.02	0.2	20.000	18.28506
Nitrate-N	45	0.0222	0.0914	0.002031674	0	0.11	0.002	0.244	0.000497
DO	6	0.1667	0.0914	0.015237553	14.6	6.36	0.858	85.833	1.30789
BOD	5	0.2	0.0914	0.018285064	0	1.43	0.286	28.600	0.522953
				$\Sigma W_n = 1$				**$\Sigma W_nQ_n = 42.37926904$**	
								WQI = 42.38	

Table 4.16 Water Quality Index (WQI) of treated water from Tuipui river.

Parameters	**S_n**	**$1/S_n$**	***k***	**$W_n = (k/S_n)$**	**Ideal value (V_{id})**	**Mean conc. Value (V_n)**	**V_n/S_n**	**$Q_n = V_n/S_n*100$**	**W_nQ_n**
Turbidity	2.5	0.4	0.0914	0.036570128	0	5.14	2.056	205.60	7.518818
TDS	300	0.0033	0.0914	0.000304751	0	34.04	0.113	11.35	0.003458
pH	7.5	0.1333	0.0914	0.012190043	7	7.27	0.18	18.00	0.219421
T.Hardness	300	0.0033	0.0914	0.000304751	0	33.86	0.113	11.29	0.00344
T.Alkalinity	200	0.005	0.0914	0.000457127	0	52.94	0.265	26.47	0.0121
Chloride	250	0.004	0.0914	0.000365701	0	4.31	0.017	1.72	0.00063
Phosphate-P	0.1	10	0.0914	0.914253208	0	0.02	0.2	20.00	18.28506
Nitrate-N	45	0.0222	0.0914	0.002031674	0	0.11	0.002	0.24	0.000497
DO	6	0.1667	0.0914	0.015237553	14.6	7.78	0.71	71.04	1.082501
BOD	5	0.2	0.0914	0.018285064	0	0.8	0.16	16.00	0.292561
				$\Sigma W_n = 1$				**$\Sigma W_nQ_n = 27.41849029$**	
								WQI = 27.42	

Table 4.17 Categories for water quality based on WQI

Grading	**WQI**	**Status**	**Tuipui river grade**
A	0 – 25	Excellent quality	
B	26 – 50	Good quality (Slightly polluted)	Pre-treated, Treated
C	51 – 75	Poor quality (Moderately polluted)	
D	76 – 100	Very poor quality (Polluted)	
E	>100	Unsuitable (Excessively polluted)	

CHAPTER – 5

DISCUSSION

DISCUSSION

5.1 Assessment of Water Quality Parameters

There are a variety of chemical, physical and biological substances that are present in water. It also contains several organisms that can react with the physical and chemical elements present in the water. The physical, chemical and biological characteristics of water help in determining the health of aquatic ecosystem (Henry and Heinke, 1996; Venkatesharaju *et al.*, 2010).

In modern days, due to presence of toxic and hazardous chemicals that were discharged into the environment, raw water supplies are generally not immune from contaminations. Setting of water quality standards is therefore necessary. Determination of river water quality is of great importance because river water is generally used for public water supply, domestic purposes, agriculture and many other ways (Sincero and Sincero, 1996; Venkatramanan *et al.*, 2014).

Various scientific agencies such as United States Public Health (USPH, 1962), Bureau of Indian Standards (BIS, 2012), Indian Council of Medical Research (ICMR, 1975) and World Health Organization (WHO, 2008) have set up standards for different water quality parameters. The water quality standards for drinking water given by various scientific agencies and range of values obtained in present study is presented in **Table 5.1**.

Table 5.1: Water quality standards given by various scientific agencies and range of values during present investigation.

Parameters	Water Quality Standards				Range of water quality during study period	
	USPH	BIS	ICMR	WHO	Pre-treated	Treated
Temperature *(℃)*	N/A	40	N/A	30	16.9 - 24.59	18 - 24.62
Turbidity *(NTU)*	5	1	2.5	5	2.1 - 34.89	0.6 - 11.87
TDS *(mg/L)*	500	300	500	1000	29.48 - 45.37	28.78 - 43.45
pH	6.0 to 8.5	6.5 to 8.5	6.0 to 8.5	6.5-9.2	6.9 - 7.2	7.1 - 7.3
Total Hardness *(mg/L $CaCO_3$)*	N/A	300	300	300	30.12 - 47.83	27.16 - 42
Total Alkalinity *(mg/L $CaCO_3$)*	120	200	200	200-600	45.66 - 78.83	42.08 - 74.08
Acidity *(mg/L $CaCO_3$)*	N/A	N/A	N/A	N/A	16.67 - 50.33	10.33 - 22.33
Chloride *(mg/L)*	250	250	200	250	0.32 - 0.57	4 - 4.9
Phosphate-P *(mg/L)*	0.1	N/A	N/A	N/A	0.01 - 0.02	0.01 - 0.02
Nitrate-N *(mg/L)*	45	45	150	50	0.1 - 0.12	0.1 - 0.12
DO*(mg/L)*	4.0-6.0	3	N/A	4.0-6.0	6.22 - 6.5	7.5 - 8.3
B.O.D *(mg/L)*	N/A	N/A	N/A	5	1.2 - 1.8	0.2 - 0.8
Total Coliform *(MPN)*	N/A	nil/100ml	N/A	nil/100ml	2.0 - 4.0	0

5.1.1 Temperature

Temperature is one important factor that can influence the biochemical processes in the aquatic system and is known to influence the pH, alkalinity and DO concentration in water. It also has a direct effect on the aquatic life as it can reduce the DO concentration in water, which can cause unavailability of oxygen for respiration by aquatic animals (Kumar *et al.*, 2010; Firozia and Sanalkumar, 2013). In slow flowing rivers and lakes, the surface water gets heat up rapidly during summer than the water below it. However, the aquatic ecosystem rarely exceeds temperature of 37°C. Temperature of water varies depending on the ambient air temperature, geographical locations, seasons and chemical reactions that took place in the water body (Henry and Heinke, 1996; Warren, 1971; Ahipathi and Puttaiah, 2006).

The findings of present investigation depict that water temperature was increased from pre-monsoon to monsoon season and then slowly decreased from monsoon to post-monsoon season. A similar trend in results has been observed in both the years. The temperature was found to be highest during the monsoon season for both the years. This may be due to the discharge and decomposition of organic matters into the water bodies due to surface runoff which resulted in a rise in temperature as influenced by microbial activities. The temperature range is well within the standards given by various scientific agencies. The findings conform to the work of Sunar and Mishra (2016), Mishra *et. al.*, (2009), Chenkual *et. al.*, (2016), Lalparmawii (2012), Mishra and Tripathi (2000, 2001 and 2003), Singh and Gupta (2010), Karmakar and Biswas (2016) and Khatoon *et. al.*, (2013).

5.1.2 Turbidity

Turbidity is the generally indicated by the presence of cloudiness in water. It has an inverse relationship with penetration of light i.e., when turbidity is high, light penetration is low and vice versa. It is mainly caused by the presence of suspended solids, colloidal particles and coarse dispersion of sewage (Kataria, 1995). Control of turbidity in public water supply is done because it makes drinking water unpalatable. Apart from being aesthetically objectionable, turbidity is also a health concern because colloidal particles can possess harmful pathogens. Increase of turbidity in river water may be due to heavy rainfall causing soil erosion and discharge of large amount of sand, silt and other debris into water bodies (Munshi and Singh, 1991; Eyarin Jehamalar *et. al.*, 2010).

The findings reveal that there is a very high turbidity during the monsoon season which is above the permissible limit set by different water quality standards. For pre-monsoon season and post monsoon season, the turbidity values were within the permissible limit. The high turbidity during monsoon season was mainly due to the influx of clay and soil particles into the river during heavy rainfall. Surface runoff may also be the reason for increase in turbidity value during monsoon season. The treatment plant does not remove turbidity of river water to a desired pace in monsoon season. Similar observations have also been reported by Chenkual *et. al.,* (2016), Sunar (2018), Thasangzuala and Mishra (2014), Trivedi *et. al.,* (2010), Joshi *et. al.,* (2009) and Singh *et. al.,* (2012).

5.1.3 Total Dissolved Solids (TDS)

TDS measures the dissolved impurities present in water. Increase in TDS of water can be an indication of the presence of extraneous pollutant source (Kataria *et. al.,* 1996). Presence of high amount of dissolved, suspended and total solids in water affects the quality of water and can make it unsuitable for agricultural and drinking purposes. Higher amount causes psychological effects on the human system (Garg, 2021).The TDS of water may vary from season to season and affects the quality of water. High concentration of TDS in water may also be due to increase in nutrient content (Imtiyaz *et. al.,* 2012; Singh and Mathur, 2005).

The findings reveal that TDS values were within the permissible limits given by different scientific agencies. Higher TDS values have been recorded during the pre-monsoon and post-monsoon season which may be due to the low volume of river water during these seasons. The findings are in conformity with the work of Laldintluanga *et. al.,* (2016), Ranjith *et. al.,* (2020) and Kumar *et. al.,* (2015).

5.1.4 pH

pH is the measurement of hydrogen ion concentration. The pH of water greatly influences the chemical and biochemical reactions in the water bodies. Most of the metabolic activities that occur in aquatic ecosystem are pH dependent. pH below 7 are acidic whereas, pH higher than 7 are alkaline. Greater toxicity is observed in acidic water than in alkaline water (Abed and Jazie, 2014; Singh *et. al.*, 1989; Jehangir *et. al.*, 2011).

