CHAPTER 3

PHYSICO-CHEMICAL PARAMETERS
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3.1 Introduction

Water is ‘life’. It is one of the basic needs in the world. Water is probably the only natural resource to touch all aspects of human civilization from agricultural and industrial development to cultural and religious values rooted in society. The total amount of water on the earth is about 1.35 billion cubic kilometers. About 97.1 % has been locked into oceans as saltwater. Ice sheets and glaciers have arrested 2.1 %, and only 0.2 % is the fresh water present on the earth, which can be used by human for variety of purposes. Remaining 0.6 % is in underground form and India has 4% of water resources of the world, while it has to support 16% of the world population and 15% of livestock, unfortunately it has been getting polluted day by day due to different anthropogenic activities. So it is necessary to conserve the water and prevent it from every type of pollution. There should be proper investigation of quality and management of water. This could be possible by continuous water quality monitoring. Freshwater is one of the basic needs of the mankind and is vital to all forms of life. It exists in lentic and lotic habitats. All the lentic habitats, such as reservoirs, ponds and lakes, are extremely important as they are endowed with abundance of other natural resources too. Dams are also called artificial lakes. In order to fulfill the various needs of man, dams have been constructed across the rivers so as to form a pool of water on the upstream side of the barrier. These artificial lakes are called water reservoirs. The quality of this reservoir water is not much different from that of a natural lake. The water stored in the reservoir can be used easily not only for water supplies but also for irrigation, hydroelectric power generation and aquaculture. It also enhances the aesthetic as well as ecological value of the area.

Water has a unique place on planet as it supports life on earth. The entire fabric of life is woven around it. Man uses this important resource collected in depressions on earth or creates depressions by blocking the streams and constructing reservoirs, because of industrial development and unplanned urbanization. This important resource for life has been polluted to a point of crisis. A healthy environment is necessary for any organism, since life depends upon the continuance of a proper exchange of essential substances and energies between the organisms and
its surroundings (Welch, 1952)

The adverse impact is felt on the unique physical and chemical properties of water. The fish and other organisms that inhabit these reservoirs are also affected which in turn influence the functions of the reservoir. Water Quality is important for drinking, irrigation, fish production, recreation and other purposes. The water quality deterioration in reservoirs usually results from acidification, heavy metal contamination, organic pollution, obnoxious fishing practices and excessive nutrient input that leads to eutrophication. The effects of these imports into the reservoir not only affect the socio-economic functions of the reservoir negatively, but also lead to the loss of structural biodiversity of the reservoir. The physico-chemical properties of water quality assessment give a proper indication of the status, productivity and sustainability of a water body. The changes in the physico-chemical characteristics like temperature and chemical elements of water such as dissolved oxygen, nitrates and phosphates provide valuable information on the quality of the water, the source(s) of the variations and their impacts on the functions and biodiversity of the reservoir.

Hence, the consideration of the physico-chemical factors in the study of limnology is basis for the understanding of trophic dynamics of the water body. The physical and chemical properties of water immensely influence uses of a water body for the distribution and richness of biota. Each factor plays its own role but at the same time the final effect is the actual result of the interactions of all the factors. These factors serve as a basis for the richness or otherwise biological productivity of any aquatic environment. Looking at the importance of understanding physico-chemical properties of water in a water body for supporting various biota, a study was planned to find out physico-chemical status of water of Budki M.I. Tank, a perennial water body present at Budki. Following parameters we considered for the study.

3.1.1 Temperature (Temp.)

Temperature is a measure of the intensity (not the amount) of heat stored in a volume of water measured in calories and is the product of the weight of the substance (in grams), temperature (°C) and the specific heat (Cal/gram °C). Temperature of water may not be as important in pure water because of the wide range of temperature tolerance in aquatic life, but in polluted water, temperature can
have profound effects on dissolved oxygen (DO) and biological oxygen demand (BOD)

In general atmospheric ambient and water temperature depend on geographical location and meteorological conditions such as rainfall, humidity, cloud cover, wind velocity, etc. Atmospheric temperature is a measure of temperature at different levels of earth surface. It is governed by many factors including incoming solar radiation, humidity and altitude. Atmospheric temperature varies as one move vertically upwards from the earth's surface. The atmospheric and water temperature go more or less hand in hand (Macan, 1958). Water temperature is an important factor which influences the chemical, biochemical and biological characteristics of water body. Water temperature is of enormous significance as it regulates various abiotic characteristics and activities of an aquatic ecosystem (Hutchinson, 1957 and Kataria et al., 1995).

3.1.2 Water cover (WC)

In Indian climatic conditions the water level of any fresh water body fluctuates seasonally influencing water cover. The rate of inflow and outflow of water with resultant water level have a direct bearing on productivity of water body as the sudden fluctuations directly affect the biotic communities. Plankton, benthos and periphyton pulses coincide with the months of least water fluctuations, that is, all the communities are at their ebb during the months of maximum levels and water discharge (Sugunan and Pathak, 1986). The spillway discharge, apart from dislodging the standing crop of plankton, removes the oxygenated clear water of the top layer, leaving the oxygen deficient bottom water. Conversely, the deep drawdown removes the decomposing material including nutrients (Jhingran, 1975). Percentage of shallow area (littoral formation), which varies at different seasons depending on the contour of water body, is also an indicator of productive nature of the Lakes (Sugunan, 2000). An irregular shoreline encompasses more littoral formation and areas of land and water interface. Thus, a high value of shoreline development index is believed to be indicative of productive nature of the water body. High shoreline indices of Hirakud (13.5), Gobindsagar (12.26), Tilaiya (9.12), Konar (8.78), Nagarjunsagar (7.89) and Rihand (7.04) have been correlated to a moderate to rich plankton community (Sugunan, 2000).
3.1.3 Transparency (Trans.)

Transparency is a characteristic of water that varies with the combined effect of colour and turbidity. It measures the depth to which light penetrates in the water body. Transparency gives an idea about the degree of suspended particles in the water, which in turn affects the light penetration (Verma et.al., 1980). Clear water permits light to penetrate more deeply into the lake than does cloudy water. This light allows photosynthesis and production of oxygen in deeper water while pollution tends to reduce water clarity.

Evaluation of the vertical extinction and spectral characteristics of light in natural waters is commonly accomplished in situ with modern underwater quantum sensors. The Secchi disc transparency is essentially a function of the reflection of light from its surface and is therefore influenced by the absorption characteristics of both, the water and its dissolved and particulate matter. The Secchi disc transparencies range from few centimeters in turbid reservoirs to over 40 m in a few rare clear lakes. The Secchi disc transparency correlates closely with the percentage transmission of light. Higher water transparency is recorded at the beginning of dry season as a consequence of reduced rain (Cleber and Giani, 2001). Transparency of water is generally influenced by factors like wind action, plankton concentration, suspended silt particles and decomposition of organic matter at the bottom.

3.1.4 Total solids (TS), Total suspended solids (TSS) and Total dissolved solids (TDS)

Total solids are dissolved solids plus suspended and settleable solids in water. In stream water, dissolved solids consist of calcium, chlorides, nitrates, phosphorus, iron, sulfur, and other ion particles that will pass through a filter with pores of around 2 microns (0.002 cm) in size. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a 2-micron filter. A high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water.

Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial waste water. There are also nonpoint sources of suspended
solids, such as soil erosion from agricultural and construction sites. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels. TSS can also destroy fish habitat because it can harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Most people consider water with a TSS concentration less than 20 mg/L to be clear. Water with TSS levels between 40 and 80 mg/L tends to appear cloudy, while water with concentrations over 150 mg/L usually appears dirty. The nature of the particles that comprise the suspended solids may cause these numbers to vary.

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations Calcium, Magnesium, Sodium and Potassium and the anions carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater, nitrate (from agricultural use). (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in water. This material can include carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, Calcium, Magnesium, Sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Some dissolved solids come from organic sources such as leaves, silt, plankton, and industrial waste and sewage, other sources come from runoff from urban areas, road salts used on street during the winter, and fertilizers and pesticides used on lawns and farms.

As per APHA (1998), solids refer to the matter that is suspended or dissolved in the water or waste water. The total suspended solids (TSS), is a portion of total solids (TS) retained by a filter while the total dissolved solids (TDS) are the in filterable solids, mostly inorganic salts and small amount of organic matter dissolved in the water. These have been proved to be very useful parameters in determining the productivity of water, and of biological and physical waste water treatment processes.
A limit of 500 mg/L TDS is permissible in drinking water. The concentration of total dissolved solid gives an idea about suitability of this water for various uses including potability of water (Trivedy, 1995). Water in nature contains both organic and inorganic solids varying both qualitatively and quantitatively with the season. TDS may affect the water quality adversely in a number of ways. Waters with highly dissolved solids are generally of inferior potability and may induce an unfavorable physiological reaction in the transient consumer. Highly mineralized water is not suitable for many industrial applications (APHA, 1985) as it increases hardness and corrosive properties of the water and may create an imbalance for the aquatic life, whereas the suspended sediments are probably key factors controlling the availability of light.

The amount of hydrocarbonates and corresponding TDS in the water are positively correlated with phytoplankton and zooplankton diversity (Karatayev et al., 2008). The wetlands act as sinks for the nutrient deposition and hence, the high TDS value may also depend on the age of the lake (Anitha et al., 2005) as a result of gradual salt deposition.

3.1.5 pH (Potentia hydrogenii)

pH is the negative logarithm of hydrogen ion concentration, is one of the most important and frequently used test in the water chemistry. It is a valuable indicator for the acid alkali balance of water. Practically every phase of water supply and waste water treatment of acid base neutralization and water softening, precipitation, disinfection and corrosion control are pH dependent. In case of pollution by acidic and alkaline wastes, the pH serves as an index to denote the extent of pollution. pH changes in water are governed by the amount of free carbon-dioxide, carbonates and bicarbonates. The alteration of hydrogen ion concentration of water is accompanied by changes in other physico-chemical aspects. In addition to factors like temperature, salinity, atmospheric pressure, disposal of industrial wastes, etc., biological factors such as respiration and photosynthesis also influence pH.

The pH of water determines the solubility and biological availability of certain chemical nutrients such as Phosphorus, Nitrogen, Carbon as well as heavy metals like Lead, Copper, Cadmium, etc. It indicates how much and what form of Phosphorus is most abundant in water and whether aquatic life can use the form
available. Metals tend to be more toxic at lower pH because they are more soluble in acidic water. Measured on a scale of 0-14, pH of natural water usually lies in the range of 4.4 to 8.5. The rise in pH parallels with the rise in carbonate alkalinity and percentage of Oxygen saturation. It is probably not affected by photosynthetic activity of a water body (Kobbia et. al., 1992; Kebede, 1996). A weak correlation between pH and fresh water gastropod species richness has been established by Sarkar and Hakuriat (1964) whereas, with temperature, pH has been considered to cause summer minima of total phytoplankton density (Hujare, 2005). Further, Sharma et.al, (2008) have described role of pH in formation of algal bloom too. Thus, pH plays important role in controlling biotic community structure of a water body.

**3.1.6 Dissolved Oxygen (DO)**

Dissolved oxygen (DO) plays a vital role for the survival of organisms in a water body, the presence of Oxygen is a positive sign and the absence of Oxygen is a sign of severe pollution. Waters with consistently high dissolved oxygen are considered to be stable aquatic systems capable of supporting many different kinds of aquatic life. Dissolved oxygen (DO) refers to the volume of Oxygen that is contained in water. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of Oxygen across the air-water interface. The amount of Oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more Oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of Oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure (Smith, 1990).

The concentration of DO diverse significantly over 24 hours, mostly due to photosynthetic activity of plants. During the day time photosynthesis occurs and release Oxygen into the water and during night, respiration occurs which remove Oxygen from the water. In cold water the more oxygen can be dissolved therefore, DO concentrations at one location are usually higher in the winter than in the summer. During dry (summer) seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration
decreases. During rainy seasons, Oxygen concentrations tend to be higher because the rain interacts with Oxygen in the air as it falls. More sunlight and warmer temperatures also bring increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration. The aquatic plant density also affects the concentration of Oxygen, fewer plants grow in winter because of cold temperature and shorter day length and more green plants mean more photosynthesis, which produces more Oxygen during the day when the sun is shining. The anthropogenic activities also change DO due to organic wastes, urban runoff, removal of aquatic vegetation and construction of dams.

According to Ramchandra and Solanki (2007) dissolved Oxygen is essential to the respiratory metabolism of most aquatic organisms. The dynamics of oxygen distribution in inland waters are governed by a balance between inputs from the atmosphere and photosynthesis and losses from the chemical and biotic oxidations. DO is a very important parameter for the survival of fishes and other aquatic organisms. It is also needed for many chemical reactions that are important for lake functioning such as oxidation of metals, decomposition of dead and decaying matter etc.

3.1.7 Carbon dioxide (CO₂)

Free carbon dioxide is present in water in the form of a dissolved gas, surface waters usually contain less than 10 ppm free carbon dioxide and some ground waters may easily go beyond that concentration. Carbon dioxide is readily soluble in water; over the ordinary temperature range (0-30 °C) the solubility is about 200 times that of Oxygen. Calcium and Magnesium combine with carbon dioxide to form their carbonates and bicarbonates. Aquatic plant life depends upon carbon dioxide and bicarbonates in water for growth and microscopic life suspended in the water, phytoplankton, as well as large rooted plants and utilize carbon dioxide in the photosynthesis of plant materials such as starches, sugars, oils, proteins. The carbon in all these materials comes from the carbon dioxide in water.

