Chapter 3

Physicochemical Parameters

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Introduction

A basic feature of the earth is the abundance of water, which extends over 71 % of its surface. Over 99% of this immense hydrosphere is deposited in ocean depressions, glaciers and underground aquifers. A relatively small amount that occurs in fresh water lakes and rivers, depicts its fundamental importance in the maintenance and survival of terrestrial life (Wetzel, 2006). India, with more than 18% of the world's population and 2.4% of worlds' land area, depends on only 4% of worlds' renewable water resources (NWP, 2012). Freshwater available in ponds, lakes and rivers play a chief role in maintaining the water balance in the ecosystem (Meera *et al.*, 2015) and is the most important criterion for the survival of life on earth, without which life will not exist in this planet.

Freshwater systems of the world are collectively experiencing qualitative and quantitative degradation at accelerating rates (Wetzel, 1992). The health of these ecosystems depends on their physicochemical properties and biological diversity that they support. Since, the water contains dissolved and suspended materials in various proportions, it's physical and chemical characteristics differ along with its biological characteristics (Sebastian, 2012). Dynamics of physicochemical parameters, which play a major role in ascertaining the distribution pattern and quantitative abundance of organisms in the system (Singh *et al.*, 2009) determine the productivity of these ecosystems (Wetzel, 1983). Hence, it is necessary to conserve these ecosystems today.

Besides acting as a source of freshwater, reservoirs lower the ambient temperature, raise the water table increase the diversity of flora and fauna and also provide an aesthetic atmosphere (Durge *et al.*, 2018). The impact of human activities in and around the reservoir is felt on the unique physical and chemical properties of water. Deterioration of water quality in reservoirs is mainly due to excessive input of nutrients leading to eutrophication and acidification. Heavy metal contamination, organic pollution and obnoxious fishing practices add to these. These inputs affect the socio-economic functions as well as structural biodiversity of the reservoirs negatively. The quality of water generally refers to the component of water present at

the optimum level suitable for the growth of plants and animals (Qureshimatva and Solanki, 2015).

Increasing industrialization, urbanization and developmental activities carried out to cope up with population explosion have brought inevitable water crisis (Shreenivasulu *et al.*, 2014) which has led to deteriorating water quality of these tanks, lakes, ponds etc. which ultimately affects their biotic diversity. However, the burgeoning human demands, industrialization, use of agricultural fertilizers and increasing human activities highly pollute these ecosystems with harmful contaminants (Patil *et al.*, 2012). The availability of good water quality is an indispensable feature for preventing disease and improving quality of life.

The aquatic systems are also governed by the physical properties of water like existing meteorological conditions (Pawale, 2014). The effect of physical forces such as light and heat are also of great significance as they are solely responsible for certain phenomena such as thermal stratification, chemical stratification, diurnal and seasonal qualitative and quantitative variations leading to diversity in the plankton, micro and macro organisms. The interrelationship between physicochemical parameters and plankton production in an aquatic ecosystem and its relation with fluctuation of plankton populations are of great importance and basically essential in fish culture (Gupta and Dey, 2013). Thus, the assessment of water quality in a water body provides information about the concentration of various solutes in it at a given time (Shinde *et al.*, 2011) and guides in judging the suitability of water for its designated uses and to improve the existing conditions.

Physicochemical features of water

Temperature: Temperature is one of the most intrinsic parameter which influences almost all physical, chemical and biological characteristics and thus the chemistry of water. Generally, the air and water temperatures depend on the geographical location and climatic conditions such as rainfall, humidity, cloud cover, wind velocity wind magnitude, atmospheric temperature, solar radiation, salinity gradient etc. Atmospheric and water temperature play an important role in the physicochemical characteristics and physiological behavior of an aquatic system (Sawant and Chauvan, 2013). Water temperature is an important parameter as it influences the biota in a water body by affecting its activities such as behavior, respiration and metabolism (Shinde *et al.*, 2011). The catabolic energy released in the form of heat during decomposition of organic matter and respiration also adds to the temperature

(Murthuzasab *et al.*, 2010). Solar radiation is also a major energy source for aquatic ecosystems. The productivity and internal metabolism of fresh waters is driven and controlled by energy derived directly from the solar energy utilized in photosynthesis (Wetzel, 2006). Photosynthetic biochemical conversions utilizing solar energy occur within fresh water ecosystems both directly by aquatic flora as well as indirectly by terrestrial wetland plants within the drainage basin and imported to the streams and lakes as organic matter.

The seasonal and spatial variations in surface water temperature in a reservoir is generally influenced by the inflow of water, rainfall, the extent of vertical mixing and the exchange of heat with the atmosphere (Ambujam and Sudha, 2016) and is also important for biological activities and chemical reactions. Increase in temperature to a certain point leads to greater biological productivity, above and below which it fails. Thus the measurement of temperature is an important parameter required to get an idea of self-purification of reservoirs (Ramachandra *et al.*, 2006).

Water Cover: The availability of space for colonization is essential and evidently affects the cumulative productivity of the periphytic communities. The morphology has profound effects on nearly all physical, chemical and biological properties of water bodies with drainage basins influencing sediment water interactions and lake productivity. Water cover provides spatial heterogenicity from pelagic to littoral zone and also provides habitat space for colonization of communities and hence favors an important parameter in assessing status of a water body.

Total Solids (TS): According to APHA (2012), solids refer to the matter that is suspended or dissolved in the water or waste water. Solids may affect water or effluent quality adversely in number of ways. Total solids include both suspended solids, the portion that is retained by a filter and total dissolved solids the portion that passes through the filter. Their concentrations in water are both measured as total suspended solids (TSS) and total dissolved solid (TDS) respectively.

A high concentration of total solids makes drinking water unpalatable and also affects clarity, reducing the passage of light through water, thereby slowing the photosynthesis of aquatic plants. Such water heats up more rapidly and holds more heat, this in turn, might adversely affect aquatic life that has adapted to a lower temperature regime. Sources of total solids include industrial discharge, fertilizers, rain water runoff and soil erosion.

Total dissolved solids (TDS): The term "Dissolved solids" refers to the particles of solids that pass through a filter of 0.2 µm (or smaller) pore size under specific conditions (APHA, 2012). It is simply the sum of cation and anion concentrations expressed in mg/l. TDS is a direct measure of all the dissolved substances, both organic and inorganic present in waters. The range of TDS is set between 500 – 1500 mg/l prescribed by the US EPA (2002) and ICMR, WHO and BIS (1991). Water with high contents of dissolved solids generally is of inferior potability and may induce an unfavorable physiological reaction in the transient consumer. High TDS values cause harmful effect on the public health such as central nervous system, provoking paralysis of the tongue, lip and face, irritability and dizziness (Gupta *et al.*, 2017). Dissolved solid is also very important criterion for irrigation water as their gradual accumulation results in salinization of soil, thus rendering the agriculture land non-productive (Tyagi and Malik, 2018). It also indicates the general nature of salinity of water and signifies the inorganic pollution load of water system (Usha *et al.*, 2008). TDS is a useful parameter describing the chemical constituents of the water and can be considered as general edaphic relations that contribute to the productivity within a water body (Abdo, 2005).

Total suspended solids (TSS): Total suspended solid is the portion of the total solids retained by a filter and can be weighed in the lab after evaporation. Usually in the inland surface waters the standard value of suspended solid lies around 100 mg/l. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial waste and sewage. Suspended solids may be in the form of coarse, floating, fine or colloidal particles as floating film (Agarwal and Rajawar, 2010) and cause ecological imbalance in the aquatic ecosystem by mechanical abrasive action. High concentration of suspended solids can cause many problems for health of the system and also aquatic life. Suspended solids containing much organic matter may cause decomposition and consequently may consume all dissolved oxygen (Joshi *et al*., 2016). In general, TSS is used to evaluate the strength of domestic waste waters and efficiency of water treatment units.

Transparency (Secchi disc): Being a good solvent, water has many chemicals dissolved in it. By utilizing these substances in their various metabolic activities aquatic plants and animals bring about changes in chemical composition of water.

Light rays are major energy source for aquatic systems influencing activities of photosynthesis. Transparency, a characteristic of water that varies with the combined

effect of turbidity and colour influences the rate of photosynthesis (Patil and Sathe, 2013). The presence of silt, clay, plankton and colloidal organic matter results into low transparency. Suspended solids present in sanitary wastewater and many types of industrial waste water add to these. There are also non-point sources of suspended solids, such as soil erosion from agricultural and construction sites decreasing transparency.