The findings depict that the pH values were within the permissible limit as given by different water quality standards. The low pH observed during the monsoon season indicates high rate of decomposition of organic matter present in water. Presence of carbonic acid in river water could also be a reason for above. Similar results were also reported by Sunar *et. al.*, (2016), Mishra and Tripathi (2000, 2001, and 2003), Gandotra *et. al.,* (2008), Suresh *et. al.,* (2011) and Laldintluanga *et. al.*, (2016).

5.1.5 Total Hardness

Total hardness is the total sum of calcium and magnesium present in the water. Temporary hardness is caused due to the presence of bicarbonates and carbonates of calcium and magnesium salts whereas, permanent hardness is caused due to the presence of chlorides and sulphates of calcium and magnesium. The inability of water to form lathering from soap solution is an indication of hardness of water (Kalra *et. al.,* 2012). Sawyer (1960) and Saravanakumar and Kumar (2011) have classified water as follows:

Water quality	***Total Hardness value (mg/L $CaCO_3$)***
Soft	0 – <75
Moderately hard	75 – <150
Hard	150 – <300
Very Hard	>300

On the basis of the above classification, the water quality of supply water at Champhai town falls under soft water category. The study depict that total hardness was highest for pre-monsoon season. Evaporation of water, inflow of sewage containing calcium and magnesium salts as well as soaps and detergents into the river water may cause for the higher values during pre-monsoon season. Whereas, dilution of the river water by rainwater may be one of the important factors for the lower value of total hardness during the monsoon season. A similar trend in result was reported by Mishra and Tripathi (2000, 2001, and 2003), Singh and Gupta (2010), Hafizurrahman *et. al.,* (2016), Laldinpuii (2021) and Bozniak *et. al.,* (1968).

5.1.6 Total Alkalinity

Total alkalinity is primarily caused due to the presence of carbonate and bicarbonate ions in the water. Alkalinity is used as a measure of productivity of natural waters. It is the measure of presence of concentration of ions that will neutralize the hydrogen ions in water and it also reflects on the carbonates, hydroxide contents, phosphates, sulphates and nitrates in surface water (Shinde *et. al.,* 2011; Erondu and Chindah, 1991; Singh *et. al.,* 2010). Schaeperclaus (1990) categorized the aquatic ecosystem into three groups based on their alkalinity values as follows:

Water quality	***Total Alkalinity value (mg/L $CaCO_3$)***
Less Productive	0 – 15
Medium Productive	15 – 100
Highly Productive	100 – 250

Based on the category given above, the water quality of Tuipui river falls under the medium productive group. Total alkalinity of treated and pre-treated water showed highest value during pre-monsoon and lowest value during monsoon season. Less volume of water in the river during pre-monsoon season and the inflow of sewage lead to high alkalinity. Alkalinity is mainly due to the presence of bicarbonates, carbonates and hydroxides of calcium, magnesium, sodium and potassium in the water (Chenkual *et. al.*, 2014). Dilution of river water by heavy rainfall during the monsoon season may lead to lower values. All the values obtained are within the permissible limit of water quality standards. The findings are in conformity with the works of Mishra and Tripathi (2000, 2001 and 2003), Gangwar *et. al.*, (2012), Khatoon *et. al.*, (2013), Laldinpuii (2021) and Ayoade *et. al.*, (2009).

5.1.7 Acidity

Acidity in water is the capacity to neutralize strong base to a designated pH. Acidity influences the chemical reactions and biological activities in the water bodies. The major component of acidity in natural water is carbon dioxide and it also contributes to the corrosiveness of water (Mishra, 2009). There are two types of acidity viz. mineral acidity (pH < 4) and CO_2 (pH of 8.5).

In the present investigation, higher values of acidity were observed during the monsoon season. The practice of jhum cultivation (slash and burn) during the pre-monsoon months every year has resulted in the release of more carbon dioxide and other particulate substances in the air. This carbon dioxide in the atmosphere reaches the river water in the form of precipitation which may cause higher acidity during the monsoon season. The findings are in conformity with the work of Laldintluanga *et. al.*, (2016), Lalparmawii (2012), Lalchhingpuii (2011) and Mishra *et. al.*, (2000).

5.1.8 Chloride

Chloride in aquatic ecosystem is present normally in the form of salts of sodium (NaCl), potassium (KCl), and calcium chloride ($CaCl_2$). Chloride content in water may increase due to disposal of sewage, industrial wastes and decomposition of organic matters (Sirsath *et. al.,* 2016).

The findings of present study reveal that the chloride content of water samples were within the permissible limit given by scientific agencies. However, the presence of organic matters and surface run-off may cause a slight increase in chloride content during the monsoon season. The treated water goes through chlorination process for disinfection, which increased the chloride content of treated water. The findings are in conformity with the works of Jain (1999), Mishra and Tripathi (2000, 2001, 2003) and Rout *et. al.,* (2016).

5.1.9 Phosphate-P

Presence of phosphate in water promotes floral growth and phytoplankton production. The main sources of phosphate in water are domestic sewage, industrial wastes, agriculture runoff and fertilizers. In high concentration, phosphate can lead to eutrophication and depleting the dissolved oxygen in water (Sharma *et. al.,* 2004; Davie, 2003; Koshy and Nayar, 2000).

The phosphate-P content of the pre-treated and treated water was higher in monsoon season. Surface runoff, leaching from rocks and soil, and anthropogenic sources can cause the increase of phosphate-P content during the monsoon season. With the use of fertilizers and other phosphate containing compounds for harvesting crops in the field, some amount of phosphate-P is released into the river water by surface run-off. However, the concentrations present in the water bodies are within the permissible limit. Similar trends in results were also reported by Mishra *et. al,.* (2000), Chenkual and Mishra (2016), Sah *et. al.,* (2000), Lalchhingpuii *et. al.,* (2011), Laldinpuii (2021) and Singh *et. al.*, (2010).

5.1.10 Nitrate-N

Presence of nitrate-N in water is mainly caused by the agricultural drainage, leachate from wastes piles, nitrogenous waste product human and industrial wastes (Parvizishad M. *et. al.,* 2017; Kirmeyer *et. al.,* 1995). Presence of high concentration of nitrate in water can lead to methemoglobinemia also known as blue baby syndrome.

The higher values during the monsoon season may be due to the runoff from agricultural land that contains inorganic fertilizers and manures, leachate from wastes and transformation of organic matters to nitrate by mineralization and hydrolysis (Ward *et al.,* 2005; Cartes *et al.,* 2009). The values are within the permissible limit given by various scientific agencies. A similar trend in results was observed by Lalchhingpuii *et al.,* (2011), Prabu *et al.,* (2008), Laldinpuii (2021), and Fatema *et al.,* (2014).

5.1.11 Dissolved Oxygen (DO)

DO content of water depends on physical, chemical, and biological activities in water. Oxygen is generally absorbed by water from the atmosphere but is consumed by unstable organic matters for oxidation. If oxygen present in water is found to be less than saturation level, it indicates the presence of organic matter and consequently makes the water suspicious. Thus, DO content has been extensively used as a measure of the degree of freshness of water (Fakayode, 2005).

The DO content of the treated and pre-treated water was higher during the pre-monsoon season than the other seasons. The higher value of DO content in treated water was mainly due to aerations of water during the transmission of water through different pumping stations. Reduction of microbial activities and low organism respiratory demand during winter season may also lead to higher DO content during post-monsoon season. The lower DO content during monsoon season may be caused by the increase in microbial activities due to presence of high organic material load through surface run-off resulting in high temperature. A similar trend in results was observed by Mishra and Tripathi (2001, 2003), Srivastava *et. al.,* (2009), Laldinpuii (2021) and Jitendra *et. al.,* (2008).

5.1.12 Biochemical Oxygen Demand (BOD)

BOD represents the level of organic matter contamination in the surface water. Low BOD content indicates good water quality, whereas high BOD content denotes presence of organic matter. Whenever DO level decreases, the BOD level increases due to the consumption of oxygen available in the water by microorganisms during process of decomposition (Metcalf and Eddy, 2003; Agarwal and Rozgar, 2010).

The presence of organic matters and enhanced microbial activities may lead to higher BOD content during the monsoon season. Also, the huge influx of soil and other organic matters into the water bodies due to surface run-off during monsoon season results in the depletion of oxygen. The low temperature during winter season did not favor any microbial activities which may lead to low BOD content during the pre-monsoon season. The BOD content of the water was within the permissible limit. The findings are in conformity with the works of Mishra and Tripathi (2000, 2001), Chenkual *et. al.*, (2016), Lalparmawii and Mishra (2012) and Sunar and Mishra (2016).

5.1.13 Total Coliform

Coliform bacteria are those that found in the digestive tracts of animals, including human, and their wastes products. The can also be present in plant and soil materials. The most basic test for bacterial contamination of the water supply is by conducting a test for total coliform bacteria. Total coliform count gives a general estimate for the sanitary condition of water supply. Testing for coliform bacteria acts as an indicator for presence of harmful pathogens, because they came from the same sources as pathogenic organisms (Unc *et al*., 2004; Ryan *et al*., 2004).

The monsoon season showed the highest value of MPN index for total coliform bacteria. Due to the presence of several organic matters and runoff form the surface during rainy season, the detection of total coliform in the pre-treated water sample was very likely. The MPN index for total coliform bacteria in treated water was zero.

5.2 Pollutant Removal Efficiency of the Water Treatment Plant

Pollutant removal efficiency of the water treatment plant at PHE Champhai town had also been assessed during the study period. The water treatment plant at Champhai is based on the conventional water treatment system where the pre-treated Tuipui river goes through screening, sedimentation, filtration, and disinfection before being supplied to the public.