Free CO₂ in water accumulates due to microbial activity and respiration of organisms. It imparts the acidity to the water because of the formation of carbonic acid. Photosynthesis and respiration are two major processes that influence the amount of CO₂ in water. Algae and submerged macrophytes require an abundant and
readily available source of Carbon for high sustainable growth. The dissolved carbon
dioxide influences water quality properties such as acidity, hardness and related
characteristics. Thus, it is essential that the rudiments of dissolved inorganic Carbon
reactivity be evolved. Hence, CO₂ forms an important component in aquatic ecosystem.

A high level of carbon dioxide usually indicates that there is a lot of dead
material undergoing decomposition. This may occur naturally, but could be the result
of different types of water pollution or water treatment. The carbon dioxide in a lake
is not constant but it changes. Dead organisms usually sink as a result the carbon
dioxide level caused by their decomposition is usually greater near the bottom of the
lake. The level of carbon dioxide will be higher at night because the plants will be
using Oxygen and producing carbon dioxide at the time. The carbon dioxide level
will be greater in the fall due to dead algae and animals that have died over the winter
and are now decaying and in terms of succession; an older lake will have more
carbon dioxide because of more decay due to more organisms.

3.1.8 Total hardness (TH)

Total hardness (Calcium and Magnesium) is an important parameter in the
detection of water pollution. It exists mainly as bicarbonates of Ca⁺² and Mg⁺² and to
a lesser degree in the form of Sulphates and Chlorides. Calcium is an essential
nutritional element for animal life and also aids in maintaining the structure of plant
cells and soil. Magnesium possesses no major concern with public health. Limits of
concentration of hardness set for water are based mainly on palatability, corrosion and
incrustation.

The water hardness is a traditional measure of the capacity of water to react
with soap. Hard water requires a considerable amount of soap to leather. Calcium and
Magnesium are the most abundant elements that render hardness to natural surface as
well as ground waters. They exist mainly as bicarbonates of (Ca⁺²), (Mg⁺²) and to a
lesser degree in the form of Sulphates (SO₄⁻²) and Chlorides (Cl⁻). Hardness caused
by, bicarbonates and carbonates of Calcium and Magnesium is called temporary
hardness whereas that caused by their sulphates and chlorides is called permanent
hardness. Natural hardness of water depends upon the geological nature of the
catchment area. It plays an important role in the distribution of aquatic biota and
many species are identified as indicators for hard and soft waters (Ramchandra et al., 2006). In the presence of carbon dioxide, calcium carbonate is dissolved in water. It maintains the pH of the most natural waters between 6.0 to 8.0. However, dissolved Magnesium concentrations are lower than Calcium for a majority of the natural waters. Because of the high solubility of magnesium salts, this metal tends to remain in solution and is less readily precipitated than Calcium. Calcium is an essential nutrient element for animal life that aids in maintaining the structure of plant cells and soils. The hardness may range from zero to hundreds of milligrams per liter depending on the source and treatment to which the water has been subjected.

According to Larry (1996) total hardness observed for streams and rivers throughout the world range between 1-1000 ppm as CaCO$_3$. Hardness reflects the composite measure of polyvalent cations whereas Calcium and Magnesium are the primary constituent of hardness. Hardness value above 500mg/L is generally unacceptable, although this level is tolerable in some communities (Zoeteman, 1980). Total hardness is an important parameter in the detection of water pollution and causes various diseases. Hardness of water is mainly caused by Calcium and Magnesium in addition to water sulphates, nitrates, and silicates may also contribute to hardness. Temporary hardness is caused by carbonate and bicarbonate ions and they are removed by boiling of water on the other hand chlorides, sulphates and heavy metals are difficult to remove. Hardness has been evaluated and correlated by different workers for different purposes. Kudari et al., (2006) classified water bodies based on the hardness as slightly hard moderately hard and hard. While, Moshood, (2008) stated that the utilization of Calcium and Magnesium ions by organisms probably causes decrease in the concentration of total hardness in the dry season. Higher hardness and conductivity of water in winter has been correlated to more productive during this season. Hardness is very important parameter in decreasing the toxic effects of poisonous elements.

3.1.9 Chlorides (Cl$^-$)

The chloride concentration is one of the important indicators of water pollution (Munawar, 1970 and Khare et al., 2007). The maximum permissible limit i.e. 500mg/L for drinking water prescribed by WHO. According to Rajkumar et al.(2004) Chlorides occur naturally in all types of waters, high concentration of
chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin and chlorides are troublesome in irrigation water and also harmful to aquatic life. In high concentrations, chlorides in urban areas are indicators of large amounts of non-point pollution; pesticides, grease and oil, metals and other toxic materials with high levels of chlorides. Chlorides are commonly found in sewage, streams and wastewater. Chlorides are leached from various rocks into soil and water by weathering. The chloride ions highly mobile and is transported to closed basins. Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts, thus increasing levels of metals in drinking water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion. It can also increase the rate of pitting corrosion of metal pipes.

The concentrations of four major cations Ca$^{++}$, Mg$^{++}$, Na$^{+}$ and K$^{+}$ and four major anions, HCO$_3^-$, CO$_3^{2-}$, SO$_4^{2-}$ and Cl$^-$, usually constitute the total ionic salinity of the water for all practical purposes. Of these chlorides influence, in general, osmotic salinity balance and ion exchange. However, metabolic utilization does not cause large variations in the spatial and seasonal distribution of chlorides within most lakes, but high chloride content may indicate the pollution by sewage/industrial waste or intrusion of the saline water (APHA, 1998).

3.1.10 Nitrates (NO$_3^-$)

Nitrates are one of the most important nutrients in an aquatic ecosystem. They are the highly oxidized form of nitrogen compounds commonly present in the natural water. They are the products of the aerobic decomposition of nitrogenous matter received from domestic sewage, agricultural runoff and industrial effluents. Nitrate is an inorganic chemical that is highly soluble in water; major sources of nitrate in drinking water contain fertilizers, sewage and animal manure. Nitrogen is a major nutrient that affects the productivity of fresh water. Dominant forms of nitrogen in fresh waters include dissolved molecular N$_2$, ammonia (NH$_3$), nitrite (NO$_2^-$), nitrate (NO$_3^-$) and large number of organic compounds like amino acids, amines, nucleotides, proteins and refractory humic compounds of low nitrogen content (Wetzel, 2006). Most nitrogen containing materials in natural waters tend to be converted to nitrate. Nitrates also occur naturally in the environment, in mineral
deposits, soil, seawater, freshwater systems, and the atmosphere.

Human activities and mainly those related to agriculture are a major cause of the presence of nitrates and nitrites in surface water. These two substances are responsible for many problems not only for environment but also for human health. Indeed, although not directly toxic, they participate in eutrophication phenomena of surface water. The nitrate concentration in the range (0-7.00 mg/L), the nitrites concentration in the range (0-0.28 mg/L), and the ammonium ion concentration in the range (0-0.03 mg/L). This allows us to notice that the rates of nitrates obtained are lower than the standards required which are in the order of 50 mg/L. (WHO, 2004). Their presence can be explained by an incomplete oxidation of the ammonia water or a nitrate reduction reaction. This pollution can be caused by intense agricultural activity (the studied region is known for its agricultural vocation) and misuse of chemical fertilizers around the sewage waste water.

Nitrates generally occur in trace quantities in surface waters but may attain low levels in ground water. However, the high amounts of nitrates are generally indicative of water pollution. The runoff water coming from intensive agricultural activities like use of fertilizers, also contributes to significant nitrate contents in surface waters.

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to find out the level of contaminants in drinking water at which no complicated health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water. The MCLG for nitrate is 10 mg/L or 10 ppm. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for nitrate, called a maximum contaminant level (MCL), at 10 mg/L or 10 ppm. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation.
Nitrates are found only in small amounts in fresh domestic water. It is an essential nutrient for many photosynthetic autotrophs and in some cases has been identified as growth limiting nutrient. Many workers have reported the presence of nitrates at higher levels in effluent water compared to fresh water. Adeyeye and Abulude, (2004) Nitrates in natural waters can be traced to percolating nitrates from sources such as decaying plant and animal materials, agricultural fertilizers and domestic sewage. The presence of nitrates in the water samples is suggestive of some bacterial action and bacterial growth (Narayan et. al., 2007). Low levels of nitrates and phosphates are not indicative of low productivity as these nutrients are quickly recycled (Sugunan, 2000). The natural concentration of 0.3 mg/L of nitrates may be enhanced by fertilizer in the runoff, industrial and municipal waste waters up to 5 mg/L. In Lakes, concentration of nitrates in excess of 0.2 mg/L is found Nitrogen stimulates algal growth leading to eutrophication (Ramchandra and Solanki, 2007). According to Trevisan and Forsberg (2007) phytoplankton of Amazonian system of lakes is mainly controlled by the availability of nutrients, especially nitrogen, during the dry period. The concentration of nutrients, mainly Nitrogen and Phosphorus, are the factors which govern the phytoplankton growth and distribution. Forbes et. al., (2008) could not detect any significant relationship between bioavailable nitrogen (i.e. nitrate) and N\textsubscript{2} fixation potentials with the help of both multiple linear regressions and the pruned regression tree analysis. However, the roles of bioavailable nitrogen, as well as temperature are normally revealed in the seasonal N\textsubscript{2} fixation (Scott et. al., 2008). A relationship between total Nitrogen and total phosphate exists which indicates that both zooplankton and phytoplankton biomass increase with the increase of total Nitrogen and total phosphate concentrations (Chun et. al., 2007).

3.1.11 Phosphates (PO\textsubscript{4}\textsuperscript{3-})

Phosphorus is necessary for the growth of biological organisms, including both their metabolic and photosynthetic processes, it occurs naturally in water bodies mainly in the form of phosphates a compound of phosphorus and oxygen. Phosphorus is a nutrient essential for all organisms for the basic processes of life and natural element found in rocks, soils and organic material. Phosphorus clings tightly to soil particles and is used by plants, so its concentrations in clean waters are generally very low. However, Phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity. Many harmless
activities added together can cause Phosphorus overloads. Phosphates promote the growth of plankton and aquatic plants which provide food for larger organisms, including zooplankton, fish, humans, and other mammals. Plankton represents the base of the food chain. Initially, this increased productivity will cause an increase in the fish population and overall biological diversity of the system. The role of Phosphate in promoting plant growth actually makes it a dangerous pollutant when dumped in excessive quantities into aquatic ecosystems. In fact, plants have so much difficulty that the chemical is a limiting nutrient. The rate at which plants can grow and reproduce is limited by the amount of usable phosphates in the soil or water (for aquatic plants). When humans add extra Phosphorous to water, they create a condition called eutrophication that can wipe out aquatic ecosystems. Eutrophication is characterized by a rapid growth in the plant population called algal bloom. With more living plants come more dead plants needing decomposition. The bacteria that decompose the dead plants use Oxygen, and eventually burn up so much that not enough remains to support fish, insects, mussels, and other animals, leading to a massive die-off. The deposition of Phosphorus into lake sediments occurs by mechanisms such as a) sedimentation of Phosphorus minerals imported from the drainage basin, b) adsorption or precipitation of Phosphorus with inorganic compounds c) uptake of phosphorus from the water column by algal and other attached microbial communities (Bostrom et. al., 1988). The quantities of Phosphorus entering the surface drainage vary with the amount of Phosphorus in catchment soils, topography, vegetative cover, quantity and duration of runoff flow, land use and pollution.

The presence of phosphates in almost every detergent, including household cleaners and laundry soap, used to contribute significantly to eutrophication. In the United States, the problem was moderated somewhat in the 1970 when the Clean Water Act and other laws mandated the removal of Phosphates from many detergents (next time you do laundry, look on the side of the box and should find the phrase “Contains No Phosphates”), although industrial cleaners and some specialty detergents still use phosphates.

3.1.12 Sulphate (SO$_4^{2-}$)

Sulfate is a substance that occurs naturally in drinking water, regarding to
health sulfate in drinking water have been raised because of reports that diarrhoea may be associated with the ingestion of water containing high levels of sulfate. The general population that may be at higher risk from the laxative effects of sulfates when they experience a quick change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations. According to Delisle and Schmidt (1977), sulfates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. Sodium, Potassium and Magnesium sulfates are all highly soluble in water, whereas calcium and barium sulfates and many heavy metal sulfates are less soluble. Atmospheric sulfur dioxide, formed by the combustion of fossil fuels and in metallurgical roasting processes, may contribute to the sulfate content of surface waters. Sulfur trioxide, produced by the photolytic or catalytic oxidation of sulfur dioxide, combines with water vapour to form dilute sulfuric acid, which falls as “acid rain.” According to Greenwood and Earnshaw (1984), sulfates and sulfuric acid products are used in the production of fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. They are also used in the mining, wood pulp, metal and plating industries, in sewage treatment and in leather processing. Aluminum sulfate (alum) is used as a sedimentation agent in the treatment of drinking water. Copper sulfate has been used for the control of algae in raw and public water supplies (McGuire, 1984).