Transparency is a characteristic of water that varies with the combined effect of colour and turbidity. It gives an idea about degree of suspended particles in the water, which in turn affect the light penetration (Verma *et al.*, 1980). Clear water permits light to penetrate more deeply and allows photosynthesis and production of oxygen up to deeper water while polluted murky water tends to reduce the same. Transparency is universally proportional to the turbidity which intern is directly proportional to the amount of suspended organic and inorganic matter (Sawant and Chauvan, 2013).

pH (Potentia hydrogeni): The term pH originally derived from a French word pouvoir hydrogen, meaning hydrogen power, shows the quantity of hydrogen ions (H^+) in the water. Its measurement is one of the most important and frequently used tests in water chemistry (APHA, 2012). At a given temperature, the intensity of acidic or basic character of a solution is indicated by pH (hydrogen ion concentration) which works as an index of general environmental conditions (Welch, 1952). Natural waters usually have pH values in the range of 4 to 9 and most are slightly basic because of the presence of bicarbonates and carbonates of alkali and alkaline earth metals (APHA, 2012). A few plants and animals are extremely sensitive to even small pH changes and exist only within a very narrow pH range (Michael, 1984) but most animals are able to maintain a constant internal pH. pH changes quickly due to loss or gain of dissolved gases such as CO_2 and O_2 but is also controlled by reactions involving carbonate system in most of the natural waters (Uddin *et al*., 2016). It is interdependent with other water quality parameters, such as carbon dioxide, alkalinity, hardness, atmospheric pressure and changes are also influenced by the disposal of industrial wastes. A pH range of 6.7 and 8.4 is considered to be safe for aquatic life and to maintain productivity (Muniyellappa, 2018). However, pH below 4 and above 9.6 is hazardous to most life forms. Partial decomposition of organic matter by bacteria and fungi has been recognized to produce various organic acids that are capable of lowering the pH of aqueous solution (Irenosen *et al.*, 2012) which also affects the salt balance in an organism (Lloyd, 1992). The reduced rate of

photosynthetic activity and assimilation of carbon dioxide and bicarbonate are ultimately responsible for increased pH and the low oxygen values coincide with high temperature during the summer months (Bateria and Jain, 2016) whereas high pH values suggest that carbon dioxide, carbonate, bicarbonate equilibrium is affected more due to change in physicochemical conditions.

Dissolved oxygen (DO): Oxygen is the most fundamental parameter of water quality and water itself. Dissolved in water, it is obviously essential to the metabolism of all aerobic aquatic ecosystems. The solubility and dynamics of oxygen distribution influences behavior and growth of aquatic organisms (Wetzel, 2006). The solubility of oxygen is affected non-linearly by temperature and increases considerably in cold water. It is extremely useful in self-purification of water bodies. Algae and rooted plants also give out oxygen into water through photosynthesis. In natural waters, the oxygen content varies with temperature, salinity, turbulence, the photosynthetic activity of algae and higher plants and the atmospheric pressure (Ramachandra *et al*., 2006). At the same time consumption of oxygen during decomposition of organic matter may reduce its concentration to zero level and hence reflect the degree of organic pollution.

The oxygen required by plants and animals for respiration is acquired from atmosphere and the photosynthetic process of green plants. Oxygen from air is absorbed by direct diffusion and agitation of surface water by wind action and turbulence. Photosynthesis by aquatic plants releases oxygen in the day light hours and become more eutrophic. The diurnal fluctuation in dissolved oxygen concentration becomes more extreme in eutrophic water bodies (Sharifinia *et al*., 2013) Depending upon water temperature and salinity, saturation rate of DO vary between 5 – 9 mg/l.

Dissolved oxygen in water also affects the oxidation reduction state of many of the chemical compounds such as nitrate and ammonia, sulphate and sulphide, ferrous and ferric ions (Ramachandra *et al*., 2006). Organic wastes and other nutrient input from sewage and industrial discharges and agricultural and urban runoff also result in decreased oxygen levels (Irenosen *et al*., 2012). The reduction in DO level causes anaerobic condition of water and adversely affects the aquatic biota. Oxygen demand for decomposition of materials also results in depletion of DO in water, which threatens life and deteriorates water quality.

Its, short and long-term variations in fresh water bodies give a good measure of their trophic state hence level of dissolved oxygen is important for water quality, ecological status, productivity and health of lake (Sharifinia, *et al.*,2013).

Free carbon dioxide (CO_2): Free carbon dioxide in water accumulates due to microbial activity and respiration of organisms (Ramachandra *et al*., 2006) which imparts acidity to the waters by formation of carbonic acids. High levels of free carbon dioxide may also enhance the effects of deoxygenation and high ammonia concentration (EPA. 2001). Free CO_2 concentration in water indicates the presence of decomposable organic matter, bacterial action on organic matter etc. (Yosef and Alemayehu, 2016). It reacts with water and forms carbonic acid which soon dissociates into carbonates and bicarbonates (Murthuzasab *et al*., 2010), which alters the pH of water. Aquatic vegetation and phytoplankton require carbon dioxide for photosynthetic activity (Ayyanna and Narayudu, 2013). Carbon dioxide in water bodies is produced as the end product of respiration and decomposition of organic matter. Further it also diffuses directly from the atmosphere and readily dissolved in water. It is present in the freshwater as carbonates and bicarbonates of calcium, magnesium and other minerals.

Total Hardness (TH): The total hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions (Tyagi and Malik, 2018). Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purpose (EPA, 2001). It is also the capacity of water to destroy the lather of soap. Calcium and magnesium are the main constituents of hardness while barium, strontium and iron are also contributing to it, normally with low concentrations that they can be ignored. The widespread abundance of calcium and magnesium in rock formations leads to considerable hardness in surface and ground waters (EPA, 2001). Hardness caused by bicarbonates and carbonates of calcium and magnesium cations is called temporary hardness (Ramachandra *et al*., 2006) while sulphates and chlorides of calcium and magnesium cause permanent hardness. Natural hardness of water depends upon the geological nature of the catchment area and plays an important role in the distribution of aquatic biota. Many species are identified as indicators of hard and soft waters (Ramachandra *et al*., 2006). In the presence of carbon dioxide, calcium carbonate dissolves in water and maintains a pH of 6 - 8. However, dissolved magnesium concentrations are lower than calcium for a majority of these water resources. Hardness of water can be categorized as soft

(0.75 mg/l) moderate (75 – 150 mg/l), hard (150 – 300 mg/l) and above 300 mg/l as very hard (Azmi *et al.*, 2015).

Calcium Hardness (CaH): Calcium is the most important and abundant cation in the human body and an adequate intake is essential for normal growth and health (EPA, 2011). It is one of the most abundant ions in fresh water and plays a pivotal role in shell construction, bone building and plant precipitation (Jhingran, 1975; Hamidi-Chergui *et al.*, 2013). There is some evidence to show that the incidence of heart disease is reduced in areas served by public water supply with a high degree of hardness, the primary constituent of which is calcium, hence the presence of the element in water supply is beneficial to health. The presence of calcium in water results from passage through or over deposits of limestone, dolomite, gypsum and other such calcium bearing rocks (Khan *et al*., 2012) which contributes to total hardness of water and is an important micro-nutrient in aquatic environment (Hamaidi-Chergui *et al*., 2013). It is specially needed in large quantities by molluscs and vertebrates. According to WHO, (1996) 75 mg/l is the maximum acceptable limit for International standard and 200 mg/l as an acceptable limit.

Calcium, in the form of Ca^{+2} ions, is one of the major inorganic cations or positive ions, in sea water and fresh water. It can be originated from the dissociation of salts, such as calcium chloride or calcium sulphate in water.

$CaCl_2\ (s) \rightarrow Ca^{2+}2Cl^-$

$CaSO_4\ (s) \rightarrow Ca^{2+}\ (aq) + SO_4^{2-}\ (aq)$

Calcium carbonate is relatively insoluble in water, but dissolves more rapidly in water containing significant levels of dissolved carbon dioxide.

$CaCO_3\ (s) + CO_2\ (aq) + H_2O\ (l) \leftrightarrow Ca^{2+}(aq)+2HCO_3^-\ (aq)$

If the calcium ion concentration in fresh water drops below 5 mg/l, it can support only sparse plant and animal life, a condition known as oligotrophic (Bhateria and Jain, 2016). Hence, calcium influences the growth and population dynamics of fresh water flora and fauna both directly and indirectly (Wetzel, 2006).

Magnesium Hardness (MgH): Magnesium is required universally by chlorophyllous plants for the magnesium porphyrin component of chlorophyll molecules and as a micronutrient in enzymatic transformations, especially in transphosphorylation by algae, fungi and bacteria (Wetzel, 2006). Like calcium, magnesium is abundant and a major dietary requirement for humans around 0.3 to 0.5 g/day (EPA, 2002). It is the second major constituent of hardness and generally comprises 15 to 20 percent of the

total hardness expressed as $CaCO_3$. Processes like chemical softening, reverse osmosis or ion exchange reduces magnesium and associated hardness to acceptable level. Concentration greater than 125 mg/l can have a cathartic and diuretic effect (APHA, 2012). According to Osborne *et al*. (1987) concentration of magnesium varies according to water level, increasing in low water levels and decreasing in high. The presence of calcium and magnesium ions in moderate level classifies the reservoir as eutrophic which will support diverse plant and animal life including fish (Mustapha, 2008). Magnesium salts when broken down contributing to the hardness of water and also form scales in boilers due to heat (Bhateria and Jain, 2016). It is found in various salt and minerals, frequently in association with iron compound (Kumar *et al*., 2014), and is often associated with calcium in all kinds of water. The variation in calcium and magnesium concentration may be related to the geology of the area, climate and seasonal variations, different biogeochemical activities in the water ecosystem, human activities, water uses and due to the addition of surface runoff from agricultural and other catchment areas (Toma, 2013).