Turbidity removal efficiency was highest during post-monsoon season (2018-19) and pre-monsoon season (2019-20). However, turbidity of pre-treated water was very low during these seasons. The high turbidity during monsoon season was mainly due to surface run-off and presence of organic matters (Chenkual *et. al.,* 2016). After treatment of the water, the treated water still possesses high value of turbidity which was above the desired limit. This indicates the inability of the water treatment system to efficiently remove the turbidity of the source water. Improper mixing of coagulant, poor maintenance of sedimentation tank and filtration bed may be the main cause for the problem (Cheng *et. al.,* 2010).

The TDS removal efficiency was high during post-monsoon season (2018-19) and monsoon (2019-20). There was an increase in the TDS value of treated water during post-monsoon (2019-20), as compare to the pre-treated water. This indicates that the transportation of water through pipes may cause the increase of TDS in treated water. . Lack of necessary equipment to further reduce the total dissolve solid concentration may be the cause for the low efficiency of TDS removal.

Highest TH removal efficiency was observed during post-monsoon (2018-19) and pre-monsoon (2019-20). The annual average of removal efficiency was higher in 2019-20 compared to 2018-19. Low removal efficiency during monsoon season may be due to the lower concentration of hardness in the water. Deposits of carbonate scales in the equipment and pipes may also attribute to the low removal efficiency.

Highest TA removal was observed during monsoon seasons for both the years. However, the annual average of removal efficiency drops sharply from 2018-19 to 2019-20. The removal efficiency of TA during monsoon season appears to be high compared to pre-monsoon and post-monsoon season, but the removal percentage is very low. TA value of treated water increased compared to the pre-treated water during the post-monsoon (2019-20),. This may be due to the presence of carbonate scales and deposits in the pipes and tanks, and also, the addition of lime during coagulation process may attribute to the low removal efficiency of TA.

The acidity removal efficiency was found to be highest during monsoon seasons for both the years. The annual averages of efficiency for both the years are more or less the same. The high removal efficiency during monsoon season may be due to the high concentration of acidity during monsoon season, and most of the acidity eventually gets neutralized during treatment process.

The DO increase percentage (removal efficiency of oxygen-demanding matters) was highest during pre-monsoon season for both the years. The annual average of efficiency drops slightly from 2018-19 to 2019-20. Aeration of the water leads to proper removal of organic matters in the water and this may be the main reason for increase in DO for treated water. However, further increase of DO level can be attained from proper maintenance and improvement of treatment plant equipment.

The BOD removal efficiency was found to be highest during the pre-monsoon seasons for both the years and lowest during the monsoon season. The annual average of efficiency slightly increase from 2018-19 to 2019-20. The high efficiency during pre-monsoon may be due to the fact that, during this season, there is a low microbial activity due to low temperature. By increasing the aeration process and proper screening of water during intake to remove organic matters and suspended solids, the removal efficiency of BOD can be increased.

5.3 Water Quality Index (WQI)

WQI is a useful tool for the qualitative analysis of water bodies. It is possible to evaluate the existing quality conditions of water by classifying the water bodies into certain categories such as: excellent, good, poor, very poor, and unsuitable for drinking purposes (Ishaku *et. al.,* 2012; Igwe and Idris, 2019).

The WQI and the water quality attributes show that the pre-treated Tuipui river water is of good quality, but slightly polluted. However, during monsoon season, the intensity of turbidity tends to increase to a high degree which renders the pre-treated water unsuitable for consumption. The treated water also falls to the category of good quality water. Even though all the quality attributes of treated water were within the permissible limit, turbidity of water has been observed in the treated water during monsoon season. Slight cloudiness in the treated water during the monsoon season may be due to the presence of clay particles that passes through the filtration process during treatment of water.

CHAPTER – 6

MANAGEMENT STRATEGIES

MANAGEMENT STRATEGIES

The Greater Champhai Water Supply Scheme (2001) is based on a conventional water treatment system with the components such as screening tank at the intake of river water, sedimentation tank, filtration tank and disinfected using chlorinator and stored in the main reservoir for supply to the public (**Fig. 6.1**).

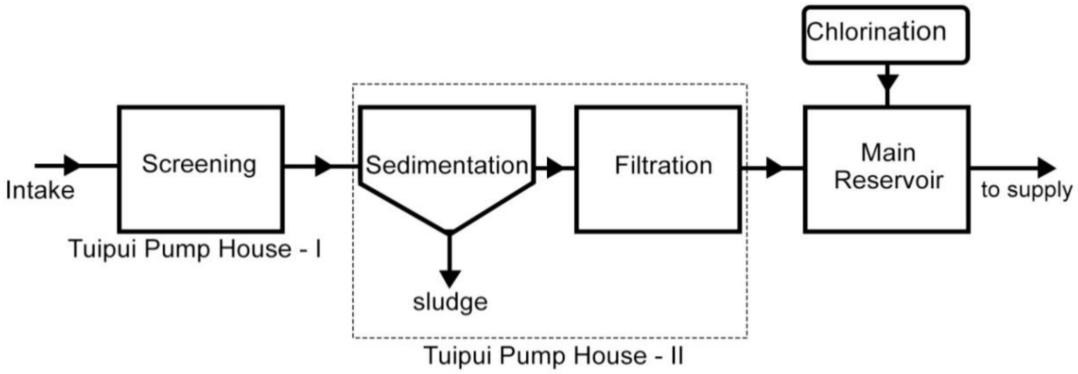


Fig. 6.1 Schematic diagram of water treatment plant at Champhai town, Mizoram.

For further improvement of the quality of treated water and to increase the working efficiency of the water treatment plant, the following management strategies have been formulated based on the observation of the present investigation on the pre-treated and treated water of Tuipui river, Champhai.

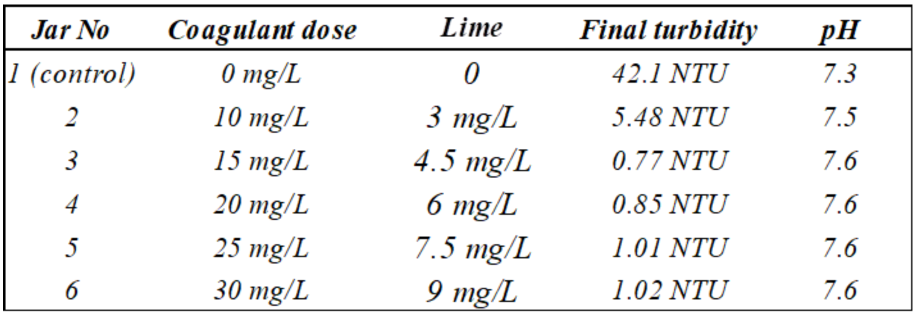
6.1 Proper Dosage of Coagulant for Turbidity Removal

It has been observed that there is no significant removal of turbidity during the monsoon season; this may be due to less dosage of coagulant or incomplete dispersion of the coagulant. The large amount of suspended matters such as silt, clay and other organic matters that enter into the river during monsoon season have resulted in high value of turbidity.

Since colloidal clay particles present in the water cannot settle down properly in the sedimentation tank, they pass through the filtration bed and resulted in the presence of cloudiness in the treated water. They can be removed by increasing their size by changing them into flocculated particles. For this purpose, certain chemical compounds called coagulants are added into the water, which on rapid mixing forms floc. Very fine colloidal particles get attracted and absorbed in these flocs, forming bigger sized particles that can easily be settling down in the sedimentation tank.

In light of this, a jar test was conducted to determine the optimum dose of coagulant required to bring the high turbidity of pre-treated water to clean water. For this experiment, PAC (poly-aluminium chloride) was used as a coagulant to treat the water sample along with 30% of the coagulant amount as lime. For the experiment, the water sample having high turbidity (42.1 NTU) was collected from Tuipui river during monsoon season. Coagulant with varying dosage was added to the water and the removal of turbidity was observed and presented in a tabular form **Table 6.1**.

Table 6.1 Jar test for optimum coagulant dosage.



Jar No	*Coagulant dose*	*Lime*	*Final turbidity*	*pH*
1 (control)	*0 mg/L*	*0*	*42.1 NTU*	*7.3*
2	*10 mg/L*	*3 mg/L*	*5.48 NTU*	*7.5*
3	*15 mg/L*	*4.5 mg/L*	*0.77 NTU*	*7.6*
4	*20 mg/L*	*6 mg/L*	*0.85 NTU*	*7.6*
5	*25 mg/L*	*7.5 mg/L*	*1.01 NTU*	*7.6*
6	*30 mg/L*	*9 mg/L*	*1.02 NTU*	*7.6*

From this experiment, it was observed that the amount of coagulant dosage required to bring down turbidity to permissible limit was 15 mg/L of PAC. Using this dose to treat the pre-treated water from the river resulted in removal of turbidity by 98.2%.

By conducting the same jar test every time the treatment plant is operating the water treatment process will help in improving the efficiency of the turbidity removal. The coagulant dosage also depends on the intensity of turbidity of the water, thus, it is a requirement to conduct jar test each time the plant is operational. This will result in more efficient and clean water treatment process.

6.2 Improvement of Treatment Plant

Determining the coagulant dosage for pre-treated water to remove turbidity in water sample is not enough to improve the quality of water because mixing of coagulant with water required mixing tank to work with in order to provide more efficient removal of turbidity.

To provide more efficient removal of turbidity, improvement of treatment plant by constructing or installing of a proper “mixing basin and flocculation tank” is required (**Fig. 6.2**). The process of addition of chemical (coagulant) and mixing (flocculation) is usually referred to as coagulation. The coagulated water then passed through the sedimentation tank where they settle down. Initially, rapid mixing is provided for the dispersal of the coagulant into the water and after that slow mixing is done during which growth of floc.