Iron sulphides such as, FeS may be exposed to water and atmospheric Oxygen by mining or rock excavation, producing sulphuric acid, which contributes sulphate to ground and surface waters. Sulphates are also released during blasting and the deposition of waste rock in dumps at metal mines. This is known as acid rock drainage and is a significant source of sulphate generation in British Columbia. The burning of fossil fuels is also a major source of Sulphur to the atmosphere. Most of the man's emissions of Sulphur to the atmosphere, about 95%, are in the form of SO2. Sulphate fertilizers are also a major source of sulphate to ambient waters. Sulphate concentrations typically range between about 2 and 30 mg/L for most lakes and rivers in British Columbia. Although, some lakes in the Cariboo Region and in Richter Pass near Osoyoos have particularly high natural sulphate levels in the thousands of mg/L. Seasonal fluctuations in dissolved sulphate concentrations are obvious in most rivers, with low concentrations during freshet and elevated concentrations during winter low
Sulfates in drinking water currently have a secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L), based on aesthetic effects (i.e., taste and odor). This regulation is not a federally enforceable standard, but is provided as a guideline for states and public water systems. EPA estimates that about 3% of the public drinking water systems in the country may have sulfate levels of 250 mg/L or greater. The Safe Drinking Water Act (SDWA), as amended in 1996, directs the U.S. Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) to jointly conduct a study to establish a reliable dose-response relationship for the adverse human health effects from exposure to sulfate in drinking water, including the health effects that may be experienced by sensitive subpopulations (infants and travelers).

According to Cocchetto and Levy, (1981) ingestion of 8 g of sodium sulfate and 7 g of magnesium sulfate caused catharsis in adult males. Cathartic effects are commonly reported to be experienced by people consuming drinking-water containing sulfates in concentrations exceeding 600 mg/L (US DHEW, 1962). Dehydration has also been reported as a common side-effect following the ingestion of large amounts of magnesium or sodium sulfate (Fingl, 1980)

3.1.13 Magnesium (Mg)

Magnesium is present in seawater and amounts about 1300 ppm., after Sodium it is the most commonly found cation in oceans. Rivers contain approximately 4 ppm of Magnesium, marine algae 6000-20,000 ppm and oysters 1200 ppm. Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water, and water containing low amounts of these ions is called soft water. According to Pitter (1999) Magnesium is usually less abundant in waters than Calcium, which is easy to understand since Magnesium is found in the earth’s crust in much lower amounts as compared with Calcium. In common underground and surface waters the weight concentration of Ca is usually several times higher compared to that of Mg, the Ca to Mg ratio reaching up to 10. Drinking water contains magnesium salts, the level of which varies depending on the geographical region. It can enter the environment from discharge and emissions from industries that use or manufacture Magnesium.
According to Weast (1987), Magnesium is the eighth most common element in the crust of the Earth and is mainly tied up within mineral deposits, for example as magnesite (magnesium carbonate \([\text{MgCO}_3]\)) and dolomite. The most plentiful source of biologically available Magnesium, however, is the hydrosphere (i.e. oceans and rivers). In the sea, the concentration of Magnesium is \(\sim 55 \text{ mmol/L}\) and in the Dead Sea as an extreme example the concentration is reported to be \(198 \text{ mmol/L}\). Magnesium has steadily increased over time. Magnesium salts dissolve easily in water and are much more soluble than the respective Calcium salts. As a result, Magnesium is readily available to organisms. Magnesium plays an important role in plants and animals alike. In plants, Magnesium is the central ion of chlorophyll. In vertebrates, Magnesium is the fourth most abundant cation and is essential, especially within cells, being the second most common intracellular cation after Potassium, with both these elements being vital for numerous physiological functions. Magnesium is also used widely for technical and medical applications ranging from alloy production, pyrotechnics and fertilizers to health care. Traditionally, magnesium salts are used as antacids or laxatives in the form of magnesium hydroxide \([\text{Mg(OH)}_2]\), magnesium chloride \((\text{MgCl}_2)\), magnesium citrate \((\text{C}_6\text{H}_8\text{O}_7\text{Mg})\) or magnesium sulphate \((\text{MgSO}_4)\).

### 3.1.14 Calcium (Ca)

Calcium (\(\text{Ca}^{++}\)) and Magnesium (\(\text{Mg}^{++}\)) ions are both common in natural waters and both are essential elements for all organisms. Calcium and Magnesium, when combined with bicarbonate, carbonate and sulphate, contribute to the hardness of natural waters. The effect of this hardness can be seen as deposited scale when such waters are heated. Normally hardness due to Calcium predominates although in certain regions, Magnesium hardness can be high. In some river catchments, hardness can vary seasonally reaching peak values during low flow conditions.

According to Annalakshmi and Amsath, (2012) Calcium is an important micronutrient in an aquatic environment and this environment is affected by adsorption of calcium ion on the metallic oxides. In addition to this it has effect on microorganisms, which play an important role in Calcium exchange between sediments and overlying water. Calcium is the fifth most abundant natural element. As per NAQUADAT (1977), the greatest concentration, 365 mg/L, was recorded in Prince Edward Island, and the lowest, 0.3 mg/L, in Newfoundland. Data collected
from 24 stations in Saskatchewan in 1980 and 1981 showed that the concentration of Calcium in surface waters ranged from 2 to 141 mg/L, whereas the average concentrations from sampling stations in all provinces ranged from 1 to 336 mg/L.

Calcium enters the freshwater system through the weathering of rocks, especially limestone, and from the soil through seepage, leaching and runoff. (Day, 1963). The leaching of calcium from soil has been found to increase significantly with the acidity of rainwater. (Overrein, 1972).

Calcium occurs in water naturally. Seawater contains approximately 400 ppm calcium. One of the main reasons for the abundance of Calcium in water is its natural occurrence in the earth's crust, Calcium is also a constituent of coral. Rivers generally contain 1-2 ppm of Calcium, but in lime are as rivers may contain Calcium concentrations as high as 100 ppm. Examples of calcium concentrations in water organisms: seaweed _luctuca_ 800-6500 ppm (moist mass), _oysters_ approximately 1500 ppm (dry mass). In a watery solution calcium is mainly present as Ca$^{2+}$ (aq), but it may also occur as CaOH$^+$ (aq) or Ca(OH)$_2$(aq), or as CaSO$_4$ in seawater. Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste. Water hardness influences aquatic organisms concerning metal toxicity. In softer water membrane permeability in the gills is increased. Calcium also competes with other ions for binding spots in the gills. Consequently, hard water better protects fishes from direct metal uptake. pH values of 4.5-4.9 may harm Salmon eggs and grown Salmons, when the Calcium, Sodium and Chlorine content is low.

3.2 Material and Methods

The study site was visited at an interval of a month from January, 2009 to December, 2010. Total 24 visits were made during the study period. To collect water samples for analysis, plastic containers of two liters capacity were used. Surface water samples were collected from three sites at Budki M.I. tank namely A, B and C between 8 a.m. to 10 a.m. in three separate clean containers and labeled station wise to indicate date, location and brought to the laboratory for analysis. The parameters such as Water Temperature (WT), pH and Carbon-dioxide were analyzed at the field station itself while Dissolved Oxygen (DO) was fixed in separate BOD sample bottles. Analysis of other parameters such as Total Hardness (TH), Chlorides (Cl$^-$),
pH, Nitrates (NO$_3$) and Phosphates (PO$_4^{3-}$) were carried out in the laboratory. To retain the chemical properties, all the samples were protected from heat and direct sunlight during transportation and until estimated.

3.2.1 Physical parameters

3.2.1.1 Temperature (Temp.)
Both Atmospheric or Ambient (AT) and Water Temperature (WT) were measured using Mercury thermometer and noted in $^0$C.

3.2.1.2 Water Cover (WC)
The water cover was estimated visually in terms of percentage as compared to maximum filled level.

3.2.1.3 Transparency (Trans.)
Transparency was determined using Secchi disc, a metallic disc of 20 cm diameter with four alternate black and white quarters on the upper surface. The disc with centrally placed weight at the lower surface is suspended with a graduated cord at the centre. Transparency was measured by gradually lowering the Secchi disc at respective sampling stations. The depths at which it disappears (A) and reappears (B) in the water were noted. The transparency of the water body was computed as follows, Secchi disc light penetration = A + B / 2

Where, A = depth at which Secchi disc disappears.

B = depth at which Secchi disc reappears.

3.2.1.4 Total Solids (TS)
Total solids were determined as the residues left after evaporation of the unfiltered sample. An evaporating dish of 100 ml capacity was ignited at 550 ± 50 $^0$C in muffle furnace for half an hour, cooled in desiccators and weighed. Then 100 ml of unfiltered sample was evaporated in an evaporating dish on a hot plate at 98 $^0$C. After heating the residues at 103-105 $^0$C in an oven for one hour the evaporating dish was cooled in a desiccators and weighed. TS was calculated as,

$$\text{Total Solids in mg/L} = \frac{(A - B) \times 1000}{V}$$

Where, $A =$ Final weight of the dish in gm.
3.2.1.5 **Total Dissolved Solids (TDS)**

Total dissolved solids were determined as the residues left after evaporation of the filtered sample. As reported for TS an evaporating dish of 100 ml capacity was ignited at 550 ± 50 °C in muffle furnace for half an hour, cooled in desiccators and weighed. 100 ml of filtered sample was added to it and evaporated in a pre-weighed evaporating dish on the hot plate at 98 °C. The residues were heated at 103-105 °C in an oven for one hour and final weight was taken after cooling the evaporating dish in a desiccators. TDS was calculated as,

\[
\text{Total Dissolved Solids in mg/L} = \frac{(A - B) \times 1000}{V}
\]

Where, $A$ = Final weight of the dish in grams.
$B$ = Initial weight of the dish in grams.
$V$ = Volume of sample taken in ml.

3.2.1.6 **Total Suspended Solids (TSS)**

It is the difference between the total solids and total dissolved solids.

\[
\text{TSS} = \text{TS} - \text{TDS}
\]

3.2.2 **Chemical parameters**

3.2.2.1 **pH (Electrometric method)**

The pH of water sample was measured by electronic portable pH meter. The pH meter was calibrated with phosphate buffer of known pH. It uses electrodes (Eqip-Tronics, Model No.EQ-615) that are free from interference. At constant temperature, a pH change produces a corresponding change in the electrical property of the solution. This change was read by the electrode and the accuracy was the greatest in the middle pH ranges.

3.2.2.2 **Dissolved Oxygen (DO) (Winkler's method - APHA, 1998)**

The Manganese sulphate reacts with alkali (KOH) to form a white precipitate of manganous hydroxide. In presence of oxygen it gets oxidized to form a brown coloured manganese oxyhydrate which is equivalent to the amount of dissolved...
Oxygen present in water. In the presence of iodide ion acidification, oxides of manganese revert to divalent state with the liberation of Iodine equivalent to originally dissolved Oxygen content in the sample. The Iodine is then titrated with standard solution of sodium thiosulphate using starch as an indicator.

For the estimation of Dissolved Oxygen the water samples were collected with care in BOD bottles without bubble formation. The DO was then fixed at the station itself by adding 1 ml each of Manganese Sulphate and Alkali-iodide azide reagents. The precipitates formed were dissolved by adding 2 ml. of concentrated Sulphuric acid. From this 50ml sample was taken and titrated against 0.1N Sodium thiosulphate. To estimate Iodine generated starch was used as an indicator and the end point was noted as the solution turns from blue to colorless. The DO was calculated using following formula

\[
\text{DO mg/L} = \frac{\text{B. R.} \times N \times 1000}{\text{Amount of sample taken (ml)}}
\]

Where, C. B.R. = Constant Burette Reading (Amount of titrant used).
N = Normality of Sodium thiosulphate.

3.2.2.3 Free Carbon dioxide (CO$_2$) (APHA, 1998)

The method is based on the principle that free carbon dioxide (CO$_2$) in water reacts with sodium hydroxide (NaOH) to form sodium bicarbonate (Na$_2$CO$_3$) and the end point is indicated by development of pink colour using phenolphthalein as an indicator at pH 8.3. To estimate CO$_2$ in water in 100 ml. sample 2 to 3 drops of phenolphthalein were added and the sample was titrated against 0.05N Sodium hydroxide until a pink color was obtained. The free carbon dioxide was calculated using following formula:

\[
\text{Free carbondioxide mg/L} = \frac{\text{B. R.} \times N \times 44 \times 1000}{\text{Amount of sample taken (ml)}}
\]

Where, C.B.R. = Constant Burette Reading (Amount of titrant used).
N = Normality of Sodium Hydroxide (0.05N).
44 = Equivalent weight of CO$_2$.

3.2.2.4 Total Hardness (TH) (EDTA Titrimetric Method, APHA, 1998)

Hardness is generally due to Calcium and Magnesium ions present in the
water. EDTA (Ethylene di-amine tetra acetic acid) and its sodium salts as well as Eriochrome Black-T form a chelated soluble complex when added to a solution of certain metal cations. When a small amount of Eriochrome Black-T Calamite indicator is added to the aqueous solution containing Calcium and Magnesium ions at pH 10.0 it forms Calcium and Magnesium ion complexes and the solution becomes wine red. Since EDTA has strong affinity towards Calcium and Magnesium ions, with the addition of EDTA as titrant, the complex binds to EDTA and Eriochrome Black T is released free. As a result the solution turned from wine red to blue, indicating the end point.