Chloride (Cl^-): Chloride in the form of chloride ion (Cl^-) is one of the major inorganic ions in water and waste water (APHA, 2012). The salty taste produced by chloride concentration is variable and dependent on the chemical composition of water. The chloride concentration is higher in wastewater than in raw water because sodium chloride (NaCl) is a common article of diet and passes unchanged through the digestive system (APHA, 2012). Chlorine alone as (Cl_2) is highly toxic but when combined to sodium it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plant and animal life.

Chlorides may get into surface water from several sources including rocks containing chlorides, agricultural runoff, and waste water from industries, oil well wastes and effluent waste, water from waste water treatment plants. In fresh water, presence of chlorides is attributed to the dissolution of salt deposits, irrigation drainage and sewage discharges (Ramachandra *et al*., 2006). A high chloride content has damaging effect on agricultural crops.

Chloride exists in all-natural waters PPM/ppt the concentrations varying very widely and reaching a maximum in sea water (upto 351000 mg/l). Natural levels in rivers and other fresh waters are usually in the range 15 – 35 mg/l, much below drinking water standards. An increase in even 5 mg/l at one station may give rise to suspicious of

sewage discharge, especially if the free ammonia levels are also elevated (EPA, 2011).

The chloride content of any water body gives an idea of the organic matter and nitrate present in it. Various agencies have given a permissible chloride range in aquatic systems (e.g. BIS: 250-1000 mg/l, WHO: 250 mg/l, USEPA: 250 mg/l and ICMR: 200 – 1000 mg/l).

It has been emphasized that the general distribution of chloride ions in lakes is usually not dominant in open ecosystems, but pollution sources of chlorides can modify natural concentrations greatly (Wetzel, 2006). The higher chloride range has been ascribed to increased human interference (bathing, washing etc.) and cattle pollution (Slathia and Dutta, 2013), and also because of pollution from chlorine rich effluent of sewage and municipal waste (Arya *et al*., 2013).

Nitrates (NO_3^+): Nitrate (NO_3^-) is the common form of inorganic nitrogen entering fresh waters from the drainage basin in surface waters, ground water and precipitation (Wetzel, 2006). However, the accumulation of nitrogen in reservoirs and water bodies due to intensive human activity has become a common phenomenon which alters ecological process in many parts of the world. Nitrate is one of the forms of nitrogen that affects aquatic ecosystem. It is the oxidized form of nitrogen and the end product of aerobic decomposition of organic nitrogenous matter (Sebastian, 2012). Nitrate is a plant nutrient and part of inorganic fertilizer that enters water supply sources from septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary load fills as well as garbage dumps (Krishnan, 2008). Nevertheless, Nitrates feed plankton, aquatic plants and algae which are then eaten by higher animal forms.

Nitrates generally occur in trace quantities in surface waters but may attain low levels in ground water. However, high amounts of nitrates are indicative of water pollution. It is an essential nutrient for many photosynthetic autotrophs and in some cases has been identified as growth limiting nutrient. Nitrogen along with phosphorus, is essential building block in synthesis of proteins (Ramachandra and Solanki, 2007). Nitrate is formed through nitrification process *i.e.* oxidation of NO_2 into nitrate by action of aerobic metabolism. In tropical systems, denitrification is most intense in the areas like: a) where detritus accumulates; b) in water bodies subject to enhanced nutrient loading from pollution; c) in water bodies with long residence times and d) in wetland ecosystem subjected to periodic drying, where oxygen inputs during drying

periods is stimulated coupled with mineralization-nitrification-denitrification in organically rich sediments (Furnas, 1992).

Relatively little of nitrate found in natural water is of mineral origin including waste discharge, most nitrates coming from organic and inorganic sources, chiefly artificial fertilizers. However, bacterial oxidation and fixing of nitrogen by plants can produce nitrate. High nitrate levels in waters to be used for drinking render it hazardous to infants as they induce "blue baby" syndrome (methemoglobinaemia) (EPA, 2001).

Phosphates (PO_4^-): Phosphorus occurs in natural waters and in waste waters almost solely as phosphate (APHA, 2012). Like nitrites and nitrates in natural waters, phosphates are also present in small amounts. Organic phosphates formed primarily by biological processes contribute to the sewage by body waste and food residues. They may also be formed from orthophosphates in biological treatment processes or by receiving water. Phosphorus is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a water body (Ramachandra and Solanki, 2007). In instances where phosphates are growth limiting nutrients, their discharge in raw or untreated wastewater, agricultural drainage or certain industrial wastes water may stimulate growth of photosynthetic aquatic micro and macro organisms to the annoyance levels (APHA, 2012).

Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically bound phosphates. A lake with a phosphate concentration of less than 0.01 mg/l is considered as oligotrophic, while concentrations between 0.01 and 0.02 mg/l are considered of mesotrophic. The concentrations exceeding 0.02 mg/l are considered eutrophic (Muller and Helsel, 1999). Phosphates are not toxic to people or animals, unless they are present in very high amounts.

Among common sources of phosphorus are waste water and septic effluents, detergents, fertilizers, soil runoff (as phosphorus bound in the soil can be released), phosphate mining, insecticides, etc. Phosphorus exists in water in either a particulate form or in dissolved form. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus absorbed by particulates and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus.

Sulphates (SO_4^{-2}): Sulphates exist in nearly all-natural water resources, with a concentration varying according to the nature of the terrain through which it flows. They are often derived from the sulphates of heavy metals (iron, nickel, copper and

lead). As magnesium and calcium are present in many waters, their combination with sulphate has an enhanced laxative effect of lesser magnitude depending upon concentration. The water used for domestic purpose is therefore severely limited by high sulphate concentration upto 250mg/l SO_4 (EPA, 2001). In polluted waters in which the dissolved oxygen is zero, sulphate is reduced to sulphide causing noxious odours.

Mine drainage wastes can contribute large amounts of SO_4^{2-} through pyrite oxidation. Biological oxidation reduces sulphur to sulphate responsible for increase in its concentration. According to Khobragade and Pawar (2016) in freshwater lake, sulphate is contributed from rock weathering and in addition to the domestic waste, sewage, house hold effluents and human faeces.

Looking at the importance of these physical and chemical components of water, the study was designed to find out physicochemical composition of water from the selected three water bodies from Rain Deficient North Maharashtra over a period of three years and 3 seasons summer, monsoon and winter.

Results - Physicochemical Parameters

Physicochemical parameters (Table 3.1a, 3.2a and 3.3a., Fig.3.1b,3.2b and 3.3b)

1. Atmospheric temperature (^{0}C)

Maximum atmospheric temperatures were recorded in summer at all the three water bodies, minimum in winter, while moderate in monsoon with significant seasonal variations. The mean difference of 0.5^{o}C in atmospheric temperatures (Table 3.1a, 3.2a, 3.3a Fig. 3.1a, 3.2a and 3.3a) was noted among the water bodies. Positive significant correlation with CO_2, TS and WT, while negative significant correlation with DO and transparency was noted at all the three water bodies.

Maximum atmospheric temperatures was recorded at all the three water bodies, in summer with 26.25±0.74 ^{o}C at MD; 26.1±0.66 ^{o}C at BR (Table 3.2a Fig3.2a) and 26.0±0.63 ^{o}C at KP (Table 3.3a Fig. 3.3b), while it was minimum in winter (21.75±0.90 ^{o}C; 21.75±0.99 ^{o}C and 20.88±1.17 ^{o}C respectively) (Table 3.3a Fig. 3.3b) at KP. In monsoon it was moderate (24.25±0.53 ^{o}C; 24.75±0.45 ^{o}C; 24.5±0.5 ^{o}C).

Increasing nutrient levels at Malpur dam water temperature showed positive significant correlation with atmospheric temperature (Table 3.4, 3.5 and 3.6), carbon-dioxide, Magnesium, SO_4, TDS, TS while negative correlation with DO and WC. A positive correlation of water temperature with pH, total dissolved solids, total

hardness, chloride, phosphate. At Krishna Park reservoir temperature was positively correlated with CL, CO_2, TS, WT while negatively with DO and transparency.

Significant seasonal variations were recorded at Malpur dam with P<0.0001 $F_{2\ 21}$ 9.23, with Baldane reservoir with P0.0009 $F_{2\ 21}$ 8.8., while at Krishna Park with P<0.0001 $F_{2\ 21}$ 0.33 (Table.3.1a, 3.2a and 3.3a).

2. Water temperature (^{0}C)

Similarly maximum water temperature (Table 3.1a, 3.2a, 3.3a Fig. 3.1a, 3.2a and 3.3a) was recorded at all the three water bodies in summer with 23.13±0.44^{o}C at MD, 22.75±0.45 ^{o}C at BR and 22.75±0.45 ^{o}C at KP respectively, while it was minimum in winter (20.13±0.39 ^{o}C; 19.38±0.68 ^{o}C; 18.88±0.54 ^{o}C; respectively). In monsoon it was moderate (22.06±0.31 ^{o}C; 21.63±0.46 ^{o}C; 21.75±0.41 ^{o}C).