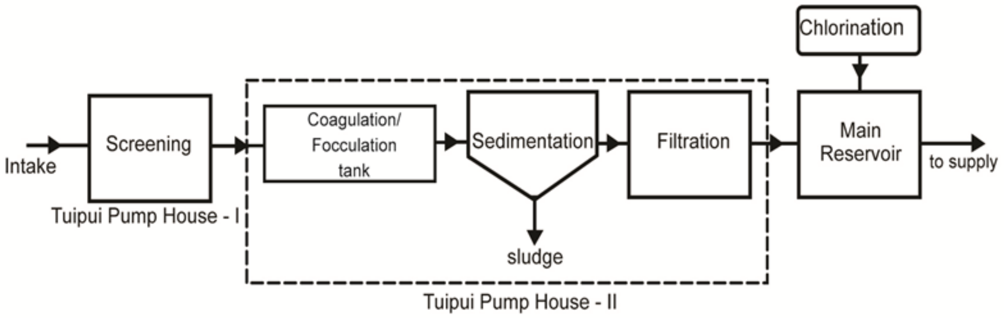


Fig. 6.2 Schematic diagram of water treatment plant at Champhai as per suggestion

The detention period inside the mixing basin varies from 0.5 to 2 minutes. From the mixing basin, the water is taken to a flocculation tank where a slow stirring motion will permit the buildup of more agglomeration of the floc particles. It generally takes 20 – 60 minutes for the detention period inside the flocculation tank, after which, the water will go into the sedimentation tank where the floc settles and are disposed as sludge. If these steps in improvement of the treatment plant could be implemented, it will result in more efficient treatment of water.

6.3 Proper Maintenance and Training of Plant Operators

The proper maintenance of the treatment plant can be more economical and a better solution. All the intricate components of the treatment plant requiring proper care and maintenance to run for a longer time are-

- Cleaning of the Sedimentation tank at an interval of 6 months will help in maintaining the efficiency of the treatment plant.
- Frequent washing of the filtration bed will also increase the efficiency and quality of the filtered water.
- Implementing the more efficient and economical technique in operation of the treatment plant will also save a lot of time, energy and money.

Training of plant operator regarding the addition of coagulant dose, cleaning of sedimentation tank and filtration tank, maintaining the pump and routine cleaning of the treatment plant is of paramount importance for more effective efficient operation of the treatment plant.

6.4 Suggested Preventive Measures for Water Treatment Plant (WTP)

The following preventive measures for better management of WTP can be suggested:

- Performing jar tests on pre-treated water samples when significant pre-treated water quality changes are observed.
- Regular inspection of sedimentation tank, filtration tank and different pipes and channels for accumulation of calcium carbonate scales. Frequent inspections are necessary if the built-up is severe.
- Cleaning of sedimentation tank annually to remove any accumulated sludge and algal growth. The accumulated sludge can lead to improper settlement of floc, and resulted in inefficient turbidity removal. Growth of algae and sludge with high organic content may impart taste and odor problems in the treated water.
- Turbidity of the effluent may be checked regularly whenever the water quality or flow rate changes.
- Presence of mud balls or air binding in the filter bed can be resulted in high head loss during filter run. To minimize the loss proper backwashing and control of flow rate is suggested.
- Improper backwashing and rapid flow rate can also damage the unit and may cause high turbidity.
- Inspection of chlorinators and storage tanks each day to ensure proper operation.
- Disinfection of water using chlorine can result in disinfection by-products (DBPs) and formation of trihalomethanes (THMs) in presence of organic

matters which may cause adverse health effects to human beings. To reduce the risks, proper screening of organic matters during intake and, elimination of organic substances as much as possible during treatment process are necessary.

- Testing of leak detectors and emergency equipment in every six months and verifying operator training in emergency procedures.

6.5 Other Viable Suggestions for Further Improvement of Efficiency of WTP

Based on the results obtained from the research work regarding the water quality parameters, the followings are the suggestive management measures for improvement of efficiency of water treatment plant (WTP):

- The TDS values before and after treatment was within the permissible limit, however, the removal efficiency of the TDS is very low. It is suggested that a regular cleaning and optimization of the treatment plant may be helpful in increasing the TDS reduction efficiency of the treatment plant.

- Total Hardness values were within permissible range. However, the removal efficiency of total hardness was quite low and this indicates that the water treatment plant may require more technological efforts to further reduce it.

- Regular scraping and cleaning of sedimentation tank and filtration tank are necessary to optimize the removal of total hardness. Installing and upgraded equipment may be helpful in optimizing the efficiency of treatment plant.

- Replacement of pipes and channels used for transferring of water from different areas in the treatment plant may improve functioning of water treatment unit.

- The coagulant dosage needs to be standardized and installation of chemical feeder is needed to adjust the quantity of coagulant added to the mixing tank and control the flow rate of the chemicals.

- Proper aeration of water to provide more oxygen for the decomposition of organic matters and proper screening before treatment of water.

CHAPTER – 7

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

7.1 Summary

Water is a chemical compound which is extremely useful for the sustenance of life. It is essential for the survival of all living beings. Among the vast distribution of water throughout the earth's system, surface waters that are readily accessible such as rivers, lakes, ponds and dams etc. are utilized for drinking purposes, irrigation and generation of power supply. Due to increase in population, many countries of the world are facing water shortages. Due to the growth of industries, factories and many other large scale production activities, water resources became polluted and unfit for public consumption, this problem adds to the water shortage crisis in the world today. The qualities of surface water in different areas are largely affected by the natural and anthropogenic activities such as industrial wastes, agricultural wastes and domestic waste disposal (Garg, 2021; Varol *et al.*, 2011).

Surface water mixed together with different kinds of undesirable substances during its travel across the agricultural lands and industrial areas. Agricultural return water may contain nitrates, phosphates, other elements and microorganisms from the soil. Contaminated water is responsible for the spread of different types of contagious diseases. Disease causing microorganisms (pathogens) can grow and multiply inside the host which results in an infection. Contamination by human feces is one of the main sources of pathogens in water bodies. The human feces of an infected individual may contain billions of these pathogens. If they enter into the water supply, they can cause epidemic of huge proportions (Hammer and Hammer, 1996).

Most rivers that flow in the country are highly contaminated due to discharge of industrial effluents and discharge of untreated sewages in to the water body. The degradation of water quality in our river ecosystem needs to be monitored and necessary measures should be taken to increase their utilization capability and to restore better water quality of the river ecosystem. Water supplies for public use are generally derived from rivers. To ensure the safety to public health, it is necessary to properly inspect, examine and treat the pre-treated water to a safe and permissible limit prior to supplying water for domestic use. Present day water treatment plants are designed to continuously supply water that fulfills the standards at every household. The present investigation was carried out with the objectives as follows:

1. To study the water quality of treated supply water in Champhai Town and pre-treated water at source point.
2. To determine pollutant removal efficiency of the water treatment plant.
3. To formulate appropriate management strategies for betterment of supply water

For detailed study, two sample sites for collection of water samples has been selected. Site 1 is River Tuipui, the source river where the pre-treated water was collected. This was taken as the reference site to compare result with the treated water. And, Site 2 is Darthlalang tlang main water reservoir, for collecting treated water samples.

During the research, water samples was accumulated from the Tuipui river (source point) before treatment (pre-treated water) and PHE treated water (treated water) on a monthly basis (in triplicate) for two successive years from February 2018 to January 2019, and February 2019 to January 2020 using plastic bottles with proper care. Water samples were brought to the laboratory in properly sealed bottles after collection. The various physicochemical characteristics namely, Turbidity, Total Dissolved Solids, Total Hardness, Total Alkalinity, Acidity, Chloride, Phosphate-P, Nitrogen-N, Dissolved Oxygen, Biochemical Oxygen Demand and Total Coliform were analyzed within the first 24 hours of sample collection. Temperature and pH of the water samples were measured at the sample collection sites and water samples were also fixed at the sampling site for dissolved oxygen (DO) estimation. Water samples were kept at 4°C storage before carrying out further analysis. Monthly observations have been computed on seasonal basis i.e., pre-monsoon season (February to May), monsoon season (June to September) and post-monsoon season (October to January). To check the validity and significance of the data observed during the study period, two-way analysis of variance (ANOVA) and Pearson correlation coefficient was also done.

7.1.1 Water Quality Parameters

The findings obtained from of the present investigation on the water quality of pre-treated and treated water can be sum up as follows:

1. Temperature of the water ranged from 16.95°C (post-monsoon, 2018-19) to 24.59°C (monsoon, 2019-20) for pre-treated water, and 18°C (post-monsoon, 2018-19) to 24.62°C (monsoon, 2019-20) for treated water. The value of temperature was found to be higher during the monsoon season and lower during the post-monsoon season.
2. Turbidity of the water ranged from 2.1 NTU (pre-monsoon, 2019-20) to 34.89 NTU (monsoon, 2018-19) for pre-treated water, and 0.6 NTU (pre-monsoon, 2019-20) to 11.87 NTU (monsoon, 2018-19) for treated water. It

was found that the turbidity value was higher during the monsoon season and lower during the pre-monsoon season for both the years.