For the estimation of total hardness, in 100 ml of sample, 1 to 2 ml of buffer solution and a pinch of Eriochrome Black-T (used as an indicator) were added. After the appearance of wine red colour, the mixture was titrated against EDTA stirring continuously till end point change of wine red to blue colour was achieved. The total hardness was calculated using following formula,

\[
\text{Total hardness expressed as } \frac{\text{mg CaCO}_3}{L} = \frac{A \times N \times 1000}{\text{Amount of sample taken (ml)}}
\]

Where \(A\) = ml of titrant (EDTA) used.
\(N\) = Normality of EDTA.

3.2.2.5 Chlorides (Cl\(^-\)) (Argentometric Titremetric method, APHA, 1998)

Silver nitrate reacts with chlorides to form very slightly soluble white precipitates of AgCl\(_2\). In a neutral or slightly alkaline solution, chloride is estimated with silver nitrate as titrant using potassium chromate as an indicator. Silver chloride is precipitated quantitatively before red silver chromate is formed.

In 100 ml. sample, 1 ml. of K\(_2\)CrO\(_4\) indicator was added and titrated against 0.02N AgNO\(_3\) till brick red precipitates were formed. The formula used to calculate mg. of Cl\(^-\)/l is as follows,

\[
\text{mg of Cl} /L = \frac{\text{C.B.R.} \times N \times 35.45 \times 1000}{\text{Amount of sample taken (ml)}}
\]

Where, \(\text{C.B.R.}\) = Constant Burette reading (Amount of titrant used).
\(N\) = Normality of Silver Nitrate.
35.45 = Equivalent weight of Chloride.
3.2.2.6 Nitrates (NO\textsubscript{3}) (Cadmium Reduction Method, APHA, 1998)

Nitrite (NO\textsubscript{2}) is reduced to nitrate (NO\textsubscript{3}) in the presence of Cadmium (Cd). This method uses commercially available Cd granules coated with 2% copper sulphate (CuSO\textsubscript{4}) packed in a glass column. The Nitrates (NO\textsubscript{3}) produced was determined by diazotizing it with color reagent containing sulfanilamide coupled with N-(1- naphthyl)-ethylenediamine dihydrochloride (NEDD) to form highly coloured azo dye. The color developed was measured colorimetrically at 410 nm. A correction was made for any NO\textsubscript{3}\textsuperscript{-} present in the sample by analyzing the sample without the reduction step. A standard graph was plotted to obtain the factor. Nitrates were calculated as

\[
\text{NO mg/L} = \frac{\text{O.D.} \times \text{Factor}}{\text{Amount of sample taken (ml)}},
\]

Where, O.D. = Optical Density

3.2.2.7 Phosphates (PO\textsubscript{4}\textsuperscript{3-}) (APHA, 1998)

The phosphates in water react with ammonium molybdate and form complex molybdophosphoric acid which gets reduced to a complex of blue colour in the presence of SnCl\textsubscript{2}. The absorption of light by this blue colour can be measured at 690 nm to calculate the concentration of phosphates.

In a conical flask containing 100ml. of sample, 4ml of strong acid and 4 ml of ammonium molybdate were added followed by 10 drops of SnCl\textsubscript{2}. The blue colour developed was measured after 10 minutes at 690 nm with colorimeter model Photochem 5.0. It is necessary to make a standard graph before the analysis of sample to obtain the factor. The instrument was set by running a reagent blank. The Phosphates were calculated as

\[
\text{PO as mg/L} = \frac{\text{O. D.} \times \text{Factor}}{\text{Amount of sample taken (ml)}},
\]

Where, O.D. = Optical Density

For the convenience of analysis the monthly data were pooled for three seasons: namely 1.Summer (January, February, March and April) ; 2.Monsoon (May, June, July and August) and 3.Winter (September, October, November and December). The results given are in the form of Mean ± SEM. The data were subjected to ANOVA across the season with the help of Prism 3 software (Graphpad software, San
Diego, California U.S.A.). The P value for ANOVA is non significant if $P > 0.05$ (ns), significant if $P < 0.05(*)$, significantly significant ($**$) if $P < 0.001$ and highly significant ($***$) if $P < 0.0001$. The Pearson Correlation between various parameters were also calculated with the help of SPSS 7.5/12 for windows. If ($**$) Correlation is significant at the 0.01 level (two-tailed), whereas at (*) correlation is significant at 0.05 level (two-tailed).

### 3.2.2.8 Sulphates (SO4) Turbidimetric method
1. 100 ml of clear sample was taken (not containing more than 40 mg/L of SO$_4$) or a suitable aliquot diluted to 100 ml in 250 ml conical flask and 5.0 ml of conditioning reagent was added.
2. The sample was stirred on a magnetic stirrer and during stirring, a spoonful of BaCl$_2$ crystals were added. Stirring for only one minute after addition of BaCl$_2$ crystals was done.
3. The reading were taken on a spectrophotometer (Schimabzu, 2450) at 420 nm exactly after 4 minutes. The concentration of sulphate from the standard curve were calculated.
4. The standard curve was prepared by employing the same procedure as described above, for 0.0-40.0 mg/L.

### 3.2.2.9 Magnesium (Mg) EDTA Titration
1. The volume of EDTA used in Calcium determination was found out.
2. The volume of EDTA used in hardness (Ca$^{++}$ Mg$^{++}$) determination with same volume of the sample as taken in the Calcium determination was also noted.

\[
\text{Magnesium}, \text{ mg/l} = \frac{Y - X \times 400.8}{\text{ml of sample} \times 1.645}
\]

Where, $X =$ EDTA used for Ca determination for the same volume of the sample $Y =$ EDTA used for hardness (Ca+Mg)

### 3.2.2.10 Calcium (Ca) EDTA Titration
1. 50 ml sample in a conical flask was taken. If the sample having higher alkalinity, use smaller volume diluted to 50 ml.
2. 2.0ml of NaOH solution added in the sample.
3. 100 to 200 mg of murexide indicator was added a pink color changes.
4. Titrated against EDTA solution until the pink color changed to purple. For better judgment of end point, compared the purple color with the distilled water blank titration end point.

\[
\text{Calcium, mg/L} = \frac{X \times 400.8}{\text{ml of sample}}
\]

Where, \(X\) = Volume of EDTA used.

3.3 Result and Discussion

For convenience, the results were accessible into two groups: **Group I** (Physical Parameters) Ambient Temperature (AT), Water Temperature (WT), Water Cover (WC), Transparency (Trans), Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). **Group II** (Chemical Parameters) pH, Dissolved Oxygen (DO), Carbon Dioxide (CO\(_2\)), Total Hardness (TH) and Chlorides (Cl\(^-\)), Nitrates (NO\(_3^-\)), Phosphates (PO\(_4^{3-}\)) and Sulphates (SO\(_4^{2-}\)).

3.3.1 Group I: Physical Parameters

3.3.1.1 Temperature (Temp.)

Atmospheric (AT) and water temperature (WT) are two important environmental factors. The range of atmospheric temperature recorded during the period of two years January 2009 to December 2010. The minimum temperature recorded during winter season (24.4\(^{0}\)C ± 0.56\(^{0}\)C) and maximum temperature recorded in summer (31\(^{0}\)C ± 1.32\(^{0}\)C) during the study period (Table 3.1). Similar results are observed by Gaike and Shejule (2012), the atmospheric temperature recorded between ranging from 16\(^{0}\)C to 32\(^{0}\)C and the water temperature recorded from 16\(^{0}\)C to 29\(^{0}\)C. In Kasura dam, maximum atmospheric temperature was recorded in the month of May 32\(^{0}\)C and minimum 16\(^{0}\)C was recorded in the month of December. The maximum water temperature recorded in May was 29\(^{0}\)C and the minimum of 16\(^{0}\)C was recorded in December. Temperature is a physical factor indicated the quality of water and it has effect on growth and distribution of aquatic life, concentration of dissolved gases and chemical solutes. Chavan et. al. (2012), observed minimum temperature 21.4\(^{0}\)C during winter season and maximum temperature 26.53\(^{0}\)C summer in season. The low water temperature in the winter might be due to high water levels and lower solar radiation whereas maximum in the summer might be due to low water level, greater solar radiation and clear atmosphere. According to Sahni and Yadav (2012),
temperature (AT) was observed ranging between 16.12 to 36.75°C of which maximum value (36.75°C) was noticed in summer season and the minimum value (16.12°C) in winter season. Similar observations were reported by Wagh et. al. (2012), minimum temperature (AT) was recorded during winter (23.2°C) and maximum was in summer (41.1°C) season and the minimum (WT) recorded (22.2°C) in winter, maximum (42.1°C) in summer season from manmade reservoir Parnear, Dist Ahmednagar, Arvind Kumar and Singh (2002) in the Mayurakshi River, Jharkhand and Dwivedi and Pandey, (2002), Sedamkar and Angadi (2003). The values of AT are given in (Table3.1). It showed highly significant seasonal variations (P<0.0001 $F_{2, 21}$12.3) in the region of Budki M.I.Tank (BMIT). It showed positive significant correlation (Table3.3) with Cl, CO$_2$, PO$_4^{3-}$, TDS, TH, TS and WT while it was negatively correlated with DO, Transparency and WC both at 0.01 levels. Similarly, maximum water temperature (Table 3.1) was also recorded in summer (26.5°C). It slightly decreased in monsoon (24.8°C) and it was minimum in winter (21.5 °C) with highly significant seasonal variations (P<0.0001 $F_{2, 21}$ 10.7). Water temperature showed significant positive correlations (Table3.3) with AT, Cl, CO$_2$, PO$_4^{3-}$, TDS, TS and TH (at 0.01 level, two-tailed), while it showed negative significant correlations with DO, Trans and WC at 0.01 level. Das (2000), Transparency (Reid and Wood, 1976), and water cover at the same level, similar result reported by Patil (2011) during the study of selected faunal biodiversity of Toranmal area, Lotus lake as well as Ekhande (2011) at Yashwant Lake Toranmal in Maharashtra. According to Sutar et. al. (2008), the atmospheric temperature of Mhaswad reservoir was recorded in the range between 23.7°C to 38.2°C. According to Bhandarkar and Bhandarkar (2013), temperature was higher during summer months and lower during winter months and water temperature recorded the ranged between 23.95°C to 29.4°C. The minimum water temperature recorded in the winter season and maximum in the summer months, similar observations were recorded by Mithani et. al.(2012) of River Wardha (23.13°C to 31.13°C) Chandrapur, Maharashtra, Bade et.al. (2009) in Sai reservoir, Latur and Manjare et. al.(2010) in Tamdale tank, Kolhapur. The atmospheric temperature was found to be in the range between 23°C to 35.7°C. It was minimum during January and December and maximum in the month of April and May (Rai et.al.,2013).

Water Temperature is mainly most important for its special effects on a certain chemical and biological behavior in the organism attributing in aquatic media. The
water temperature and air temperature were found more or less similar. In Indian subcontinent, the temperature in most of the water bodies varied between 7.8°C to 38.5°C was reported by Sirighal et. al.(1986). Water temperature also controls the physiological activities and distribution of aquatic organisms and has effect on natural environment. Variation of water temperature is generally governed by the atmospheric condition. According to Desai (1995) water temperature may be depending on the season, geographic location and sampling time from Dudhasagar river. This is reflected by lower water temperature at Budki M.I.Tank in monsoon due to cloudy weather and rainfall while in winter due to cold climatic conditions with shorter sunshine period. During summer season solar radiation and clear sky condition enhanced the climatic condition. The variation in the temperature of the present study is similar with the findings of Rao et. al., (1982) for Nainital lake (8°C to 23°C), Billore and Vyas (1982) for Pichhola lake (0.6°C to 26.3°C) and Singhai et. al., (1990).Temperature control the hydrochemistry of parameters like Dissolved Oxygen, Solubility, pH, Conductivity, etc. Patil (2011),Ramachandra and Solanki (2007). In general water holds lesser Oxygen as the temperature increases Kulkarni et. al., (2007) in Khushavati river; Awasthi and Tiwari (2004) of Govindgharh lake, hence an inverse relationship between the two, but a positive significant correlation with Alkalinity, Acidity, Atmospheric Temperature, Chloride, CO₂, pH, Phosphate, TDS, TS and water cover is noted at 0.01 level in the present study. With reference to thermal cover between AT and WT and annual variations in temperature, Jaychandra and Joseph (1988) recorded maximum difference of 2.7°C between AT and WT at a tropical Vellayani Lake in Kerala while Kanan and Job (1980) have reported a difference of 5.5°C in Diurnal depth wise and seasonal changes of physicochemical factors in Sathiyar reservoir and Sreenivasan at.el.(1997) a difference of 6°C in Limnological study of a shallow water body (Kolovoi Lake) in Tamilnadu. Water temperature of Indrapuri dam ranged between 21.3°C to 28.8°C. It was minimum during November and December and maximum in the month of April and May (Rai et.al., 2013). In the present study maximum mean value of AT was recorded in summer (31.0 ± 1.32°C) and minimum value was recorded in winter (24.4 ± 0.56°C). The difference between AT and WT were between 4.5°C to 2.9°C respectively in summer and winter. It is a well established fact that land heats up and cools down faster than water the same effect is produced at BMIT. Water temperature regulates the biochemical behavior in the aquatic environment. The physiological and metabolic activities of organism such as feeding, reproduction, movements and
distribution are seriously influenced by water temperature.