Significant seasonal variations were recorded at Malpur dam with P<0.0001 $F_{2\ 21}$ 15.57, with Baldane reservoir with P<0.0009 $F_{2\ 21}$ 10.07, while at Krishna Park with P<0.0001 $F_{2\ 21}$ 17.95.

Water temperature administered positive significant correlation (Table 3.4,3.5 and 3.6) with CO_2, TS and WT, while a negative significant correlation with DO and transparency at all water bodies. At Malpur dam it was a significant positive correlation with Cl, Mg and negative significant corelation with WC, while at Krishna Park significant positive correlation with Cl, CaH, and MgH was observed.

3. Water Cover (%)

Maximum water cover (Table 3.1a, 3.2a, 3.3a., Fig. 3.1a, 3.2a and 3.3a) was recorded in monsoon in all the three monsoon dependent water bodies. At Malpur dam, Baldane Reservoir and Krishna park water cover was 66.25±3.98%; 64.38±5.13% and 68.13±6.33% to respectively, it declined in winter to 62.88±0.88%; 58.13±2.1%; 60.63±1.99% and to minimum in summer 50.63±1.48; 40±2.67; 42.13±2.78 respectively.

Significant seasonal variation were recorded at all the three water bodies with Malpur dam P<0.0006 $F_{2\ 21}$10.79, Baldane Reservoir P<0.0002 $F_{2\ 21}$ 12.71 and Krishna Park showing P<0.0007 $F_{2\ 21}$ 10.37.

Water cover showed significant positive correlation with DO and pH, while it showed a significant negative correlation with Cl, CO_2, Mg, pH, TDS and TH at all the three water bodies.

4. Total Solids (TS) mg/lit.

Maximum Total Solids were recorded with 204.9±5.45 mg/lit at MD; 227.4±8.58 mg/lit. at BD; and 236.3±6.59 mg/lit. at KP (Table 3.1a, 3.2a, 3.3a., Fig. 3.1a, 3.2a and 3.3a). It was minimum in winter (165.6±3.08 mg/lit.; 175.5±3.51 mg/lit.; 180.1±2.09 mg/lit.; respectively) while moderate in summer (191.4±3.95mg/lit; 208.5±5.98 mg/lit. and 220.6±6.84mg/lit. respectively). Among all the three water bodies maximum TS as recorded in Krishna Park while minimum at Malpur dam.

Highly significant seasonal variations in TS were recorded at all the three water bodies. Malpur dam $P<0.0001$ $F_{2\ 21}$ 2.84, Baldane reservoir $P<0.0001$ $F_{2\ 21}16.99$ and at Krishna park it was $P<0.0001$ $F_{2\ 21}26.59$.

Total solids showed significant positive correlation (Table 3.4, 3.5 and 3.6) with AT, CO_2, TSS, WT while a negative significant correlation with transparency at all the three water bodies. It is positively significantly correlated with transparency at Baldane reservoir and Krishna Park, while significantly correlated with transparency at Krishna Park.

5. Total Dissolved solids (TDS) mg/lit.

Maximum TDS (Table 3.1a, 3.2a, 3.3a., Fig. 3.1a, 3.2a and 3.3a) was recorded in summer at all the three water bodies i.e. 169.1±4.34 mg/lit. at MD, 155.6±2.54 mg/lit. at BD, and 173.1±4.63 mg/lit at KP respectively while was minimum in winter 136.1±2.93mg/lit., 142.1±3.64 mg/lit. and 143.8±3.11 mg/lit. respectively while moderate 128±5.28mg/lit.; 148.8±7.20 mg/lit.; 149.4±5.70 mg/lit. respectively.

Among all the three water bodies maximum TDS were recorded at Krishna Park. Highly significant seasonal variations were recorded at all water bodies, (Malpur dam $P<0.0001$ $F_{2\ 21}14.09$, Baldane Reservoir $P<0.0044$ $F_{2\ 21}$ 7.10 and Krishna park $P<0.0004$ $F_{2\ 21}11.48$.

TDS showed showed significant positive correlation (Table 3.4, 3.5 and 3.6) with Cl, CO_2, MgH, pH, SO_4, TH, WT, while significantly negatively correlate with DO, PO_4, WC at all the three water bodies except from the Malpur dam. The TDS is positive significant correlation with AT, SO_4 and negative significant correlation with NO3 and TSS. The TDS of Krishna Park is also significantly positively correlated with AT, Ca and TS.

6. Total Suspended Solids (TSS)

Maximum TSS as recorded in at all the three water bodies (Table 3.1a, 3.2a, 3.3a., Fig. 3.1a, 3.2a and 3.3a) durin monsoon with 76.88±4.26 mg/lit at Malpur dam (Table

3.1a), 78.63±1.13 mg/lit. at Baldane reservoir (Table 3.2a) and 86.88±3.65 mg/lit. at Krishna park (Table 3.3a) respectively. It was minimum in winter with (29.50±2.19 mg/lit., 33.38±1.80 mg/lit., 36.3±81.74 mg/lit.) while moderate in summer with (35.75±1.59 mg/lit., 39.38±2.06 mg/lit., 47.5±2.5 mg/lit. respectively).

Among all three water bodies maximum TSS in all seasons was recorded at Krishna park. Highly significant seasonal variations were recorded at all three water bodies Malpur dam ($P<0.0001$ $F_{2\ 21}$21.84), Baldane reservoir ($P<0.0001$ $F_{2\ 21}$ 73.77) and at Krishna park ($P<0.0001$ $F_{2\ 21}$ 93.38).

TSS shows significant positive correlation (Table 3.4, 3.5 and 3.6) with PO_4 and TS, while significant negative correlation with pH, SO_4, TH, and transparency at all the three water bodies. Apart from the Malpur dam TSS is positively correlated with TDS in the two water bodies. The TSS at Baldane reservoir significantly negatively correlated CaH and MgH. TSS is positively correlated with WC at Krishna park while negatively significantly correlated with Cl and Mg.

7. Transparency

Maximum transparency (Table 3.1a, 3.2a, 3.3a., Fig. 3.1a, 3.2a and 3.3a) was noted in winter at Malpur dam with 115.3±4.41cm at Baldane Reservoir with107.3±4.16 cm and Krishna Park with 117.1±3.48cm; respectively, and it was minimum in monsoon with 72.13±5.39cm; 69±5.71cm; 70.75±5.56 respectively while moderate in summer with 94.50±3.33 cm; 94±3.7 cm; 90.13±3.17 cm respectively.

Significant seasonal variations were recorded at all the three water bodies with Malpur dam ($P<0.0001$ $F_{2\ 21}$ 29.07); Baldane Reservoir ($P<0.0001$ $F_{2\ 21}$ 24.43); and Krishna Park ($P<0.0001$ $F_{2\ 21}$ 17.15).

Transparency showed a positive significant correlation (Table 3.4, 3.5 and 3.6) with DO and pH, while negative significant correlate with AT, CO_2, TS, TSS and WT at all the three bodies.

(Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b)

Chemical parameters

1. pH

Maximum pH was recorded in summer at all three water bodies (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b). At Malpur dam, Baldane reservoir and Krishna park it was 8.12±0.10, 8.10.05 and 8.19±0.02 respectively. It was minimum in monsoon (7.2±0.05, 7.21±0.29, 7.28±0.03, respectively), while moderate in winter (7.76±0.05, 7.74±0.04, 8.19±0.03, respectively). Though the differences were not high, pH of

water was maximum at Krishna park (8.19±0.03) and minimum at Baldane reservoir (8.1±0.05).

Significantly seasonal variations were recorded at all the three water bodies for pH with MD P<0.0001 $F_{2\ 21}$ 76.16, BR P<0.0001 $F_{2\ 21}$ 135.2, KP P<0.0001 F_{221} 135.5).

Among three water bodies very slight variations were recorded in same season. All three water bodies remained alkaline throughout the study period.

pH showed significant positive correlation (Table 3.4, 3.5 and 3.6) with Mg, $SO_{4,}$ TDS, TH and transparency while a significant negative correlation with $PO_{4,}$ TSS and WC at all three water bodies. Significant positive correlation was also recorded with Cl of pH at Malpur dam and Baldane reservoir, while pH was positively significantly correlated with CaH at Krishna Park.

2. Dissolved Oxygen (DO) mg/lit.

Maximum dissolved oxygen was recorded in winter at all the three water bodies (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) with 7.21±0.28mg/lit. at MD, 7.7±0.31mg/lit. at BR and 7.41±0.30 mg/lit. at KP. Minimum DO was recorded in summer 4.19±0.11mg/lit., 4.73±0.35mg/lit., 4.65±0.32mg/lit., respectively while it was moderate 5.55±0.23mg/lit., 5.79±0.38mg/lit., 5.9±0.37.mg/lit. respectively at MD, BR and KP respectively.