3. Total dissolved solids (TDS) values ranged from 29.48 mg/L (post-monsoon, 2019-20) to 45.37 mg/L (pre-monsoon, 2019-20) for pre-treated water, and 28.78 mg/L (monsoon, 2018-19) to 43.45 mg/L (pre-monsoon, 2019-20) for treated water. The value of total dissolved solids (TDS) was found to be higher during the pre-monsoon season and lower during the monsoon season.
4. The pH ranged from 6.9 (monsoon, 2019-20) to 7.2 (pre-monsoon, 2018-19) for pre-treated water, and 7.1 (monsoon, 2019-20) to 7.3 (pre-monsoon, 2018-19) for treated water. The pH value was generally higher during the pre-monsoon season and low during the monsoon season for both the years.
5. Total hardness values ranged from 30.12 mg/L $CaCO_3$ (post-monsoon, 2018-19) to 47.83 mg/L $CaCO_3$ (pre-monsoon, 2019-20) for pre-treated water, and 27.16 mg/L $CaCO_3$ (post-monsoon, 2018-19) to 42 mg/L $CaCO_3$ (pre-monsoon, 2019-20) for treated water. The total hardness value was found to be higher during the pre-monsoon season and lower during the post-monsoon season.
6. Total alkalinity values ranged from 45.66 mg/L $CaCO_3$ (monsoon, 2018-19) to 78.83 mg/L $CaCO_3$ (pre-monsoon, 2018-19) for pre-treated water, and 42.08 mg/L $CaCO_3$ (monsoon, 2018-19) to 74.08 mg/L $CaCO_3$ (pre-monsoon, 2018-19) for treated water. The total alkalinity value was found to be higher during the pre-monsoon season and lower during the monsoon season.
7. Acidity values ranged from 16.67 mg/L $CaCO_3$ (pre-monsoon, 2018-19) to 50.33 mg/L $CaCO_3$ (monsoon, 2019-20) for pre-treated water, and 10.33

mg/L $CaCO_3$ (pre-monsoon, 2018-19) to 22.33 mg/L $CaCO_3$ (monsoon, 2018-19) for treated water. The acidity values were found to be higher during the monsoon season and lower during the pre-monsoon season.

8. The chloride content ranged from 0.32 mg/L (post-monsoon, 2018-19) to 0.57 mg/L (monsoon, 2018-19) for pre-treated water, and 4 mg/L (post-monsoon, 2018-19) to 4.9 mg/L (monsoon, 2019-20) for treated water. Chloride content was found to be higher during the monsoon season and lower during the post-monsoon season. Because of disinfection process, chloride content is higher in treated water.
9. The phosphate-P values ranged from 0.01 mg/L (pre-monsoon, 2018-19) to 0.02 mg/L (monsoon, 2018-19) for pre-treated water, and 0.01 mg/L (pre-monsoon, 2018-19) to 0.02 (monsoon, 2018-19) for treated water. The phosphate-P value was found to be higher during the monsoon season and lower during the pre-monsoon season.
10. The nitrate-N ranged from 0.1 mg/L (pre-monsoon, 2018-19) to 0.12 mg/L (monsoon, 2018-19) for pre-treated water, and 0.1 mg/L (pre-monsoon, 2018-19) to 0.12 mg/L (monsoon, 2018-19) for treated water. The nitrate-N value was found to be higher during the monsoon season and lower during the pre-monsoon season.
11. The dissolved oxygen (DO) values ranged from 6.22 mg/L (monsoon, 2018-19) to 6.5 mg/L (pre-monsoon, 2018-19) for pre-treated water, and 7.5 mg/L (monsoon, 2019-20) to 8.3 mg/L (pre-monsoon, 2018-19) for treated water. The dissolved oxygen (DO) content was found to be lower during the monsoon season and higher during the pre-monsoon season.

12. The biochemical oxygen demand (BOD values ranged from 1.2 mg/L (pre-monsoon, 2019-20) to 1.8 mg/L (monsoon, 2018-19) for pre-treated water, and 0.2 mg/L (pre-monsoon, 2019-20) to 0.8 mg/L (monsoon, 2018-19) for treated water. The biochemical oxygen demand (BOD) level was found to be higher during the monsoon season and lower during the pre-monsoon season.
13. Total coliform count ranged from 2 MPN/100mL (pre-monsoon, 2018-19) to 4 MPN/100mL (monsoon, 2019-20) for pre-treated water, and 0 MPN/100 mL for treated water.
14. Statistical analysis namely, two-way ANOVA and Pearson correlation coefficient were done to check on significance and validity of the data obtained.

7.1.2 Pollutant Removal Efficiency

The findings on present study on the pollutant removal efficiency of water treatment plant on key parameters can be summarized as follows:

1. The turbidity removal efficiency during the study period ranged from 64.44% (pre-monsoon) to 75.95% (post-monsoon) during 2018-19, and from 46.15% (post-monsoon) to 71.43% (pre-monsoon) during 2019-20.
2. The TDS removal efficiency during the study period ranged from 4.16% (monsoon) to 6.08% (post-monsoon) during 2018-19, and from 7.29% increase (post-monsoon) to 7.00% (monsoon) during 2019-20.
3. The total hardness removal efficiency during the study period ranged from 6.54% (monsoon) to 9.83% (post-monsoon) during 2018-19, and from 6.79% (post-monsoon) to 12.19% (pre-monsoon) during 2019-20.

4. The total alkalinity removal efficiency ranged from 5.54% (post-monsoon) to 7.84% (monsoon) during 2018-19, and from 2.90% (post-monsoon) to -8.96% (pre-monsoon) during 2019-20.
5. The acidity removal efficiency during the study period ranged from 21.12% (post-monsoon) to 54.12% (monsoon) during 2018-19, and from 11.91% (post-monsoon) to 58.93% (monsoon) during 2019-20.
6. The dissolved oxygen (DO) increase in the treated water (removal of organic matters) during the study period ranged from 22.97% (post-monsoon) to 27.69% (pre-monsoon) during 2018-19, and from 18.75% (post-monsoon) to 25% (pre-monsoon) during 2019-20.
7. The BOD removal efficiency during the study period ranged from 55.56% (monsoon) to 83.33% (pre-monsoon) during 2018-19, and 62.50% (monsoon) to 83.33% (pre-monsoon) during 2019-20.
8. The observed values of TDS, pH, TH, TA, Acidity were all within the permissible limits, however, the overall removal efficiency is low.
9. The increase in DO after treatment was found to be satisfactory, whereas, the BOD removal efficiency can be further optimized.

7.1.3 Management Strategies

1. A jar test was conducted to determine the coagulant dosage required for turbidity removal and it was found to be 15 mg/L of P.A.C with 30% of the coagulant as Lime.
2. However, it is suggested that, a regular jar test should be conducted every time the WTP is operated to produce the most desirable turbidity removal.
3. Cleaning and regular backwashing of sedimentation tank and filtration tank to obtained desirable results.

4. Optimization and upgrading of present operational unit will greatly improve the efficiency of treated water.
5. Training of plant operators and proper maintaining of the WTP will greatly improve the workings of the WTP and also decrease the financial requirement to repair or install new units.

The findings of present study on various water quality attributes are in conformity with the earlier works in the field of water quality assessment. The results revealed that there was a significant variation in some physical, chemical and bacteriological parameters. Of all the parameters during the study period, turbidity reading was the only parameter that crossed the permissible limit given by various scientific agencies. Other parameters were all in the normal and permissible range of water quality.

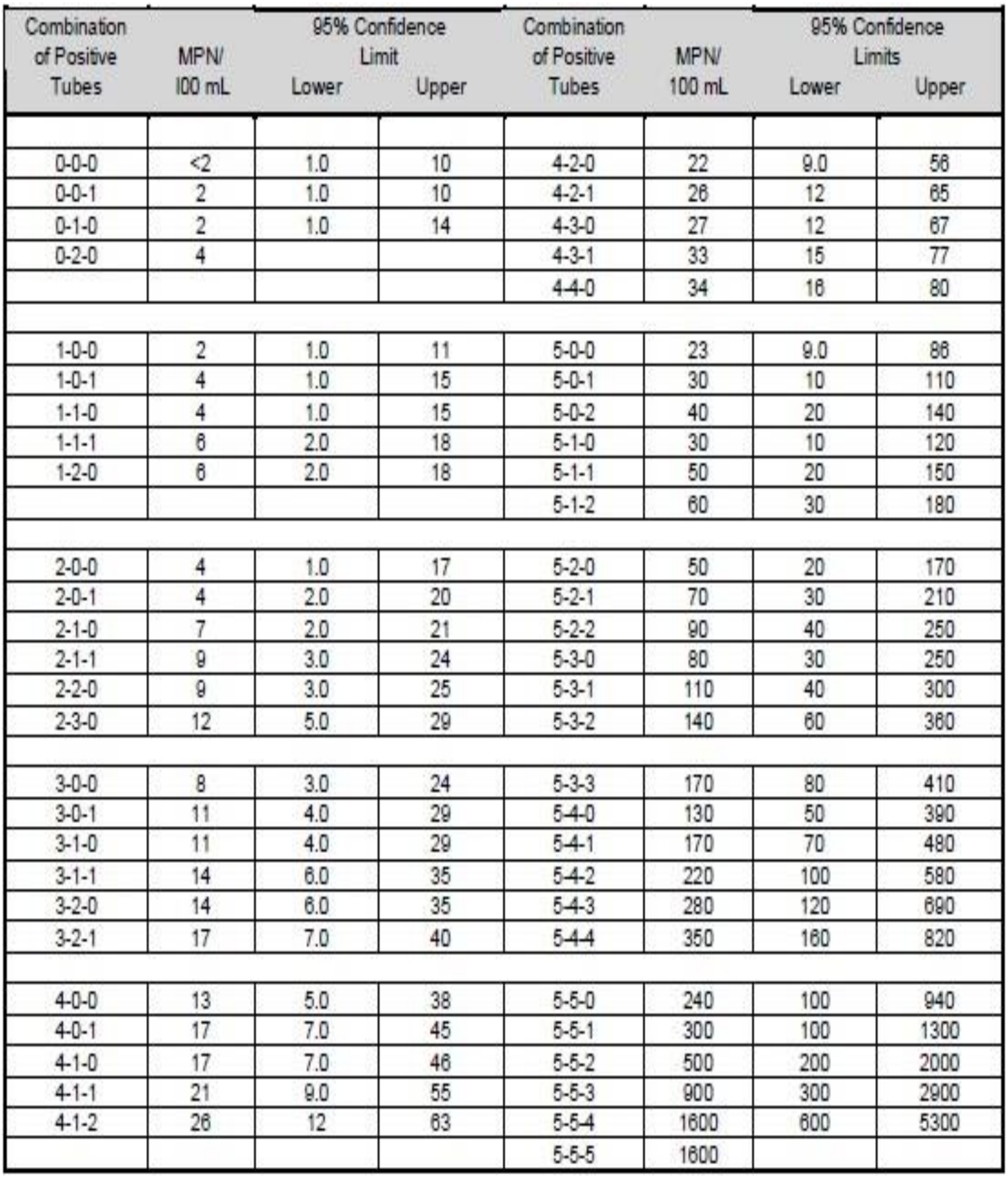
The high value of turbidity in treated water during the rainy season (monsoon) reflects the inefficiency of the water treatment plant to produce a desired value. During monsoon season, there was a huge influx of silt, clay and other organic matters that enters the river water; this led to a higher turbidity readings for untreated water. To produce a desirable quality of treated water, management strategies such as coagulant dosage and improvement of treatment plant were suggested. These strategies can help improve the quality of supply water with a high efficiency and cost effective.