3.3.1.2 Water Cover (WC %)

At BMIT study area the maximum percentage of water cover (Table 3.1, Fig. 3.2) was recorded in winter (84.4%) and minimum in summer (61.5%), and medium in monsoon (79.4%).

The maximum water surface recorded at BMIT in the monsoon and minimum in the summer indicated that the area received rainfall mainly during south-west monsoon. At BMIT water cover started increasing in rainy season because of rain water and collection continued from tributary present in the surrounding of BMIT. Water cover was minimum in summer due to percolation, evaporation of water and was used for domestic purposes by the people around BMIT. The high DO in the reservoirs compared to the tanks is slightly lesser than high water level (Water Cover) and therefore, more dissolution of atmospheric Oxygen (Hegde and Hudder, 1995). Hence, water cover was positively correlated to DO at study area. The seasonal variation in the percentage of water cover with the contour of water body determines the littoral formation; it is an indicator of productive nature of the lakes in India (Sugunan2000). An irregular shoreline encompasses more littoral formation produces more area of land and water interface. At BMIT the shoreline is less irregular and hence less littoral formation in water cover. The space is essential for colonization and clearly affects the composite production of periphytic communities (Wetzel, 2006). Large lakes are typical repositories of the greatest numbers of species because their
greater surface area provides more opportunities for colonization. They contain a greater variety of microhabitats and their internal environmental conditions are more stable compared to smaller water bodies (Pip, 1987). These opportunities for development of various organisms are provided by water cover that in turn determines the extent of littoral formation. As far as producers like algae are concerned spatial heterogeneity in their rates of production is usually very high because of the great variability in littoral habitats within freshwater ecosystem. Most lakes of the world are shallow and possess large littoral zone. Such shallow lakes with a well developed littoral habitat can function as a refuge for zooplankton, fish and invertebrate predation that prevails in the open water. In the current investigation at BMIT water cover, the maximum mean percentage of water cover (Table 3.1) was recorded in winter (84.0 ± 2.56 %) and minimum in summer (61.5 ± 3.50 %), and medium in monsoon (79.4 ± 5.13). Water cover showed positive significant correlations (Table 3.3) with DO while it showed negatively significant correlations with AT, Cl⁻, CO₂, TDS, TS, TH, and WT at 0.01 level.

![Seasonal variation in Water cover (%) at Budaki dam during January, 2009 to December, 2010](image)

### 3.3.1.3 Total Solids (TS)

During the period of research at BMIT water study, the total solids in water were found to be increased in monsoon period (205±4.36 mg/L) and minimum during in winter season (156 ± 4.40 mg/L), it was moderate in summer (198±4.5Lmg/) (Table 3.1, Fig 3.3.).

Total Solids are useful parameter demonstrating the chemical status of the
water and can be considered as an initiator of edaphic relations that constitute to productivity within the water body (Goher 2002). Maximum total solids of BMIT water in the monsoon period which reflects the input of rain water which brought large amount of dissolved solids and suspended solids with it as well as agitation of lake water due to water current. As the rain stops the solids settle down minimizing their levels by winter. TS were lower during the lean month’s winter and when the interferenced due to flood and precipitation were low. However, comparatively higher levels during summer may be due to concentration due to evaporation. Deshkar (2008) were observed higher in summer (2.6 mg/L) and lower in winter (0.27 mg/L) of wetlands in semi-arid zone of Central Gujarat and Patil et. al.(2011) recorded maximum TS in Monsoon (203.2 mg/L) and minimum in winter (160.5 mg/L) of Lotus lake from Maharashtra. Total Solids also showed highly significant seasonal variations (P<0.0001, F₂ 21 35.4). TS showed positive significant correlations (Table 3.3) with AT, Cl⁻, CO₂, NO₃, PO₄³⁻, SO₄, TDS, TSS and WT while, negative significantly correlation to DO, Transparency and WC both at 0.01 level.

![Seasonal variation in TDS, TSS and TS (mg/L) at Budaki dam during January, 2009 to December 2010](image)

### 3.3.1.4 Total Dissolved Solids (TDS)

In the present research at BMIT total dissolved solids were maximum 160 ± 2.94 mg/L in summer and minimum 127 ± 3.12 mg/L in winter, while it was 150 ± 4.36 mg/L in monsoon. (Table3.1, Fig, 3.3). TDS were positively significantly correlated (Table 3.3) with AT, Cl⁻, CO₂, PO₄³⁻, TS and while negatively significantly with DO, Trans. and WC with highly significant seasonal variations (P< 0.0001, F₂ 21
Gonzalves and Joshi (1946) at algae tank of Bandra and Sayed et.al (2011) of Wadi El-Rayyan Lakes, western desert, Egypt also observed highest (13772 mg/L) concentration of total dissolved solids during summer, which decrease during rainy seasons due to dilution of rainwater. Medudhula et.al.(2012)TDS value ranged from 261.25 to 269.05 mg/L in winter and Summer seasons, Shib Abir, (2014) also recorded maximum TDS during Summer(216 mg/L) and minimum during winter (80 mg/L) at Rudrasagar wet land, Tripura. Salve and Hiware, (2006) reported seasonal analysis and stated that low TDS recorded in winter season while maximum value in monsoon due to addition of solids from surface run off in Wanparakalpa reservoir, Nagapur near Parali Vaijanath Dist. Beed, Maharashtra.

According to Rahaman the maximum TDS values of the Ganges, Brahmaputra and confluence were 376 mg/L, 245 mg/L & 231 mg/L and minimum values were 102 mg/L, 62 mg/L & 61mg/L and the average values were 260±96 mg/L, 155±61 mg/L & 155±55 mg/L. The total dissolved solids (TDS) mainly indicate the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates and metallic ions etc which are comprised both colloidal and dissolved solids in water. As per the investigation of Aggarwal and Arora (2012) of Kaushalya River TDS and TSS are common indicators of polluted waters and observed that TDS values ranged between 152mg/L to 252 mg/L and TSS values ranged from 2 mg/L to 27 mg/L. The water with TDS and TSS can be considered to be good. Shivayogimath et.al (2012), reported seasonal changes TDS from various station of River Ghataprabha. The average TDS values at station 1 were 128.48 and 116.48 mg/l during pre-monsoon and post-monsoon seasons. From stations 2 to 7 the values ranged between 182 to 254 mg/L and 163 to 227 mg/L during pre-monsoon and post-monsoon seasons, concluded that the values of TDS in both the seasons were well within the limits of drinking water. Mafruha Ahmed (2013) were found maximum value (334 mg/L.) of TDS in dry season and minimum value (212 mg/L) in wet season from Gulshan lake.

The higher values of TDS were recorded by many workers such as Sahni and Yadav(2013)Total dissolved solids (TDS) value ranged from 2908.70 to 4373.00 mg/L of which higher value (4373.00 mg/L) was reported in summer season while the lower value (2908.70mg/L) in winter season from Bharawas Pond, Rewari, Haryana. Higher values of TDS in summer season may be due to evaporation of water,
contamination of domestic waste water, garbage and fertilizers etc. Olatunji et.al (2011) the mean values of the total dissolved solids (TDS) range from 704.60 to 1,799.80 mg/L in Asa River. The total dissolved solids ranged between 88 and 2560 mg/L. reported by Lawson (2011) from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. Dhanalakshmi et.al.(2013) TDS of Pollachi town pond water recorded during (2006-07 and 2007-08) the maximum value of 1320 mg/L and 1346 mg/L in monsoon month and minimum of 842 mg/L and 925 mg/L in summer month respectively.

The high amount of TDS increased turbidity which in turn decreased the light penetration in water. This affects the photosynthesis thereby suppressing the primary production in the form of algae and microphytes. Positive significant correlation with AT, CL, CO$_2$, PO$_4$, TS and WT while; the significantly negative correlations between with DO, Trans. and WC both at 0.01 levels were noted at BMIT. Positively significant correlation with CO$_2$ at study stations indicate decline in photosynthetic activity due to lower light penetrance. The highest TDS recorded in summer at BMIT may be due to decaying vegetation (Table3.1) The products of decaying vegetation at the surface when started sinking might have increased the TSS as well as TDS (Khan and Khan, 1985 in Seikha jheel at Aligarh.; Iqbal and Kataria (1995) of upper Lake of Bhopal). It reduces solubility of gases (like Oxygen), utility of water for drinking purpose and also enhances eutrophication of the aquatic ecosystem of Pushkar Lake, Ajmer Rajasthan (Mathur et. al., 2008). The wetlands act as sinks for nutrient deposition hence, the high TDS values may also depend on the age of the lake Anitha et. al. (2005) as a result of gradual salt deposition, an observation not always applicable for monsoonal wetlands in Mir Alam Lake, Hyderabad. However, at BMIT the values of TDS were within the permissible limits of 500 mg/L (BIS, 1991), thus water can be used for drinking as well as agriculture purpose.

3.3.1.5 Total Suspended Solids (TSS)

At BMIT maximum TSS mean value recorded 54.6 ± 1.89 mg/L in monsoon and minimum 29.5±2.46mg/L in winter, while it was 37.9±1.66 mg/L in summer (Table3.1) with variations at P < 0.0001 across the season. Total suspended solids administered positive significant correlations (Table3.3) with AT, CL, CO$_2$, TDS and WT at the level of 0.05 and NO$_3$, PO$_4$, SO$_4$,TS at 0.01 level while Trans. at the level of 0.01 were significantly negatively correlated.
During tenure research work of BMIT the highest concentration of TSS found in monsoon (54.6 mg/L.) and lowest in winter season (29.5 mg/L.) Similar trend was observed by Garnaik et.al. (2013) of Nagavali River, Odisha (maximum in Monsoon 82 mg/L and minimum in Post Monsoon (38 mg/L), where as Anhwange et.al. (2012), reported the mean values for total suspended solid (TSS) observed ranged between 12.55 to 49.57 mg/L during the wet season and range of 4.80 to 347.60 mg/L was recorded during dry season from Bengue river. Raut et. al.(2011) of Ravivar Peth Lake at Ambajogai, the high values of total suspended solids during monsoon (146.3±20.87 mg/L) may be due to siltation, deterioration and heavy precipitation and low during winter (70.01±22.23 mg/L.) Solids concerned to suspended and dissolved matter in water. They are useful parameters to describe the chemical constituents of the water and can be considered as general relation that contributes to productivity in the water body by Goher (2002) in Qarun lake. In accordance to TSS, maximum was recorded in monsoon as a result of water runoff from the catchment area which brings various suspended matter. TSS also increases due to decaying vegetation. When the products of decaying vegetation at the surface start sinking, it may increase the TSS as well as TDS (Khan and Khan, 1985; Iqbal and Kataria, 1995). Such processes are minimum in winter hence the minimum TSS in winter when the water of the lake is stabilized and most of the suspended matter settles down. Increased level of suspended solids results in increased turbidity and lower photosynthesis, rise in water temperature and decrease in dissolved Oxygen Sharma et.al. (2008). According to Prabhakar et. al.(2012) of Palar River in Tamil Nadu. TS and TSS varied from 800.63 to 903.15 mg/L, 453.19 to 510.10 mg/L and 346.00 to 390.20 mg/L respectively. The TSS value exceeded the desirable limit of WHO and BIS standards, therefore, water was not recommended for drinking and bathing purposes.

3.3.1.6 Transparency (Trans) (Secchi Depth).

The transparency of water fluctuated both spatially and temporally. In general, the highest transparency values were recorded in winter (111±3.32 cm), and the lowest in monsoon season (71.1±5.45 cm.) (Table. 3.1, Fig.3.4). Transparency showed positive correlation with dissolved Oxygen DO with at 0.001 level while Ca, Mg, TH, WC were non significantly correlated and significant negative correlation with AT, Cl, NO₃, PO₄, SO₄, TS, TSS and TDS at 0.01 level. Transparency also
showed highly significant seasonal variations (P< 0.0001, F_{2,21} = 28.2).

According to Nayak and Behara (2004), transparency recorded that the whole lagoon remained turbid throughout the year, the highest Secchi disc depth was 0.91 M. The turbid nature of the lagoon due to influence of freshwater influx during monsoon from Chilika lagoon near Sipakuda. Sahni and Yadav (2012), transparency noted ranged between 12.12 to 15.12 cms of which higher value (15.12 cm) was reported in winter season while the lower value (12.12 cm) in summer season. Lower value of transparency during summer season might be due to low level of water. Similar conclusion was reported by Kamal et. al. (2007) reported highest in winter (66 cm) and lowest in monsoon (15 cm) of Mouri River, Khulna, Bangladesh. Kadam et.al.(2007) from Masoli reservoir of Parbhani district, Maharashta , Syeda and Shaikh (2013) from Rupsha River, Bangladesh, reported that higher transparency occurred, during winter in December (42.4±8.72cm) due to absence of rain, runoff and flood water as well as gradual settling of suspended particles. Ibrahim et.al.(2009), reported from Kontagora Reservoir the higher dry season Secchi disc transparency mean value compared to that of the rainy season could be due to absence of floodwater, surface run-offs and settling effect of suspended materials that followed the ending of rainfall. Similar observation was also recorded by Ikom et.al. (2003) of river Adofi from Nigeria, the higher transparency observed during the dry season could also be due to reduction in allochthonous substances that find their ways into the reservoir with flood. According to Adebisi (1981) in Upper Ogun River. Wade (1985), who observed that onset of rain decreased the Secchi-disc visibility in two mine lakes around Jos, Nigeria. Lower transparency recorded during rainy season when there was turbulence and high turbidity, has a corresponding low primary productivity, because turbidity reduces the amount of light penetration, which in turn reduces photosynthesis and hence primary productivity.