Among all the three water bodies maximum DO was recorded in winter with Baldane having highest levels while minimum at Malpur dam.

Significant seasonal variations were recorded at all the three water bodies for DO with Malpur dam P<0.0001 $F_{2\ 21}$ 49.07, Baldane reservoir P<0.0001 $F_{2\ 21}$ 18.71 while at Krishna Park P<0.0001 $F_{2\ 21}$ 17.28.

Dissolved oxygen administered significant positive correlation (Table 3.4, 3.5 and 3.6) with PO4, water cover and transparency, significant negative correlation with AT, Cl, CO_2, Mg, TDS, TH, TS and WT at all three water bodies.

3. Free carbon dioxide (CO_2) mg/lit.

Maximum free CO_2 (Table 3.1b, 3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) was recorded at all three water bodies in summer with 3.80±0.14mg/lit. at MD, 3.81±0.21mg/lit. at BR and 3.91±0.19mg/lit. at KP respectively, while it was minimum in winter 2.01±0.24mg/lit., 1.50±0.35mg/lit., 1.65±0.19mg/lit. respectively, while it was moderate in monsoon 3.23±0.17mg/lit., 2.80±0.11 mg/lit., and 2.84±0.11mg/lit. respectively.

Significant seasonal variations were recorded at all three water bodies for CO_2 with Malpur dam P<0.0001 $F_{2\ 21}$ 2394, Baldane reservoir P<0.0001 $F_{2\ 21}$ 229 and Krishna park P<0.0001 $F_{2\ 21}$ 4551. Further, free CO_2 administered significant positive correlation with AT, MgH, SO_4,TDS, TH, TS and WT while negative correlation with DO, transparency and WC all three water bodies. However at Malpur dam and Krishna park it showed positively significant correlation with Cl while insignificant at Baldane reservoir.

4. Total Hardness

Maximum total hardness (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) was recorded in summer at all the three water bodies. MD records hardness with 143.6±3.38mg/l while BR recorded 150.8±4.17mg/l and KP 155.1±4.62mg/l. It was minimum in 106.3±4.2mg/l at MD 101.4±7.6mg/l at BR and 108.1±7.49mg/l at KP while it was moderate in winter with 122.6±1.54mg/l at MD, 123.3±1.88mg/l at BR and 127±1.59 at KP.

Among the three water bodies maximum total hardness was recorded at Krishna Park in summer and minimum at Malpur dam in same season. Significant seasonal variations of total hardness were recorded. Significant positive correlation of TH was established with Cl, CO_2, Mg, pH, TDS, and WT. while negative significant correlation with DO, PO_4., and WC at all the three water bodies. TH is positively significantly correlated with SO_4 at Malpur dam and Krishna Park reservoir.

5. Calcium Hardness ($CaCO_3$) mg/l

Maximum Ca Hardness (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) was recorded at all the three water bodies in summer with 14.53±0.72mg/l at MD, 14.88±0.71mg/l at BR and 15.68±0.59mg/l at KP. However, it was minimum in monsoon (7.87±0.55mg/l, 8.37±0.76mg/l and 9.10±0.73mg/l respectively) while moderate in winter (10.15±0.34mg/l at MD, 11.24±11.69mg/l at BR and 10.88±0.30mg/l at KP) respectively. Among three water bodies higher calcium hardness was recorded at KP in summer and lowest in the winter.

Significant seasonal variations were recorded at all the three water bodies for calcium hardness, with Malpur dam P<0.0001 $F_{2\ 21}$36.44; Baldane reservoir P<0.0001 $F_{2\ 21}$ 29.41 and Krishna Park P<0.0001 $F_{2\ 21}$ 39.71. Pearson correlation (Table 3.4, 3.5 and 3.6) showed positive significant correlation of Ca hardness with Cl, CO_2, Mg, SO_4, TDS, TH, WT and negative correlation with DO, PO4 and WC at all the three water bodies. Ca hardness is positively significantly correlated with AT at Malpur dam.

6. Magnesium hardness(Mg) mg/l

Magnesium Hardness shows significant seasonal variations. Maximum magnesium hardness was recorded in summer(Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) with 3.73±0.27 at MD, 4.56±0.44 at BR and 5.10±0.35mg/lit. at KP respectively, while minimum in monsoon with 1.66±0.11mg/l at MD, 2.15±0.24mg/l at BR and 2.43±0.21mg/l at KP in respectively. Moderate magnesium levels were observed during winer with 1.86±0.14mg/l at MD, 2.82±0.23mg/l at BR and 3.1±0.19mg/l at KP respectively.

Significant seasonal variations were recorded at all the three water bodies for magnesium hardness, with Malpur dam $P<0.0001$ $F_{2\ 21}$ 35.91; Baldane reservoir $P<0.0001$ $F_{2\ 21}$ 15.35 and Krishna Park $P<0.0001$ $F_{2\ 21}$ 29.04.

Magnesium hardness is positively significantly correlated (Table 3.4, 3.5 and 3.6)with Cl, pH, CO_2, TDS and TH while negatively significantly correlated with DO, PO_4 and WC.

7. Chloride (CL) mh/l

Maximum chlorides were recorded in summer (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) at all the three water bodies with 47.50±1.99 mg/l at MD, 48.50±2.40 mg/l at BR and 51.25±2.90 mg/l at KP and minimum in with 24.63±3.69 mg/l at MD and 25.38±3.74 mg/l at BR and 37.75±1.61 at KP.

Among three waterbodies maximum chloride was recorded at Krishna park reservoir minimum at Amrawati dam in Summer.

Significant seasonal variations in chlorides were recorded at all the three water bodies with $P<0.0001$ $F_{2\ 21}$19.16 (Malpur dam); $P<0.0001$ $F_{2\ 21}$14.96 (Baldane reservoir) and $P<0.0001$ $F_{2\ 21}$31.27 (Krishna Park).

Pearson correlation showed significant positive correlation (Table 3.4, 3.5 and 3.6) of chlorides with MgH, SO_4, TDS and TH while negative correlation with DO and WC.

8. Nitrate (NO3) Mg/l

Maximum nitrate was recorded in monsoon at all the three water bodies (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) with 0.21±0.015 mg/l at MD, 0.24±0.02 mg/l at BR and 0.27±0.02 mg/l at KP. Minimum values were recorded in winter at Baldane reservoir (0.13±0.01mg/l), at Krishna Park (0.16±0.01mg/l) and at MD (0.10±0.01mg/l). In summer it was (0.16±0.11mg/l) at Baldane reservoir and at (0.18±0.10mg/l).Krishna Park

Among three water bodies maximum Nitrate was recorded at Krishna Park (0.27±0.02) in while in same season it was minimum at MD (0.21±0.01mg/l). Least Nitrates were recorded at Malpur dam 0.05±0.01mg/l) in summer among all the three water bodies.

Significant seasonal variation were recorded at Malpur dam ($P<0.0001$ $F_{2\ 21}$ 52.31) while insignificant seasonal variations were recorded at Baldane reservoir and Krishna Park.

Pearson correlation showed significant positive correlation (Table 3.4, 3.5 and 3.6) of NO_3 with PO_4, TS, TSS, WC and significant negative correlation with MgH, pH, SO_4, TDS, TH and transparency at Malpur dam. It showed significant negative correlation with MgH and SO_4 at Krishna Park. NO_3 did not showed any significant correlation at Baldane reservoir.

9. Phosphate (PO4) Mg/l

Maximum phosphate (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) was recorded in monsoon at all the three water bodies with 0.33±0.05mg/l at MD, 0.36±0.04 mg/l at BR and 0.09± 0.04mg/l at KP. It was minimum in summer (0.08±0.01mg/l, 0.08±0.01mg/l and 0.09±0.01mg/l respectively, while moderate in winter (0.21±0.02mg/l of MD, 0.23± 0.03mg/l of BR, 0.26±0.04mg/l of KP respectively).

Among the three water bodies maximum Phosphate was recorded at Krishna Park and minimum at Malpur dam.

Significant seasonal variations were recorded at all the three water bodies, Malpur dam $P<0.0001$ $F_{2\ 21}$15.67, Baldane reservoir $P<0.0001$ $F_{2\ 21}$ 19.88 and at Krishna Park $P<0.0001$ $F_{2\ 21}$ 20.27.

Pearson correlation administered significant positive correlation (Table 3.4, 3.5 and 3.6) of Phosphate with DO, TSS and WC while negative significant correlation with Mg, pH, SO_4, TDS and TH. Phosphate showed significant correlation with Cl at Malpur dam and Baldane reservoir.

10. Sulphate (SO4) Mg/l.

Maximum sulphates were recorded in summer (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b) at all the three water bodies with 5.30±0.31 mg/l at MD, 5.83±0.47mg/l at BR and 6.28±0.52 mg/l at KP, minimum in monsoon 2.91±0.17mg/l, 3.49±0.37mg/l and 3.51±0.43mg/l respectively while in winter it was 4.19±0.43mg/l, 4.28±0.31mg/l and 4.44±0.25mg/l respectively.