Direct use of pre-treated water from Tuipui river for drinking purposes should strictly be prohibited especially during the monsoon season because of the increase in turbidity. Moreover, the long-term consumption of pre-treated water may lead to adverse effects on human health since there is presence of traces of impurities like organic substances, nitrates, and phosphates even after treatment. Proper maintaining of the treatment plant is advisable and checking of Tuipui river for the turbidity during monsoon season should be done at regularly interval to work out the proper dosage for efficient turbidity removal. Disposal of wastes and other anthropogenic activities that can compromise the quality of the river water should be avoided and kept in check. Proper awareness drive and educating the public should be conducted to provide awareness on the importance of river water and water management techniques and strategies.

APPENDICES

APPENDIX I

MPN Index and 95% confidence limits for various combinations of positive results for Multiple-Tube Fermentation Technique For Fecal Coliforms (EC Medium) and Standard Total Coliform Fermentation Technique where five tubes per dilution areused (10 mL, 1.0 mL and 0.1 mL sample portions).



Combination of Positive Tubes	MPN/ I00 mL	95% Confidence Limit Lower	Upper	Combination of Positive Tubes	MPN/ 100 mL	95% Confidence Limits Lower	Upper
0-0-0	<2	1.0	10	4-2-0	22	9.0	56
0-0-1	2	1.0	10	4-2-1	26	12	65
0-1-0	2	1.0	14	4-3-0	27	12	67
0-2-0	4			4-3-1	33	15	77
				4-4-0	34	16	80
1-0-0	2	1.0	11	5-0-0	23	9.0	86
1-0-1	4	1.0	15	5-0-1	30	10	110
1-1-0	4	1.0	15	5-0-2	40	20	140
1-1-1	6	2.0	18	5-1-0	30	10	120
1-2-0	6	2.0	18	5-1-1	50	20	150
				5-1-2	60	30	180
2-0-0	4	1.0	17	5-2-0	50	20	170
2-0-1	4	2.0	20	5-2-1	70	30	210
2-1-0	7	2.0	21	5-2-2	90	40	250
2-1-1	9	3.0	24	5-3-0	80	30	250
2-2-0	9	3.0	25	5-3-1	110	40	300
2-3-0	12	5.0	29	5-3-2	140	60	360
3-0-0	8	3.0	24	5-3-3	170	80	410
3-0-1	11	4.0	29	5-4-0	130	50	390
3-1-0	11	4.0	29	5-4-1	170	70	480
3-1-1	14	6.0	35	5-4-2	220	100	580
3-2-0	14	6.0	35	5-4-3	280	120	690
3-2-1	17	7.0	40	5-4-4	350	160	820
4-0-0	13	5.0	38	5-5-0	240	100	940
4-0-1	17	7.0	45	5-5-1	300	100	1300
4-1-0	17	7.0	46	5-5-2	500	200	2000
4-1-1	21	9.0	55	5-5-3	900	300	2900
4-1-2	26	12	63	5-5-4	1600	600	5300
				5-5-5	1600		

APPENDIX II

Correlation Coefficient (r) between the pre-treated water quality parameters for two successive years (February 2018 – January 2020)

Parameters	Temperature	Turbidity	TDS	pH	TH	TA	Acidity	Chloride	Phosphate	Nitrate	DO	BOD	T. Coliform
Temperature	1												
Turbidity	0.572	1											
TDS	0.148	-0.483	1										
pH	-0.193	-0.323	-0.262	1									
TH	-0.049	-0.447	0.619**	0.074	1								
TA	-0.145	-0.562	0.654*	0.094	0.742**	1							
Acidity	0.664*	0.865**	-0.439	-0.078	-0.552	-0.665*	1						
Chloride	0.735**	0.293	0.157	0.227	0.082	0.056	0.535	1					
Phosphate-P	0.260	0.366	-0.427	-0.189	-0.532	-0.718**	-0.428	-0.058	1				
Nitrate-N	0.748**	0.625*	-0.424	-0.046	-0.482	-0.537	0.723**	0.381	0.540	1			
DO	-0.753**	-0.363	0.152	-0.005	0.261	0.099	-0.470	-0.666*	-0.338	-0.765**	1		
BOD	0.552	0.939**	-0.531	-0.212	-0.524	-0.622*	0.930**	0.457	0.363	0.624*	-0.447	1	
T. Coliform	0.436	0.909**	-0.414	-0.519	-0.505	-0.575	0.804**	0.191	0.303	0.520	-0.268	0.915**	1

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

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

APPENDIX III

Correlation Coefficient (r) between the treated water quality parameters for two successive years (February 2018 – January 2020).

Parameters	Temperature	Turbidity	TDS	pH	TH	TA	Acidity	Chloride	Phosphate	Nitrate	DO	BOD	T. Coliform
Temperature	1												
Turbidity	0.544	1											
TDS	0.006	-0.688*	1										
pH	-0.309	-0.146	0.178	1									
TH	-0.152	0.465	0.570	-0.240	1								
TA	-0.293	-0.644*	0.625*	-0.059	0.558	1							
Acidity	0.654*	0.917**	-0.500	-0.028	-0.578*	-0.709**	1						
Chloride	-0.287	0.157	-0.125	-0.077	-0.278	-0.040	0.185	1					
Phosphate-P	0.660	0.559	-0.448	-0.473	-0.399	-0.628*	0.608*	-0.210	1				
Nitrate-N	0.780**	-0.647*	-0.485	-0.256	-0.444	-0.678*	0.702*	-0.353	0.790**	1			
DO	-0.504	-0.603*	0.666*	0.421	0.340	0.732**	-0.585*	0.262	-0.786**	-0.862**	1		
BOD	0.572	0.937**	-0.520	-0.063	-0.494	-0.664*	0.980**	0.281	0.514	0.603*	-0.546	1	
T. Coliform	-	-	-	-	-	-	-	-	-	-	-	-	-