Idowu et.al. (2013), transparency of the water was lower during the period of heavy rainfall probably due to flooding of the reservoir, which may have been caused by higher amount of rainfall during this period due to high turbidity. It could also be due to decrease in sunlight intensity due to presence of heavy cloud in the atmosphere, which in turn reduced the quantity of light reaching the water thereby decreasing light penetration, Egborge (1981) in Asejire Reservoir ; Ikom et. al. (2003) in River Adofi; Ayoade et.al. (2006) in lakes.
Transparency is considered as an important parameter of trophic status of water bodies. It depends on the intensity of sunlight, suspended soil particles, turbid water received from catchment area and density of plankton Mishra and Saksena (1991). The transparency in BMIT was maximum in summer (90.0 Cm) and minimum in monsoon (71.1Cm) low values of transparency were observed in monsoon due to accumulation of suspended matter such as silt, clay and organic matter into the water body and high value found during summer due to absence of rain, runoff and flood water as well as gradual settling of suspended particles. The water transparency is sign of productivity. The extent to which light can penetrate depends on the transparency of standing water column. Further, transparency of water is inversely proportional to turbidity, created by suspended inorganic and organic matter Saxena (1987). The transparency of water body is affected by the factors like planktonic growth, rainfall, sun's position in the sky, angle of incidence of rays, cloudiness, visibility and turbidity due to suspended inert particulate matter. Higher TS, TDS and TSS, resulted in minimum transparency in monsoon. This complies with the reports on several water bodies especially in Indian climatic conditions Zafar (1964); Singhai et. al., (1990); Kaur et. al., (1995); Ekhande (2010); and Patil (2011).

3.3.2 Group II Chemical Parameters

3.3.2.1 pH

In the present research work the pH value was maximum in summer (7.90 ± 0.13) and minimum in monsoon (7.2 ± 0.04), with slightly increase in winter it was
(7.80 ± 0.08). (Table 3.2, Fig 3.5) pH showed significantly positive correlations with CA, Mg, and TH at 0.01 level while it showed significant negative correlations with TSS at 0.05 level. pH showed highly significant seasonal variations (P< 0.0001 F2 15.4).

Sharma et.al. (2011) noted that during monsoon season water was turbid; pH fluctuated between 6.9 to 8.3. The minimum pH was recorded in monsoon, which was mainly attributed to rain water after a long dry period, and maximum pH was recorded during summer from Pichhola Lake, Udaipur. Patil et.al. (2011), observed that pH recorded in summer (8.45 ± 0.097) and minimum in winter (7.48 ± 0.02) in Lotus lake from Maharashtra.

According to Ujjania and Mistry (2011), the pH was determined by the digital pH meter and significant variation was observed during the investigation, it was noted high 7.5 to 7.9 (7.767 ± 0.115) during the immersion period while it was low 6.9-7.4 (7.150 ± 0.123) and 7.6-7.7 (7.710 ± 0.040) during the pre-immersion and post-immersion period respectively. Devi, et.al.(2013) from fish pond and around Bhimavaram West Godavari District, (A.P.) the pH of pond water was slightly basic in nature and the pH of the water samples were in the desired range of 6.5-9.5, the growth of fish will be good in the range of 7-8 and it is a tolerable range for most fish.

As per Lokhande (2013), the pH showed varied fluctuations during the study period with maximum and minimum (7.0 to 8.6) value were noticed at the reservoir, the maximum was found in April where at its minimum was in August. In the investigation the pH of the reservoir water was alkaline ranging from 7.0 to 8.6 maximum in summer season and minimum in winter season at Dhanegaon Reservoir, Osmanabad. The reservoir water was alkaline throughout the period of investigation. During the study period in the summer season photosynthetic activity was reduced due to higher temperature which resulted in the accumulation of carbon dioxide and the subsequent decrease in the pH. According to Verma et. al,(2012), the maximum pH was recorded during summer season (9.5 ± 0.27) and the minimum was recorded during winter season (8.7 ±0.11). Alkaline state of pH might be in winter, the amount of calcium increases during summer season due to rapid oxidation /decomposition of organic matter (Billore, 1981). Relatively higher proportion of Calcium in the surrounding rocks and soils might have also contributed to the rich Calcium level in
lake water. Calcium is present in water naturally, but the addition of sewage waste might also be responsible for the increase in amount of calcium. Similar result was observed in Papnash pond of Karnataka (Angadi et. al., 2005). The decrease may be due to Calcium being absorbed by living organisms in winter. Kumar et.al (2012), the pH of water ranged from 7.35 to 7.80. The maximum pH value of 7.80 was recorded in the month of May, and minimum of 7.35 in February and July, the water body was found to be slightly alkaline. The alkaline pH of water might be due to presence of alkalinity minerals in water and slightly higher pH values during non-monsoon could be recognized to increase photo synthetic assimilation of dissolved inorganic carbon by planktons (Patil, 2012).

According to Fakayode (2005) the pH of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity. The pH of the water under study area is within the WHO standards of 6.50-8.50. In the present study, the pH value was found to fluctuate from 7.20 to 7.90 at BMIT, indicating that the waters were neutral to alkaline at various months. The highest value of pH was recorded during summer season (7.90) and the lowest was recorded during monsoon season (7.20) (Table3.2). The low value during monsoon might be due to dilution of rain water. A fall in pH value in monsoon season was also recorded by Shardendu and Ambasht (1998). Whereas Venkateswarlu (1969) and Jana (1973) observed high pH values during summer and slightly lower in winter months. According to Zafar (1966) the pH of water is reliant to relative quantizes of Calcium carbonate and bicarbonates the water tend to be more alkaline when it possesses carbonates while it is much alkaline when it possesses larger quantizes of bicarbonates, CO$_2$ and Calcium. Higher pH value of summer can be due to utilization of bicarbonate and carbonate buffer system Mehrotra (1988). According to Kaul and Handoo (1980) and Satpathy et. al. (2007) were the pH of water is higher due to increased metabolic autotrophic activities. Many reports were given different pH ranges as ideal for supporting aquatic life. However all these ranges fall around similar point between 6.7 to 8.5 De (1999) and the pH level of BMIT water was in within the limit range.
3.3.2.2 Dissolved Oxygen (DO)

The present investigation showed highly significant seasonal variations ($P<0.0001$, $F_{2154.7}$). The Maximum value of DO recorded in winter was $7.25 \pm 0.17$ mg/L and minimum value in summer ($4.08 \pm 0.12$ mg/L), while it was slightly decreased in monsoon ($5.25 \pm 0.30$ mg/l) (Table 3.2, Fig. 3.6).

Similar trends were recorded by Sahni and Yadav (2012) from Bharawas Pond, Rewari, Haryana. Dissolved oxygen values varied from 4.73 to 5.34 mg/L of which maximum value (5.34 mg/L) was noted in winter season and minimum value (4.73 mg/L) in summer which are in agreement with the earlier work by Venkatesharaju et al., (2010) and Rajagopal et al. (2010). Dissolved Oxygen showed positive significant correlations (Table 3.3) with Trans. TS and WC while, it was negatively correlated with AT, Cl, CO$_2$, PO$_4$, TDS and WT both at 0.01 level.

Dissolved Oxygen is one of the most important parameters of the water quality and fundamental requirement of life for plant and animal life in water. Dissolved oxygen of water is an significant test to study the water quality. Its optimum value for good quality is able to maintain aquatic life in water and DO values are somewhat lower than (10 mg/L) value, this indicates water pollution. DO demonstrating level of water quality and organic production in the water. The survival of aquatic organisms particularly fish depends upon level of Dissolved Oxygen in the water. In present investigation, the DO of surface water varied from $7.25 \pm 0.17$ mg/L to $4.08 \pm 0.12$ mg/L at BMIT in winter and summer respectively. According to Chaurasia and
Pandey (2007), the quantity of DO in water is directly or indirectly dependent on water temperature, partial pressure of air etc. The maximum dissolved Oxygen in winter may be due to higher solubility of Oxygen and high rate of photosynthesis at comparatively lower temperature while higher level in monsoon may be credited to circulation and mixing of water and atmospheric Oxygen due to shake up of surface water and vice versa, the lower values of dissolved Oxygen during summer might be attributed to the fact that the warm water holds less oxygen as well as increases the mineralization of non living matter which demands more oxygen decreasing oxygen levels (Kumar et. al.,2005; Kumar and Kapoor, 2006). At the study area of BMIT positive correlation of dissolved Oxygen was noted with Transparency and Water Cover with significant level at 0.01 level while negative correlation was show with AT, Cl and CO₂ at 0.01 level. (Table 3.3). DO in summer is decreased due to decreased Oxygen holding capacity of water at high temperature. Rodgi and Nimbergi (1978) found that disposal of domestic sewage and other oxygen demanding wastes reduce the dissolved Oxygen of the receiving water body was lost to atmosphere during summer in Mysore city (Sachidanandamurthy and Yajurvedi ,2006). Mishra et. al. (2007) reported increase in DO in monsoon was due to low temperature and high aeration along with photosynthetic activity of Ulhas river estuary, Maharashtra. The highest dissolved oxygen was pointed out at BMIT was a good indicator and the most productive with high water quality parameters and will support diversity of aquatic life

![Fig. 3.6: Seasonal variation in Dissolved Oxygen (mg/L) at Budaki dam during January, 2009 to December, 2010](image)
3.3.2.3 Free Carbon dioxide (CO$_2$)

Free CO$_2$ in the present study varied from 2.18 to 3.68 mg/L. The lowest mean value of free carbon dioxide was recorded in winter season (2.18±0.24 mg/L) whereas the highest value (3.68±0.12 mg/L) in summer (Table 3.2). CO$_2$ showed highly significant seasonal variations (P < 0.0001, F$_{217.1}$).

Same observation recorded by Ishaq and Khan (2013); Bhadia and Vaghela (2013) the higher values of free CO$_2$ were observed during summer. These could be explained on the basis of high summer temperature which accelerated the process of decay of organic matter and respiratory activities of organisms, resulting in the addition of large quantities of CO$_2$ to the water of river Yamuna at Kalsi Dehradun. Gurumayum et. al. (2002) also reported higher values of free CO$_2$ during summer and monsoon months. The lesser level of free CO$_2$ during winter mainly due to high photosynthetic activity utilizing free CO$_2$ observed by Hazarika (2013) in Assam. However, Sahni and Yadav (2012) have reported low values of free CO$_2$ during post-monsoon (18.26 mg/L) and high in Summer (19.35 mg/L) from Bharawas pond Rewari, Haryana.

The carbon dioxide is soluble in water and the little amount of carbon dioxide is present in sample because of the small amount of it being present in the atmosphere. According to Joshi et. al.(1995) the increase in carbon dioxide level during summer may be due to decay and decomposition of organic matter. Free carbon dioxide is the source of carbon that can be assimilated and incorporated into the living matter of all the aquatic autotrophs. Free CO$_2$ is directly proportional to bicarbonates and inversely to carbonates. Similar results were reported by (maximum in summer, 4.23 mg/L and minimum in winter,0.96 mg/L) Ekhande (2010), Manjare et. al., (2010) recorded 0.0 mg/L to 28.6 mg/L and Zahoor Pir et. al. (2012) observed (0. mg/L low in July and high 5.52 mg/L in March ) while studying on different freshwater bodies.

In the BMIT investigation negative correlation of free CO$_2$ is noted with DO, and WC with significant level at 0.01 level while positive correlation shows with AT, Cl, PO$_4$, TDS, TS, and WT at 0.01 level (Table 3.3). Parameters like Mg and pH were non significantly correlated with CO$_2$. 

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3.3.2.4 Total Hardness (TH)

In the present study total hardness varied from 123 to 179 mg/L in different seasons. Maximum mean of total hardness was recorded in summer (179± 11.9 CaCO$_3$ mg/L) and minimum in monsoon (123 ± 1.53 CaCO$_3$ mg/L), while it was 143 ± 3.34 CaCO$_3$ mg/L in winter (Table 3.2).