Among all the three water bodies maximum Sulphates were recorded at Krishna Park in summer while lowest sulphate were recorded in at Amrawati dam.

ANOVA results showed significant seasonal variations at all the three water bodies. Pearson correlation showed positive significant correlation (Table 3.4, 3.5 and 3.6) of SO_4 with Cl, CO_2, Mg, pH, TDS, TH, and WT, while SO_4 showed significant positive correlation with DO, NO_3, PO_4, TSS and WC at all three water bodies. SO_4 showed significant positive correlation with AT at Malpur dam as well as Baldane reservoir.

Malpur dam with $P<0.0001$ $F_{2\ 21}$ 13.82, Baldane reservoir $P>0.0011$ $F_{2\ 21}$ 9.51 and Krishna Park (P>0.0004 F 2 21 11.69) (Table 3.1b,3.2b and 3.3b., Fig. 3.1b, 3.2b and 3.3b).

Table 3.1.a Seasonal variations in physical parameters of Malpur dam during October 2011 – September 2013. (Mean ± SEM)

Sr.No.	Parameters	F Value	Winter	Summer	Monsoon
1	AT °C	$F_{2\ 21}$ 9.23	21.75 ± 0.90	26.25 ± 0.74	24.25 ± 0.53
2	WT ^{0}C	$F_{2\ 21}$ 15.57	20.13 ± 0.39	23.13± 0.44	22.06 ± 0.31
3	Water Cover %	$F_{2\ 21}$ 10.79	62.88 ± 0.88	50.63 ± 1.48	66.25 ± 3.98
4	Total Solids (TS) mg/l	$F_{2\ 2}$ 21.84	165.6 ± 3.08	191.4 ±3.95	204.9±5.44
5	Total Dissolved Solids (TDS) mg/l	$F_{2\ 21}$ 14.09	128.0 ± 5.28	155.6 ± 2.54	136.1 ± 2.94
6	Total Suspended Solids (TSS) mg/l	$F_{2\ 21}$ 78.13	29.50± 2.19	34.75 ±1.59	76.88 ± 4.2
7	Transparency (Trans) Cm.	$F_{2\ 21}$ 29.07	117.1 ± 3.48	94.50 ± 3.33	72.13 ± 5.39

Table 3.1.b Seasonal variations in chemical parameters of Malpur Dam During Oct- 2011 to Sept- 2013 (Mean ± SEM)

Sr. No.	Parameters	F Value	Winter	Summer	Monsoon
1	pH	$F_{2\ 21}$ 76.16	7.76 ± 0.05	8.11 ± 0.10	7.20 ± 0.06
2	Dissolved Oxygen (DO) mg /l	$F_{2\ 21}$ 49.07	7.21 ± 0.28	4.19 ± 0.11	5.55 ± 0. 23
3	Free Carbon dioxide (CO_2) mg /l	$F_{2\ 21}$ 23.94	2.02 ± 0.24	3.80 ± 0.14	3.23± 0.17
4	Total Hardness (TH)	$F_{2\ 21}$ 33.56	122.6 ± 1.54	143.6 ± 3.38	106 .3± 4.20
5	Calcium (Ca) mg /l	$F_{2\ 21}$ 36.44	10.15±0.34	14.53 ± 0.72	7.88 ± 0.55
6	Magnesium (Mg) mg /l	$F_{2\ 21}$ 35.91	1.86 ± 0.14	3.73 ± 0.27	1.66±0.11
7	Chloride (Cl) mg /l	$F_{2\ 21}$ 19.16	30.75 ±2.09	47.50 ± 1.99	24.63 ± 3.69
8	Nitrates (NO_3) mg /l	$F_{2\ 21}$ 52.31	0.10 ± 0.013	0.05 ± 0.005	0.21 ± 0.01
9	Phosphate (PO4)mg /l	$F_{2\ 21}$ 15.67	0.21 ± 0.02	0.08 ± 0.01	0.33 ± 0.05
10	Sulfates (SO_4) mg/l	$F_{2\ 21}$ 13.82	4.19 ± 0.43	5.3 ± 0.31	2.9 ± 0.17

Table 3.2.a Seasonal variations in physical parameters of Baldane Reservoir dam during October 2011 – September 2013. (Mean ± SEM)

Sr. No.	Parameters	F Value	Winter	Summer	Monsoon
1	AT °C	$F_{2\ 21}$ 8.80	21.75 ± 0.99	26.1± 0.66	24.75 ± 0.45
2	WT ^{0}C	$F_{2\ 21}$ 10.07	19.38 ± 0.68	22.75± 0.45	21.63 ± 0.46
3	Water Cover %	$F_{2\ 21}$ 12.71	58.13 ± 2.1	40.0 ± 2.67	64.38 ± 5.13
4	Total Solids (TS) mg/l	$F_{2\ 21}$ 16.99	175.5 ± 3.51	208.5±5.98	227.4± 8.58
5	Total Dissolved Solids l (TDS) mg/	$F_{2\ 21}$ 7.10	142.1 ± 3.64	169.1 ± 4.34	148.8 ± 7.18
6	Total Suspended Solids (TSS) mg/l	$F_{2\ 21}$ 73.77	33.38 ± 1.8	39.38 ± 2.06	78.63 ± 4.13
7	Transparency (Trans) Cm.	$F_{2\ 21}$ 24.43	115.3 ± 4.42	94.0 ± 3.70	69.0 ± 5.7

Table 3.2.b Seasonal Variations in chemical parameter of Baldane Reservior during Oct-2011 to Sept 2013 (Mean ± SEM)

Sr. No.	Parameters	F Value	Winter	Summer	Monsoon
1	pH	$F_{2\ 21}$ 135.2	7.74 ± 0.04	8.1 ± 0.05	7.21 ± 0.03
2	Dissolved Oxygen (DO) mg /L	$F_{2\ 21}$ 18.71	7.7 ± 0.31	4.73 ± 0.35	5.79 ± 0. 38
3	Free Carbon dioxide (CO_2) mg /L	$F_{2\ 21}$ 22.9	1.49 ± 0.35	3.81 ± 0.21	2.77± 0.11
4	Total Hardness (TH)	$F_{2\ 21}$ 19.12	123.3 ± 1.88	150.8 ± 4.17	101.4± 7.60
5	Calcium (Ca) mg /L	$F_{2\ 21}$ 29.41	11.24 ± 0.35	14.88 ± 0.71	8.38 ± 0.76
6	Magnesium (Mg) mg /L	$F_{2\ 21}$ 15.35	2.82 ± 0.23	4.56 ± 0.44	2.15 ± 0.24
7	Chloride (Cl) mg /L	$F_{2\ 21}$ 14.96	32.75 ±2.86	48.5 ± 2.04	25.38 ± 3.74
8	Nitrates (NO_3) mg /L	$F_{2\ 21}$ 0.85	0.13 ± 0.01	0.16 ± 0.01	0.24 ± 0.01
9	Phosphate (PO4)mg /L	$F_{2\ 21}$ 19.88	0.23 ± 0.03	0.08 ± 0.01	0.36 ± 0.04
10	Sulfates (SO_4) mg/L	$F_{2\ 21}$ 9.50	4.27 ± 0.31	5.84 ± 0.46	3.49 ± 0.37

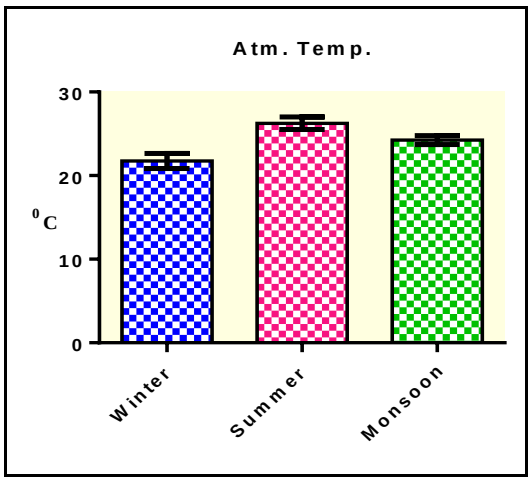
Table 3.3.a Seasonal variations in physical parameters of Krishna Park during October 2011 – September 2013. (Mean ± SEM)

Sr. No	Parameters	F value	Winter	Summer	Monsoon
1	AT °C	$F_{2\ 21}$ 0.33	20.88 ± 1.17	26.0± 0.63	24.5 ± 0.5
2	WT ^{0}C	$F_{2\ 21}$ 17.95	18.88 ± 0.54	22.75± 0.45	21.75 ± 0.41
3	Water Cover %	$F_{2\ 21}$ 10.37	60.63 ± 1.99	42.13 ± 2.78	68.13± 6.33
4	Total Solids (TS) mg/l	$F_{2\ 21}$ 26.58	180.1 ± 2.09	220.6 ±6.84	236.3 ±6.59
5	Total Dissolved Solids l (TDS) mg/	$F_{2\ 21}$ 11.48	143.8 ± 3.01	173.1 ± 4.62	149.4 ± 5.70
6	Total Suspended Solids (TSS) mg/l	$F_{2\ 21}$ 93.38	36.38± 1.74	47.5 ± 2.5	86.88 ± 3.65
7	Transparency (Trans) Cm.	$F_{2\ 21}$ 17.15	107.3 ± 4.16	90.13 ± 3.17	70.75 ± 5.56

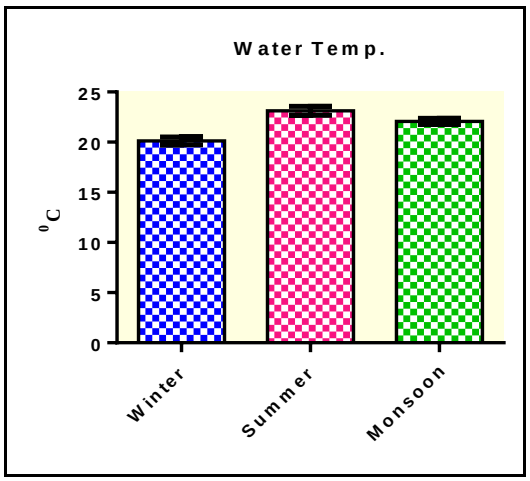
Table 3.3.b Seasonal variations in Chemical parameters of Krishna Park dam during October 2011 – September 2013. (Mean ± SEM).