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

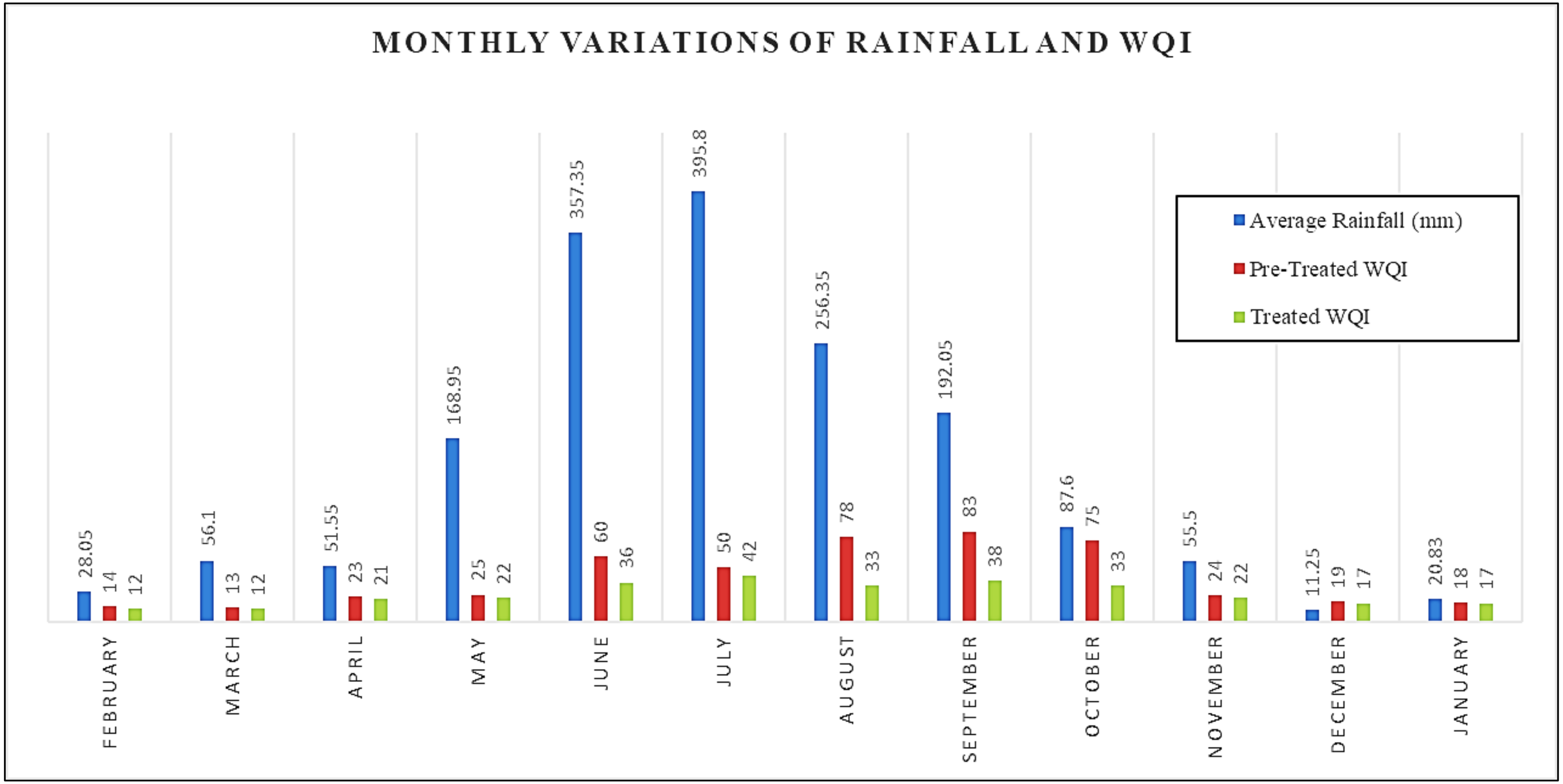
APPENDIX IV

Monthly calculated water quality index (WQI) for pre-treated and treated water during the study period.

Month	Pre-Treated WQI	Treated WQI
February	14	12
March	13	12
April	23	21
May	25	22
June	60	36
July	50	42
August	78	33
September	83	38
October	75	33
November	24	22
December	19	17
January	18	17

APPENDIX V

Chart showing monthly variations of average rainfall (in mm) and WQI during the study period.



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TITLE OF THESIS: ASSESSMENT OF EFFICIENCY OF WATER TREATMENT PLANT IN CHAMPHAI TOWN, MIZORAM: FORMULATION OF WATER MANAGEMENT STRATEGIES

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WORKSHOP/ SEMINAR:

1. Participated at “A Three Day National Level Online Faculty Development Program on Sustainable Engineering (SE)” held during 27th to 29th August, 2020 organized by the Department of Civil Engineering, Shree Vidyanikethan Engineering College (Autonomous), Tirupati.

2. Participated at the two day “National Level Webinar on Intellectual Property Rights” held during 10th and 11th August, 2020 organized by the Technology Information Forecasting & Assessment Council (TIFAC), DST-GOI and Patent Information Centre, MISTIC – Directorate of Science and Technology, GOM.

3. Attended the “International Seminar on Recent Advances in Science and Technology (ISRAST)” held during 16th to 18th November, 2020 organized by North East(India) Academy of Science and Technology (NEAST).

4. Participated in the four days “International Webinar on Earth Sciences” in celebration of National Science Day, 2021 held during 8th - 11th March, 2021 organised jointly by the Department of Environmental Science, School of Earth Science and Natural Resource Management, Mizoram University & Mizoram Scientific and Innovation Council (MISTIC).

4. Attended the “International Webinar on Advances of Science in Education (ASE-2021)” which was held during 8th to 13th February, 2021.

5. Attended the online training programme on “Digital Tools for Writing, Authoring and Reviewing Manuscripts” held during 12th to 23rd July, 2021 organized jointly by Academies, endorsed by AICTE/UGC and supported by Ministry of Electronics and Information Technology.

6. Participated at a national webinar on “Water Resource Management in Northeast India” held during the 5th of August, 2021 organized by Mizoram University (A Central University) and NMHS, GBPNIHE.

7. Participated at the Short Term Course (Online) on PhD Scholar Interaction Programme held during 14th to 20th October, 2021 organized by UGC – Human Resource Development Centre, MZU.

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1. Presented a paper entitled “Seasonal Variation of the Physical Characteristics of River Tuipui, Champhai District-Mizoram” in the 2nf Annual Convention of North East (India) Academy of Science and Technology (NEAST) & International Seminar on Recent Advances in Science and Technology (IRSRAST) during 16th – 18th November, 2020 (Virtual) organized by NEAST, Mizoram University, Aizawl, Mizoram.

2. Presented a paper entitled “Assessment of Seasonal Variation in the Chemical and Bacteriological Characteristics of River Tuipui, Champhai District – Mizoram, India” at the Online Interaction Programme for PhD Scholars & Post-Doctoral Fellows held during 14th - 20th October, 2021 organized by the UGC – Human Resource Development Centre, MZU.

3. Presented a paper entitled “Assessment of Seasonal Variation in Chemical Characteristics of Supply Water in Champhai Town, Champhai District – Mizoram, India” at the International Conference on Sustainability & Environmental Perseverance in the Era of COVID-19 (ICSEPC 2022)” held during 17th February, 2022 organized by Department of Environmental Science, Amity University, Madhya Pradesh, Gwalior, India.

PAPER PUBLICATION:

1. **Bochung, Vanlalhruaitluanga** and Mishra, B.P. (2021). Seasonal Variation in the Physical Characteristics of River Tuipui, Champhai District – Mizoram, India. *Journal of Emerging Technologies and Innovative Research (JETIR)*, 8(3):2134-2136.

2. **Bochung, Vanlalhruaitluanga** and Mishra B.P. (2022). Assessment of Seasonal Variation in Chemical Characteristics of Tuipui River, Champhai District – Mizroram, India. *Applied Ecology and Environmental Sciences*, 10(4):194-200.

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

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ABSTRACT

ASSESSMENT OF EFFICIENCY OF WATER TREATMENT PLANT IN CHAMPHAI TOWN, MIZORAM: FORMULATION OF WATER MANAGEMENT STRATEGIES

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMIENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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MAY, 2022

ABSTRACT

ASSESSMENT OF EFFICIENCY OF WATER TREATMENT PLANT IN CHAMPHAI TOWN, MIZORAM: FORMULATION OF WATER MANAGEMENT STRATEGIES

BY

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Submitted
In partial fulfillment of the requirement of the Degree of Doctor of Philosophy in Environmental Science of Mizoram University, Aizawl

ABSTRACT

Water is essential for the survival of all living beings. Among the vast distribution of water throughout the earth’s system, surface waters such as rivers, lakes, ponds and dams etc. are used for drinking purposes, irrigation and generation of power supply. Due to increase in population, many countries of the world are facing water shortages. Growth of industries, factories and many other large scale production activities, several water resources became polluted and unfit for public consumption, this problem adds to the water shortage crisis in the world today. The qualities of surface water in different areas are largely affected by the natural and anthropogenic activities such as industrial wastes, agricultural wastes and domestic waste disposal.

Surface water when traveling across the agricultural lands and industrial areas may contain nitrates, phosphates, other elements and microorganisms from the soil. Contaminated water is responsible for the spread of different types of contagious diseases. Human fecal contamination is one of the main sources of pathogens in water bodies and if they enter into the water supply, they can cause epidemic of huge proportions.

Most rivers that flow in India are highly contaminated due to discharge of industrial effluents and discharge of untreated sewages in to the water body. The degradation of water quality in our river ecosystem needs to be monitored and necessary measures should be taken to increase their utilization capability and to restore better water quality of the river ecosystem. Water supplies for public use are generally derived from rivers. To ensure the safety to public health, it is necessary to properly inspect, examine and treat the pre-treated water to a safe and permissible

limit prior to supplying water for domestic use. Present day water treatment plants are designed to continuously supply water that fulfills the standards at every household. The present investigation was carried out with the objectives as follows:

1. To study the water quality of treated supply water in Champhai Town and pre-treated water at source point.
2. To determine pollutant removal efficiency of the water treatment plant.
3. To formulate appropriate management strategies for betterment of supply water

For detailed investigation, the study sites were selected in the Champhai District (24° 05' 03.99" and 23° 00' 03.25" N latitudes and 93° 00' 31.29" and 93° 26' 17.66" E longitudes) of the state of Mizoram (92˚15' E to 93˚29' E longitudes and 21˚58' N to 24˚35' N latitudes). The supply of water in Champhai town is undertaken by the Public Health Engineering Department, Champhai under the Greater Champhai Water Supply Scheme. Two sample sites for collection of water samples have been selected. Site 1 is river Tuipui, the source river where the pre-treated water was collected. This was taken as the reference site to compare result with the treated water. Site 2 is Darthlalang tlang main water reservoir, for collecting treated water samples.

During the research, water samples was accumulated from the Tuipui river (source point) before treatment (pre-treated water) and PHE treated water (treated water) on a monthly basis (in triplicate) for two successive years from February 2018 to January 2019, and February 2019 to January 2020 using plastic bottles with proper care. Water samples were brought to the laboratory in properly sealed bottles after collection, for analysis of Analysis of various physical, chemical and bacteriological characteristics of water using the methods as outlined in the "Standard Methods for Examination of Water and Wastewater" as prescribed by APHA (2005). The physicochemical characteristics namely, Turbidity, Total Dissolved Solids, Total Hardness, Total Alkalinity, Acidity, Chloride, Phosphate-P, Nitrogen-N, Dissolved Oxygen, Biochemical Oxygen Demand and Total Coliform were analyzed within the first 24 hours of sample collection. Temperature and pH of the water samples were measured at the sample collection sites and water samples were also fixed at the sampling site for dissolved oxygen (DO) estimation. Water samples were kept at 4°C storage before carrying out further analysis. Monthly observations have been computed on seasonal basis i.e., pre-monsoon season (February to May), monsoon season (June to September) and post-monsoon season (October to January). To check the validity and significance of the data observed during the study period, two-way analysis of variance (ANOVA) and Pearson correlation coefficient was also done. Based on the observations, the management strategies are also suggested for betterment of supply water. The brief account of findings can be summarized as follows:

1. Water Quality Parameters

The findings obtained from of the present investigation on the water quality of pre-treated and treated water can be sum up as follows:

1. Temperature of the water ranged from 16.95°C (post-monsoon, 2018-19) to 24.59°C (monsoon, 2019-20) for pre-treated water, and 18°C (post-monsoon, 2018-19) to 24.62°C (monsoon, 2019-20) for treated water. The value of temperature was found to be higher during the monsoon season and lower during the post-monsoon season.