The similar range of total hardness was reported by many workers such as Kalwale et. al. (2012) in Deoli Bhorus dam was found in the range of 110.75 mg/L to 120.91 mg/L. Manjare et.al. (2010) reported hardness higher during the summer season (70 mg/L) than the rainy and winter (70 mg/L) season, this could be as are result of low water levels and the concentration of ions, and the lower rainy season value could be due to dilution. Hujare (2008) also reported total hardness which was higher during summer than rainy season and winter season in the perennial tank of Talsande, Maharashtra. Kolo and Oladimeji (2004) for Shiroro Lake. Kedar and Patil (2002) in Rishi Lake. Shimpi et. al. (2011) recorded the value of hardness fluctuates from 70 mg/L and 142 mg/L. were recorded in the month of October and April respectively. Whereas maximum total hardness was observed by Sahni and Yadav(2012) total hardness valued ranged from 968.60 to 1203.60 mg/L of which higher value was found in post-monsoon while the lower value in winter season from Bharawas Pond, Rewari. This might be due to the presence of high content of Calcium and Magnesium in addition to sulphates and nitrates. Jain et.al (2011) reported that high concentration of hardness (150 to 300 mg/L) from Kishanpura dam,
Baran Rajasthan. High values may be due to the addition of calcium and magnesium salts higher values observed in the summer season were due to increase in hardness can be attributed to the decrease in water volume and increase in the rate of evaporation at high temperature and due to the rapid oxidation of organic materials and anthropogenic activities. The input of domestic and other sewage water might be responsible for increased hardness of fish pond at Hyderabad Zaffar (1964). The BMIT showed positive significant correlations (Table3.3) with AT, Ca, Cl, Mg, pH, and WT at 0.01 levels while, it showed significant negative correlations with WC at 0.01 level and other parameter likes DO, NO3, PO4, SO4, TSS, were non-significantly correlated. The hardness of water sample of BMIT study area is (179mg/L) below the hard water when compared with permissible limit (300 mg/L) of BIS (1991) standards for drinking water.

The World Health Organization (WHO) International Standard for Drinking Water (1998) classified water with a total hardness of CaCO3 less than 50 mg/L as soft water, 50 to 150 mg/L as moderately hard water and water hardness above 150 mg/L as hard CaCO3. Thus the waters are suitable for domestic use in terms of hardness. This is because moderately hard water is preferred to soft water for drinking purposes as hard water is associated with low death rate from heart diseases ISO (1990). Ca and Mg are among the general elements essential for human health and metabolism and should be available in normal drinking water. However, if one or more of these elements occur in the water above certain limits, the water may become objectionable to consumers and even become hazardous to health.

![Fig. 3.8: Seasonal variation in Total Hardness (mg/L) during January, 2009 to December, 2010](image)
3.3.2.5 Chlorides (Cl⁻)

Chloride values in the present study of BMIT were found ranging between 40.3 to 60 mg/L of which maximum value (60 mg/L) was recorded in summer season and the minimum value (40.3 mg/L) in winter season and slightly increased in monsoon (51.8 mg/L) (Table 3.2, Fig- 3.9).

The result are in agreement with chlorides of Tapi and Aner water river of North Maharashtra studied by Patel and Lohar (1998). According to Venkatesharaju et. al. (2010),Chloride values are maximum in summer 63.9 mg/L and minimum in winter 56.2 mg/L. Sahni and Yadav (2012), reported that Chloride values were found ranging between 1107.95 to 1735.24 mg/L of which maximum value was noticed in summer season and the minimum value in winter season. The higher concentration of chlorides is considered to be an indicator of higher pollution due to higher organic waste of animal origin. Sahu and Behera (1995) observed that the higher concentration of chloride in the summer period may be due to increased temperature, low level of water and sewage mixing. Rai et. al. (2012) in their investigation, found the chlorides ranged between 41 mg/L to 70 mg/L. Hulyal, and Kaliwal (2011) Seasonal fluctuations have been occurred in chloride concentration during 2003, the maximum concentration of chloride was found in monsoon (86 mg/L) and minimum in winter (36 mg/L), while in 2004 maximum values were found in winter (83.6 mg/L) and minimum in monsoon (42.2 mg/L). Muniyan and Ambedkar (2011) found chloride level in the range of 47 to 52 mg/L which does not exceed the desirable level (200 mg/L) and permissible limit (600 mg/L) of WHO. Simpi et. al.(2011), the values of chlorides ranged from 22 mg/L in January to 32.5 mg/L in May.

Chlorides are the good indicator of pollution, the common source of chlorides in fresh water is sewage disposal and industrial waste. Human being releases a high quantity of chlorides through urine and faecal matter hence chlorides concentrate is relatively high in domestic sewage. According to Koshy and Nayar (1999), when it is above 200 mg/L the water is unsuitable for human consumption. The higher concentration of chlorides is due to higher organic waste of animal origin. Subbama and Sharma (1992), Anita et. al. (2013) and Sahu and Behera (1995) observed that the higher concentration of chlorides in the summer period may be due to increased temperature and high rate of evaporation, low level of water and sewage mixing. While lower concentration of chlorides in monsoon was due to dilution of water.
In the present study chlorides were negatively significantly correlated with DO, Trans and WC at study area whereas positively significantly correlated with AT, CO₂, PO₄³⁻, TDS, TH, TS and WT, both at 0.01 level (Table 3.3). Munawar (1970) has reported a direct correlation between chloride concentration and pollution level in freshwater ponds of Hyderabad. In present study the chloride values were relatively low, ranging between 40.3 mg/L to 60.0 mg/L. It is far less than permissible limit of BIS (Bureau of Indian Standard, 1991) which is 300 mg/L indicating that water is free from chloride hazard at BMIT hence it can be used for human consumption and agriculture purposes.

![Fig. 3.9: Seasonal variation in Chloride (mg/L) during January, 2009 to December, 2010](image)

3.3.2.6 Nitrates (NO₃⁻)

The nitrate content was fluctuated according to the seasons the nitrate values varied from 0.21 to 0.38 mg/L. The highest mean value recorded was (0.38± 0.02 mg/L) in monsoon while the lowest recorded (0.21± 0.02 mg/L) in winter (Table 3.2). Somewhat similar values found to Chisty (2002) and Rani et al. (2004).

The major sources of nitrates in reservoirs and water bodies are human activities, from catchment area by rainfall, sewage effluents, agro wastes and suspended organic matter. When algae and other suspended microorganisms die and settle down to the bottom, they carry their Nitrogen and Phosphorus with them during decomposition. Nitrates were also generated from agricultural fertilizers and mixing of human and animal wastes to the lake Murugavel and Pandian (2000); Cengiz Koc (2008). Nitrates represent the highest oxidized form of nitrogen. Nitrogen occurs in
freshwaters in various forms such as, dissolved molecular nitrogen, inorganic nitrogen in the form of ammonia, nitrates, organic nitrogen as amino acids, proteins and various complex organic compounds. Nnaji et. al.(2010) and Manjare et. al. (2010) observed the similar values of freshwater bodies, while studying on river Galma, Zaria, Nigeria and Tamdalge tank in Kolhapur district, Maharashtra respectively. Jakher and Rawat (2003), also recorded the similar observation in a tropical lake of Jodhpur, Rajasthan. The reverse observation was found by Ramalingam et. al. (2011), the nitrate content was fluctuated between the stations as well as the seasons as per him. The nitrate values varied from 0.11 to 0.90 mg/L. Patra et.al. (2010), recorded in pre monsoon season maximum value of nitrate was 117.4±0.37 μmol/L in Chadheiuguha area of Central sector and minimum amount was found to be 1.55±0.15 μmol/L in Sanakuda area of Southern sector. As per Shib Abir(2014), the maximum value of nitrates was recorded as 8.1mg/L in the month of August (Monsoon) and minimum value observed in May (Summer) 2.4mg/L with a mean value of 5.54. According to Manjare et.al. (2010) the maximum value (37.5mg/l) was recorded in the month of July (monsoon) and minimum (4.40mg/l) in the month of November (winter).

All organisms require Nitrogen for the basic process of life to synthesize protein required for growth and reproduction. The presence of nitrates in the water samples is suggestive of some bacterial action and bacterial growth. These findings support the observations of Majumder et. al., (2006). Nitrate in natural waters can be traced to percolating nitrates from sources such as decaying plant and animal material, agricultural fertilizers, domestic sewage (Adeyeye and Abulude ,2004). The nitrate content, more than 100 mg /L impart bitter taste to water and may cause physiological problem. The high concentration of nitrates in drinking water is toxic (Umavathi et. al., 2007). Drinking water contains more than 500 mg/L nitrates can cause methemoglobinemia in infants. (Uba and Aghogo, 2001). Nitrates cause the overgrowth of algae, other organisms and foul the water system.

Generally water bodies polluted by organic matter  indicates higher values of nitrates but the levels of nitrates in BMIT water were within the range of permissible limit given by WHO i.e. 45 mg/L for human consumption and agriculture purposes. Nitrates showed positive significant correlations (Table 3.3) with PO4₃⁻ SO₄, TSS, and TS while significant negative correlations with Trans. both at the 0.01 and 0.05 level.
3.3.2.7 Phosphates (PO$_4^{3-}$)

During the study period maximum Phosphate values were recorded in monsoon (0.64 mg/L) and minimum in winter (0.21 mg/L) (Table 3.2) (Fig. 3.11). Similar observation were found by many workers like Shinde et. al. (2010); Tidame and Shinde (2012), the lowest concentration of phosphates 0.45 mg/L was obtained during winter and highest 0.54 mg/L during monsoon.

Phosphates play significant role in maintenance of the fertility of water body. During the current investigation the phosphate concentration was reported higher (0.64 mg/L) in monsoon season and lower (0.21 mg/L) in winter season and slightly higher in summer. According to Tidame and Shinde (2012), might be due to rain water came from agricultural fields and mixed with the water of the reservoir, similar results reported by Arvindkumar (1995); Upadhyay and Gupta (2013), the value of phosphate fluctuated from 0.12mg/L to 12.38 mg/L the maximum value (12.38mg/L) was recorded in the month of August (monsoon) and minimum value in the month of October (winter). The high values of phosphate we mainly due to rain, surface water runoff, agriculture run off; washer man activity could have also contributed to the inorganic phosphate content. Ahangar et. al. (2013) recorded the concentration of phosphate ranged from 287.7to512.4 μg/L with an average of 394.1±21.42 μg/L. During that period, the lower values were recorded during autumn season and higher during warmer periods. The high concentration during warm periods could be attributed to decay and subsequent mineralization of dead organic matter and surface
runoff. While low concentration during summer is attributed to the utilization of nutrients by autotrophs (Kaul et. al. 1978). Sahni and Yadav (2012) Phosphate is an important nutrient for the maintenance of the fertility of water body. During the present investigation the phosphate concentration was reported higher (2.80 mg/L) in summer season and lower (2.15 mg/L) in winter season. Higher concentration of phosphates in dry seasons may be due to low level of water and pollution. Kamal et. al. (2007) observed the similar findings (4.89 mg/L to 11.46 mg/L) in their study on Mouri River. According to Simpi et.al. (2011), the seasonal variations of Phosphate values were recorded maximum (5.75mg/L) in monsoon and minimum (0.71mg/L) in winter season. The high values of phosphate in (monsoon) are mainly due to rain, surface water runoff, agriculture run off; washer man activity could have also contributed to the inorganic phosphate content

At BMIT the higher values of phosphates recorded in monsoon are mainly due to rain, surface water runoff, agriculture run off, and human activity. According to Harikrishnan and Azis (1989); Murugavel and Pandian (2000) higher values of phosphates reported in Kodiyar reservoir during monsoons and Holtan et. al.(1988) recorded high values of phosphates during rainy season might be due to transport from the surrounding catchment areas. Significant variation at the level of p<0.05 and p<0.01 were also observed during rainy season except for Nambul river. The low values of the nutrient during winter season might be probably due to lowering in input of pollutant in the river system which confirmed the findings of Clarke (1924).

According to Singh et.al (2013) the concentration ranged from 0.013 mgL\(^{-1}\) (Iril river in January, Imphal river in April) to 0.508 mgL\(^{-1}\) (Nambul river in June). Seasonal maximum mean value was 0.327 ±0.12 mg/L (Nambul river in rainy season) and minimum as 0.015 ±0.002 mg/L (Imphal river in summer season). According to Gaike and Kamble (2013) Phosphate values were nil at beginning of monsoon whereas post monsoon showed a maximum value of 0.49 mg/L. During the monsoon, precipitation eroded the land containing fertilizer got mixed to water monsoon.

The lower phosphate values reported during winter season may be correlated to its locking PO\(_4\) by macrophytes and phytoplankton during their bloom decreasing their level in water (Kant and Raina, 1990). Hutchinson (1957), has concluded that the quantity of phosphates increases due to sewage contamination in water bodies. The phosphate was fluctuated between the stations as well as the seasons. The phosphate
values varied from 0.01 to 0.24 mg/L and the seasonal variations of phosphate values were recorded maximum during monsoon/pre-monsoon and minimum during summer season. (Ramalingam et.al, 2011) The water body was eutrophic, much total PO$_4$\(^{-3}\) value was in between 20 to 30 mg/L. Welch (1986). According to Girija et. al. (2007) the natural sources of Phosphorus in water were from the leaching of phosphates being rocks and organic matter decomposition as well as anthropogenic activities.

In the present study phosphates were positively significantly correlated with AT, Cl$^-$, CO$_2$, NO$_3^-$, SO$_4$, TDS, TS, TSS and WT while negatively significantly correlated with DO and Transparency both at 0.01 levels (Table 3.3). At BMIT the phosphate value fluctuating between 0.21 to 0.64 mg/L is too much below this level. However, it crossed the permissible limit of drinking water (0.1 mg/L) as given by US Public Health Standards (De, 2002) in monsoon.