Sr. No.	Parameters	F value	Winter	Summer	Monsoon
1	pH	$F_{2\ 21}$ 135.5	7.84 ± 0.06	8.19± 0.03	7.24 ± 0.03
2	Dissolved Oxygen (DO) mg /L	$F_{2\ 21}$ 17.28	7.41 ± 0.29	4.65± 0.32	5.9 0± 0. 37
3	Free Carbon dioxide (CO_2) mg /L	$F_{2\ 21}$ 45.51	1.65 ± 0.19	3.91 ± 0.19	2.84± 0.11
4	Total Hardness (TH)	$F_{2\ 21}$ 20.93	127 ± 1.6	155.1 ± 4.6	112.1 ± 7.50
5	Calcium (Ca) mg /L	$F_{2\ 21}$ 39.71	10.88±0.3	15.68 ± 0.59	9.10 ± 0.73
6	Magnesium (Mg) mg /L	$F_{2\ 21}$ 29.04	3.1 ± 0.19	5.10 ± 0.35	2.43±0.21
7	Chloride (Cl) mg /L	$F_{2\ 21}$ 31.27	25.75±1.14	51.25 ± 2.9	37.75 ± 1.61
8	Nitrates (NO_3) mg /L	$F_{2\ 21}$ 0.876	0.16 ± 0.01	0.18 ± 0.1	0.27 ± 0.02
9	Phosphate (PO4)mg /L	$F_{2\ 21}$ 20.27	0.26 ± 0.03	0.086 ± 0.01	0.39 ± 0.44
10	Sulfates (SO_4) mg/L	$F_{2\ 21}$ 11.69	4.44 ± 0.25	6.27 ± 0.52	3.51 ± 0.47

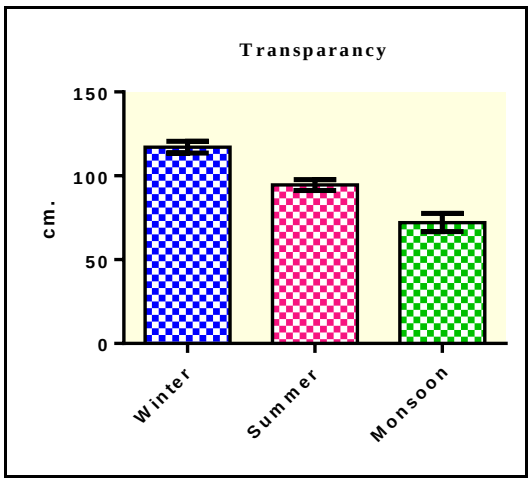
Fig.3.1a Physicochemical Parameters of Malpur Dam during October 2011–September 2013.