2. Turbidity of the water ranged from 2.1 NTU (pre-monsoon, 2019-20) to 34.89 NTU (monsoon, 2018-19) for pre-treated water, and 0.6 NTU (pre-monsoon, 2019-20) to 11.87 NTU (monsoon, 2018-19) for treated water. It was found that the turbidity value was higher during the monsoon season and lower during the pre-monsoon season for both the years.
3. Total dissolved solids (TDS) values ranged from 29.48 mg/L (post-monsoon, 2019-20) to 45.37 mg/L (pre-monsoon, 2019-20) for pre-treated water, and 28.78 mg/L (monsoon, 2018-19) to 43.45 mg/L (pre-monsoon, 2019-20) for treated water. The value of total dissolved solids (TDS) was found to be higher during the pre-monsoon season and lower during the monsoon season.
4. The pH ranged from 6.9 (monsoon, 2019-20) to 7.2 (pre-monsoon, 2018-19) for pre-treated water, and 7.1 (monsoon, 2019-20) to 7.3 (pre-monsoon, 2018-19) for treated water. The pH value was generally higher during the pre-monsoon season and low during the monsoon season for both the years.
5. Total hardness values ranged from 30.12 mg/L $CaCO_3$ (post-monsoon, 2018-19) to 47.83 mg/L $CaCO_3$ (pre-monsoon, 2019-20) for pre-treated water, and 27.16 mg/L $CaCO_3$ (post-monsoon, 2018-19) to 42 mg/L $CaCO_3$ (pre-monsoon, 2019-20) for treated water. The total hardness value was found to be higher during the pre-monsoon season and lower during the post-monsoon season.
6. Total alkalinity values ranged from 45.66 mg/L $CaCO_3$ (monsoon, 2018-19) to 78.83 mg/L $CaCO_3$ (pre-monsoon, 2018-19) for pre-treated water, and 42.08 mg/L $CaCO_3$ (monsoon, 2018-19) to 74.08 mg/L $CaCO_3$ (pre-monsoon, 2018-19) for treated water. The total alkalinity value was found to

be higher during the pre-monsoon season and lower during the monsoon season.

7. Acidity values ranged from 16.67 mg/L $CaCO_3$ (pre-monsoon, 2018-19) to 50.33 mg/L $CaCO_3$ (monsoon, 2019-20) for pre-treated water, and 10.33 mg/L $CaCO_3$ (pre-monsoon, 2018-19) to 22.33 mg/L $CaCO_3$ (monsoon, 2018-19) for treated water. The acidity values were found to be higher during the monsoon season and lower during the pre-monsoon season.
8. The chloride content ranged from 0.32 mg/L (post-monsoon, 2018-19) to 0.57 mg/L (monsoon, 2018-19) for pre-treated water, and 4 mg/L (post-monsoon, 2018-19) to 4.9 mg/L (monsoon, 2019-20) for treated water. Chloride content was found to be higher during the monsoon season and lower during the post-monsoon season. Because of disinfection process, chloride content is higher in treated water.
9. The phosphate-P values ranged from 0.01 mg/L (pre-monsoon, 2018-19) to 0.02 mg/L (monsoon, 2018-19) for pre-treated water, and 0.01 mg/L (pre-monsoon, 2018-19) to 0.02 (monsoon, 2018-19) for treated water. The phosphate-P value was found to be higher during the monsoon season and lower during the pre-monsoon season.
10. The nitrate-N ranged from 0.1 mg/L (pre-monsoon, 2018-19) to 0.12 mg/L (monsoon, 2018-19) for pre-treated water, and 0.1 mg/L (pre-monsoon, 2018-19) to 0.12 mg/L (monsoon, 2018-19) for treated water. The nitrate-N value was found to be higher during the monsoon season and lower during the pre-monsoon season.
11. The dissolved oxygen (DO) values ranged from 6.22 mg/L (monsoon, 2018-19) to 6.5 mg/L (pre-monsoon, 2018-19) for pre-treated water, and 7.5 mg/L

(monsoon, 2019-20) to 8.3 mg/L (pre-monsoon, 2018-19) for treated water. The dissolved oxygen (DO) content was found to be lower during the monsoon season and higher during the pre-monsoon season.

12. The biochemical oxygen demand (BOD values ranged from 1.2 mg/L (pre-monsoon, 2019-20) to 1.8 mg/L (monsoon, 2018-19) for pre-treated water, and 0.2 mg/L (pre-monsoon, 2019-20) to 0.8 mg/L (monsoon, 2018-19) for treated water. The biochemical oxygen demand (BOD) level was found to be higher during the monsoon season and lower during the pre-monsoon season.
13. Total coliform count ranged from 2 MPN/100mL (pre-monsoon, 2018-19) to 4 MPN/100mL (monsoon, 2019-20) for pre-treated water, and 0 MPN/100 mL for treated water.
14. Statistical analysis namely, two-way ANOVA and Pearson correlation coefficient were done to check on significance and validity of the data obtained.

2. Pollutant Removal Efficiency

The findings on present study on the pollutant removal efficiency of water treatment plant on key parameters can be summarized as follows:

1. The turbidity removal efficiency during the study period ranged from 64.44% (pre-monsoon) to 75.95% (post-monsoon) during 2018-19, and from 46.15% (post-monsoon) to 71.43% (pre-monsoon) during 2019-20.
2. The TDS removal efficiency during the study period ranged from 4.16% (monsoon) to 6.08% (post-monsoon) during 2018-19, and from 7.29% increase (post-monsoon) to 7.00% (monsoon) during 2019-20.

3. The total hardness removal efficiency during the study period ranged from 6.54% (monsoon) to 9.83% (post-monsoon) during 2018-19, and from 6.79% (post-monsoon) to 12.19% (pre-monsoon) during 2019-20.
4. The total alkalinity removal efficiency ranged from 5.54% (post-monsoon) to 7.84% (monsoon) during 2018-19, and from 2.90% (post-monsoon) to -8.96% (pre-monsoon) during 2019-20.
5. The acidity removal efficiency during the study period ranged from 21.12% (post-monsoon) to 54.12% (monsoon) during 2018-19, and from 11.91% (post-monsoon) to 58.93% (monsoon) during 2019-20.
6. The dissolved oxygen (DO) increase in the treated water (removal of organic matters) during the study period ranged from 22.97% (post-monsoon) to 27.69% (pre-monsoon) during 2018-19, and from 18.75% (post-monsoon) to 25% (pre-monsoon) during 2019-20.
7. The BOD removal efficiency during the study period ranged from 55.56% (monsoon) to 83.33% (pre-monsoon) during 2018-19, and 62.50% (monsoon) to 83.33% (pre-monsoon) during 2019-20.
8. The observed values of TDS, pH, TH, TA, Acidity were all within the permissible limits, however, the overall removal efficiency is low.
9. The increase in DO after treatment was found to be satisfactory, whereas, the BOD removal efficiency can be further optimized.

3. Management Strategies

1. A jar test was conducted to determine the coagulant dosage required for turbidity removal and it was found to be 15 mg/L of P.A.C with 30% of the coagulant as Lime.

2. However, it is suggested that, a regular jar test should be conducted every time the WTP is operated to produce the most desirable turbidity removal.
3. Cleaning and regular backwashing of sedimentation tank and filtration tank to obtained desirable results.
4. Optimization and upgrading of present operational unit will greatly improve the efficiency of treated water.
5. Training of plant operators and proper maintaining of the WTP will greatly improve the workings of the WTP and also decrease the financial requirement to repair or install new units.

The findings of present study on various water quality attributes are in conformity with the earlier works in the field of water quality assessment. The results revealed that there was a significant variation in some physical, chemical and bacteriological parameters. Of all the parameters during the study period, turbidity reading was the only parameter that crossed the permissible limit given by various scientific agencies. Other parameters were all in the normal and permissible range of water quality.

The high value of turbidity in treated water during the rainy season (monsoon) reflects the inefficiency of the water treatment plant to produce a desired value. During monsoon season, there was a huge influx of silt, clay and other organic matters that enters the river water; this led to a higher turbidity readings for untreated water. To produce a desirable quality of treated water, management strategies such as coagulant dosage and improvement of treatment plant were suggested. These strategies can help improve the quality of supply water with a high efficiency and cost effective.

Direct use of pre-treated water from Tuipui river for drinking purposes should strictly be prohibited especially during the monsoon season because of the increase in turbidity. Moreover, the long-term consumption of pre-treated water may lead to adverse effects on human health since there is presence of traces of impurities like organic substances, nitrates, and phosphates even after treatment. Proper maintaining of the treatment plant is advisable and checking of Tuipui river for the turbidity during monsoon season should be done at regularly interval to work out the proper dosage for efficient turbidity removal. Disposal of wastes and other anthropogenic activities that can compromise the quality of the river water should be avoided and kept in check. Proper awareness drive and educating the public should be conducted to provide awareness on the importance of river water and water management techniques and strategies.

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