3.3.2.8 Sulphates (SO$_4^{2-}$)

In the present investigation of BMIT water the conc. of sulphates fluctuated. The minimum value recorded in winter (4.25 mg/L).While maximum value recorded in monsoon season (7.80 mg/L) and slightly more in summer (Table.3.2 Fig 3.12). Somewhat similar observation were also reported on Nandrabad pond, Aurangabad by Nagawanshi (1997); Tiadme and Shinde (2012) in Temple pond Nasik (28.7 to 42.87 mg/L) and Jena et.al.(2013) of Kharoon River water quality at Raipur (0.45 to 0.87 mg/L)

According to Grasby et. al. (1997),dissolved sulphates can be derived from the dissolution of SO$_4$ minerals; oxidation of pyrite and other forms of reduced S;
oxidation of organic sulfides in natural soil processes; and anthropogenic inputs, i.e. fertilizers. Biological oxidation of reduced sulphur species to sulphate increase in concentration. Discharge of industrial wastes and domestic sewage in waters tends to increase its concentration (Trivedi and Goel, 1984). As per ISI (1964) the permissible presence of Sulphate has less effect on taste of water as compared to presence of chloride. High value of Sulphates above 500 mg/L produces bitter taste to water and exerts adverse effect on human. In the entire sample tested sulphate was within the permissible limit (150 mg/L) for general use.

The highest content of sulphate was recorded during summer, the high value might be due to low water level and detergent pollution during summer supported by Agarkar and Garode (2000). Lower concentration during winter may be due to reduction of sulphite and subsequent in the form of H₂S gas. Zutshi and Khan (1988) have stated that polluted waters are always rich in sulphates. The Sulphate generally shows less effect on taste than chloride and carbonates. The guideline for sulphate in drinking water is 400 mg/L based on taste. Sulphates indicate the pollution by domestic wastes, the permissible limit for human consumption is 250 mg/L. As per BIS (1991) standards for drinking water.

Maximum sulphate mean values recorded in monsoon (7.80 ± 0.40 mg/L) and minimum in winter (4.25 ± 0.46 mg/L) therefore the water of BMIT can be recommended for human consumption and irrigation purposes. Sulphate is positively significantly correlated with NO₃⁻, PO₄, TS, and TSS, while it is negatively significantly correlated with Transparency both at 0.01 and 0.05 levels at BMIT (Table 3.3).
3.3.2.9 Magnesium (Mg)

The maximum mean values of Magnesium were reported in summer \( (19.5 \pm 2.17 \text{ mg/L}) \) and minimum in monsoon \( (6.81 \pm 1.27 \text{ mg/L}) \), while it was \( (14.8 \pm 1.54 \text{ mg/L}) \) in winter (Table 3.2, Fig. 3.13) with in the limit \( (75 \text{ mg/L}) \) of ICMR (1975).

The ecological significance of major cations or hardness of calcium and magnesium in the biotic dynamics of aquatic flora and fauna is a well established fact. The Magnesium is essential for flora for chlorophyll biosynthesis and enzymatic transformations, particularly for phosphorylation in algae, fungi and bacteria. The higher concentration of Mg increases total hardness of water in accordance with Kulkarni et.al.(1983). According to Rajshekhar et.al. (2007), the main source of Ca and Mg is leaching of rocks and exoskeleton of arthropods as well as shells of mollusks. In the present study main source of Magnesium may be leaching of rocks in the catchment area. Therefore the maximum level of hardness during the summer season may be due to evaporation of water and addition of Calcium and Magnesium salts and sewage inflow. The similar result reported by Verma (2009), the conc. of Magnesium varies from 18.53 to 26.74 mg/L and 32.62 to 44.54 mg/L during winter and summer in river Betwa. Ikhile and Aderogba (2011). Magnesium is more abundant in the dry season than the wet season. The minimum value of 1.2 mg/L was recorded in the second week of January and May while the maximum value of 9.6 mg/L was also recorded in January in the basin. The mean value for the dry season was 3.4 mg/L while for the rainy season was 2.87 mg/L. Chaurasia and Pandey (2007). The Magnesium concentration was recorded beyond the permissible limit \( (50 \text{ mg/L}) \) of WHO by Sahni and Yadav (2012), Magnesium contents varied from 190.20 to 239.22 mg/L being maximum \( (239.22 \text{ mg/L}) \) during post monsoon season and minimum \( (190.20 \text{ mg/L}) \) in winter season. Murhekar (2011) observed that Magnesium is directly related to hardness, Magnesium content in his investigated water samples was ranging from 162.00 mg/L to 26.00 mg/L which were found above WHO limit.

The main source of Magnesium is being leaching of rocks in the catchment area. In BMIT Magnesium is positively significantly correlated with Ca, pH and TH at 0.01 level while, it is negatively significantly correlated with TSS and WC at 0.05 level and non significantly correlated with DO, NO\(_3\), PO\(_4\), TS. (Table 3.3).

Magnesium is commonly related with Calcium in all types of waters, but their concentrations remain generally lower than the Calcium. According to Dagaonkar and Saksena (1992), Magnesium play vital role in chlorophyll growth and acts as a limiting factor for the development of phytoplankton. The Magnesium was higher in
summer seasons and lower in monsoon season. This may be due to the uptake of Magnesium by phytoplankton and macrophytes in the formation of their chlorophyll-Magnesium perphyrin-metal complex and also might have been used in enzymatic transformations. These results are in concurrence with Verma et. al. (2012), 25 ppm in Monsoon and 34ppm in winter.

![Seasonal variation in Magnesium (mg/L) during January, 2009 to December, 2010](image)

3.3.2.10 Calcium(Ca)

The range of variation values at BMIT water for Calcium were higher (26.8mg/L) in summer season and lower (9.29 mg/L) in monsoon and slightly increased in winter (16.4 mg/L) (Table 3.2) (Fig. 3.14)

According to Viswanath and Murthy (2004), Calcium is an essential micronutrient in the aquatic environment and its concentration may be variable according to the influx of the material present in the aquatic system. They also reported that the high level of Calcium might be contributed to the geological formation. The concentration of Calcium increases during summer season due to rapid evaporation, oxidation and decomposition of organic matter. The Calcium content were found within (75 mg/L) limit of BIS (1991) in BMIT study area. The level of Calcium was low in monsoon perhaps due to dilution and flooding during the rainy season. The increased Calcium in summer was due to the decomposition of aquatic vegetation and low level of water.

The higher level of Magnesium in summer observed by several workers such as Imevbere (1970) has attributed the seasonal pattern of variation to the “effect was
seen from the concentration of ions due to evaporation during the dry season and
dilution due to flooding during the rainy season.” Sahni and Yadav (2012) found
higher (118.80mg/L) in summer season and lower (75.71 mg/L) in winter season from
Bharawas Pond, Rewari, Haryana., Ravikumar et. al., (2005) reported the maximum
Calcium hardness in the months of April in Ayyanakere tank in Harapanahalli town in
Davangere district of Karnataka. The variation in the dry season was more than the
rainy season. The maximum level of hardness during the summer season may be due
to evaporation of water, addition of Calcium and Magnesium salts and sewage inflow
(Chaurasia and Pandey, 2007). According to Ikhile and Aderogba (2011), Calcium is
more abundant in the dry season than the wet season. The lowest value of 4.0mg/L
was recorded in February and March while the highest value of 40.0 mg/L was
recorded in the last weekend of December. The mean value of Calcium for the dry
season was 9.78 mg/L while that of the rainy season was 9.39 mg/L. Calcium was
found in greater abundance in all natural water as its main source is weathering of
rocks from which it leaches out. Calcium was found in the same quantity and
comparatively higher both in summer and northeast monsoon seasons, while lower in
southwest monsoon (Jemi and Balasing 2012).

Sayed et.al. (2011) reported higher (66.12 ±1.15mg/L) during Summer and
lower value (58.97 ± 3.95mg/L) during Winter season from Wadi El-Rayon Lakes,
western desert, Egypt. Waghmare and Kulkarni (2013) observed range the minimum
value of Calcium in the river was 22.9 mg/L at S1 in the month of October and
Maximum 49.2 mg/L at S2 in the month of May in Lendi River. Garg et. al. (2006);
Jain et. al. (2011). The maximum mean range was recorded in summer (26.8 ± 1.91
mg/L).While minimum mean value was recorded in monsoon season (9.29 ± 0.877
mg/L).

The Calcium is positively significantly correlated with Mg, pH and TH at 0.01
level while it is negatively non significantly correlated with DO, NO₃, PO₄, SO₄, TSS
and WC at BMIT.(Table 3.3).

Calcium is an important element influencing flora of ecosystem, which plays
potential role in metabolism and growth. According to Kataria et. al. (1995) and
Gowd et al (1998), in the natural water extreme Cl− ions is usually found associated
with Na+, K+ and Ca++ which create salty taste when concentration is 100 mg/L.
Fig 3.14: Seasonal variation in Calcium (mg/L) during January, 2009 to December, 2010.
Table 3.1 Seasonal variations in physical parameters of Budki M.I.Tank over the period of two years from January, 2009 to December, 2010 (Mean ± SEM)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>F value</th>
<th>Summer</th>
<th>Monsoon</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AT °C</td>
<td>$F_{221}$ 12.3</td>
<td>$31.0±1.32$</td>
<td>$28.8±0.840$</td>
<td>$24.4±0.565$</td>
</tr>
<tr>
<td>2</td>
<td>WT °C</td>
<td>$F_{221}$ 10.7</td>
<td>$26.5±0.964$</td>
<td>$24.8±0.590$</td>
<td>$21.5±0.732$</td>
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<td>3</td>
<td>Water Cover %</td>
<td>$F_{221}$ 9.40</td>
<td>$61.5±3.50$</td>
<td>$79.4±5.13$</td>
<td>$84.0±2.56$</td>
</tr>
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<td>4</td>
<td>Total Solids (TS) mg/L</td>
<td>$F_{221}$ 35.4</td>
<td>$198±4.51$</td>
<td>$205±4.36$</td>
<td>$156±4.40$</td>
</tr>
<tr>
<td>5</td>
<td>Total Dissolved Solids mg/L</td>
<td>$F_{221}$ 23.8</td>
<td>$160±2.94$</td>
<td>$150±4.38$</td>
<td>$127±3.12$</td>
</tr>
<tr>
<td>6</td>
<td>Total Suspended Solids (TSS) mg/L</td>
<td>$F_{221}$ 39.7</td>
<td>$37.9±1.66$</td>
<td>$54.6±1.89$</td>
<td>$29.5±2.46$</td>
</tr>
<tr>
<td>7</td>
<td>Transparency (Trans) Cm.</td>
<td>$F_{221}$ 28.2</td>
<td>$90.0±1.15$</td>
<td>$71.1±5.45$</td>
<td>$111±3.32$</td>
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</tbody>
</table>

Table 3.2 Seasonal variations in Chemical parameters of Budki M.I.Tank over the period of two years from January, 2009 to December, 2010 (Mean ± SEM).

<table>
<thead>
<tr>
<th>Sr. No.</th>
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<th>F value</th>
<th>Summer</th>
<th>Monsoon</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Potentia hydrogenii (pH)</td>
<td>$F_{221}$ 15.4</td>
<td>$7.90±0.138$</td>
<td>$7.20±0.046$</td>
<td>$7.80±0.082$</td>
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<td>2</td>
<td>Dissolved Oxygen (DO) mg/L</td>
<td>$F_{221}$ 54.7</td>
<td>$4.08±0.125$</td>
<td>$5.25±0.306$</td>
<td>$7.25±0.179$</td>
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<tr>
<td>3</td>
<td>Free Carbon dioxide (CO₂) mg/L</td>
<td>$F_{221}$ 17.1</td>
<td>$3.68±0.129$</td>
<td>$3.20±0.159$</td>
<td>$2.18±0.247$</td>
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<td>4</td>
<td>Total Hardness (TH) mg/L</td>
<td>$F_{221}$ 15.7</td>
<td>$179±11.9$</td>
<td>$123±1.53$</td>
<td>$143±3.34$</td>
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<tr>
<td>5</td>
<td>Calcium (Ca) mg/L</td>
<td>$F_{221}$ 22.0</td>
<td>$26.8±1.91$</td>
<td>$9.29±0.877$</td>
<td>$16.4±2.49$</td>
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<td>6</td>
<td>Magnesium (Mg) mg/L</td>
<td>$F_{221}$ 14.2</td>
<td>$19.5±2.17$</td>
<td>$6.81±1.27$</td>
<td>$14.8±1.54$</td>
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<td>7</td>
<td>Chloride (Cl) mg/L</td>
<td>$F_{221}$ 13.7</td>
<td>$60.0±3.47$</td>
<td>$51.8±2.74$</td>
<td>$40.3±1.41$</td>
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<td>8</td>
<td>Nitrates (NO₃) mg /L</td>
<td>$F_{221}$ 11.0</td>
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<td>$0.381±0.026$</td>
<td>$0.214±0.023$</td>
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<td>9</td>
<td>Phosphate (PO₄)mg /L</td>
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<td>$0.435±0.031$</td>
<td>$0.645±0.043$</td>
<td>$0.213±0.026$</td>
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<td>10</td>
<td>Sulfates (SO₄) mg/L</td>
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<td>$7.80±0.406$</td>
<td>$4.25±0.466$</td>
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** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed).
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