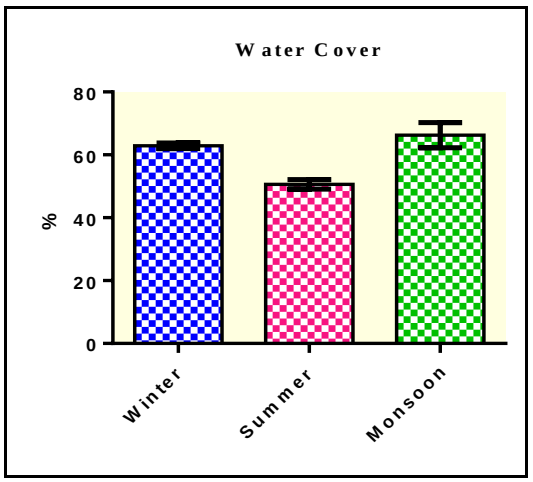
Graph 1: MD



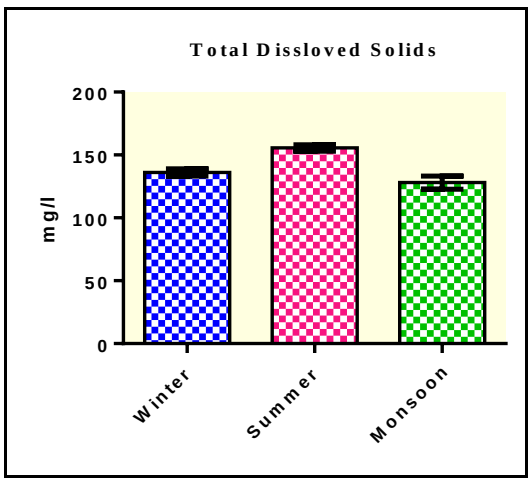
Graph 2: MD



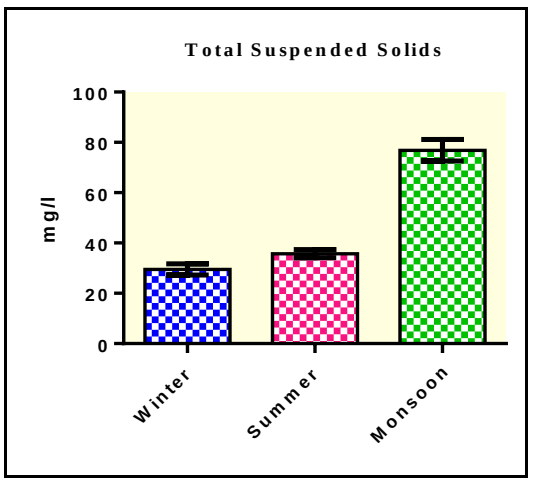
Graph 3: MD



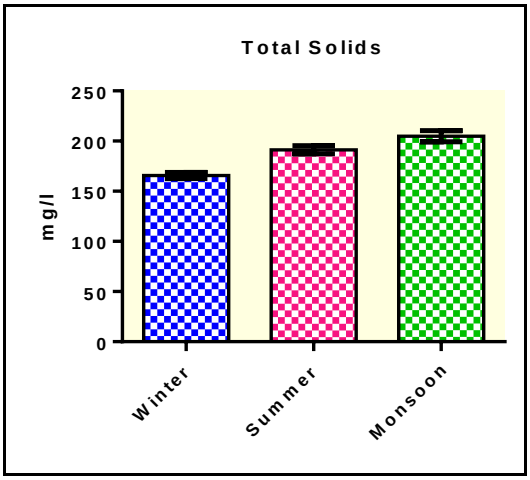
Graph 4: MD



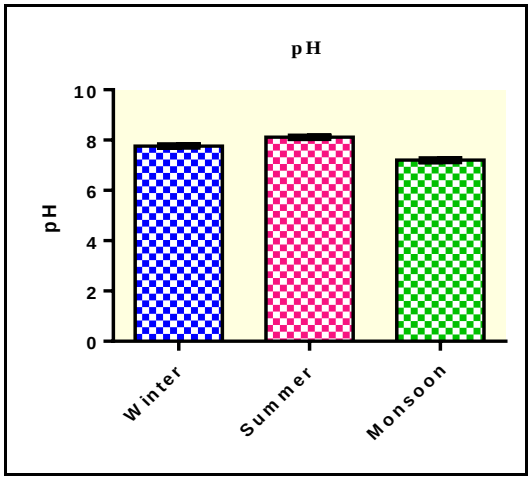
Graph 5: MD



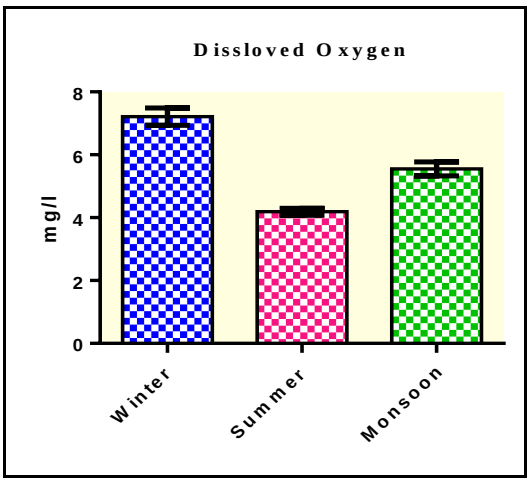
Graph 6: MD



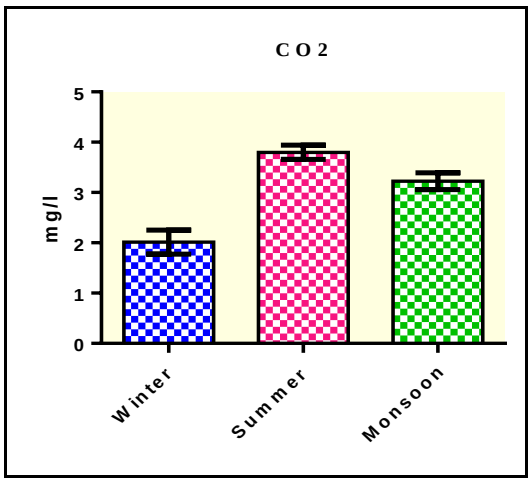
Graph 7: MD



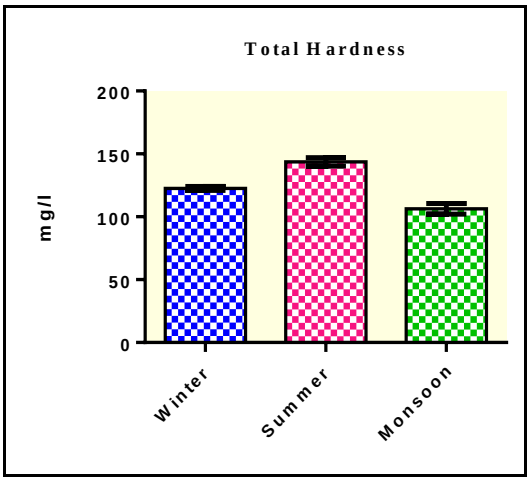
Graph 8: MD



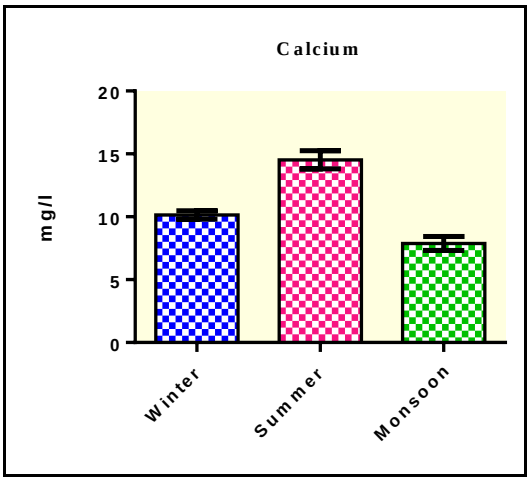
Graph 9: MD



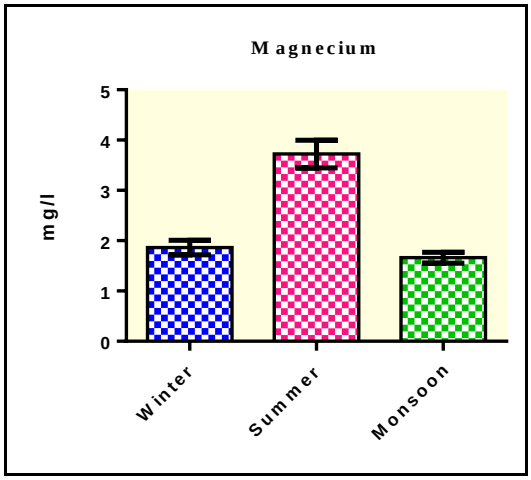
Graph 10: MD



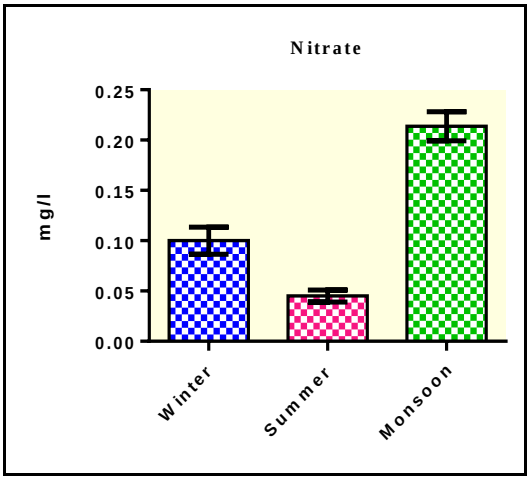
Graph 11: MD



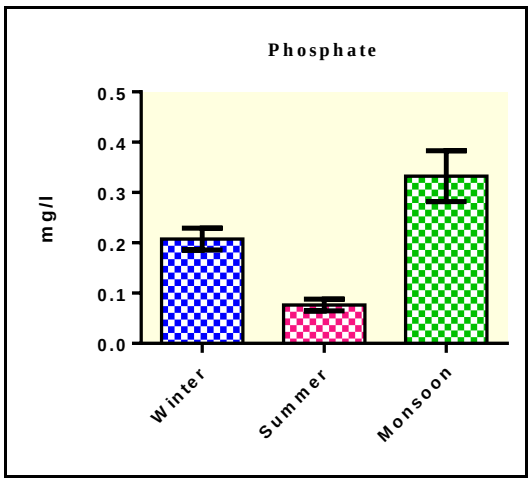
Graph 12: MD



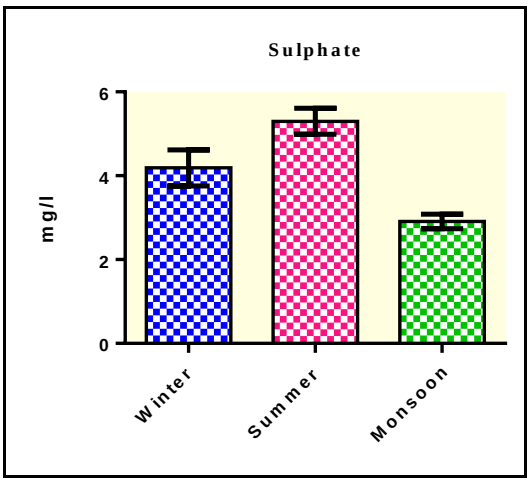
Graph 13: MD



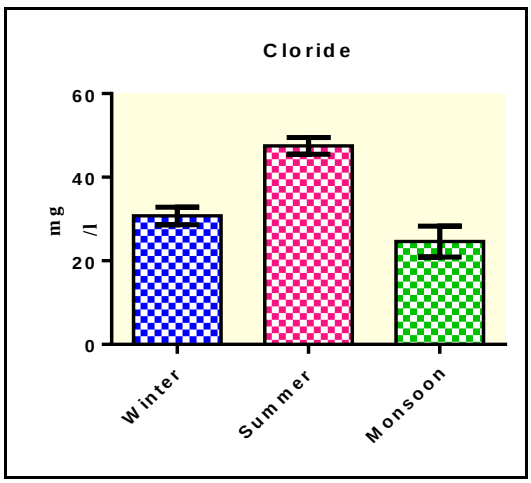
Graph 14: MD



Graph 15: MD

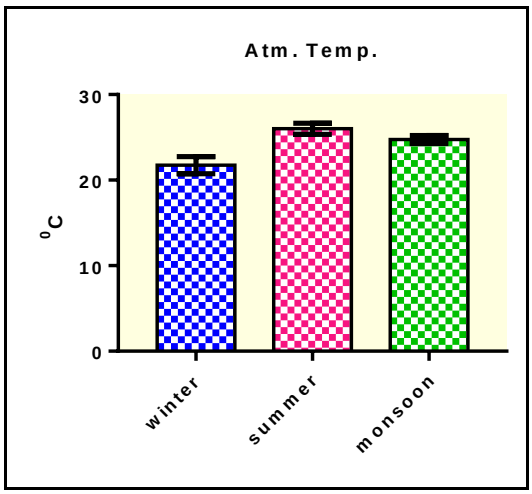


Graph 16: MD

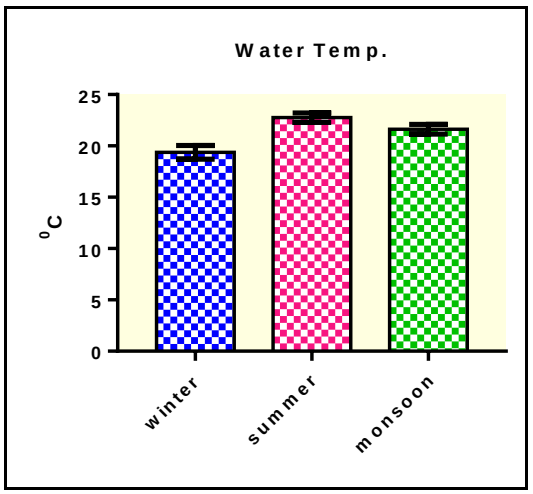


Graph 17: MD

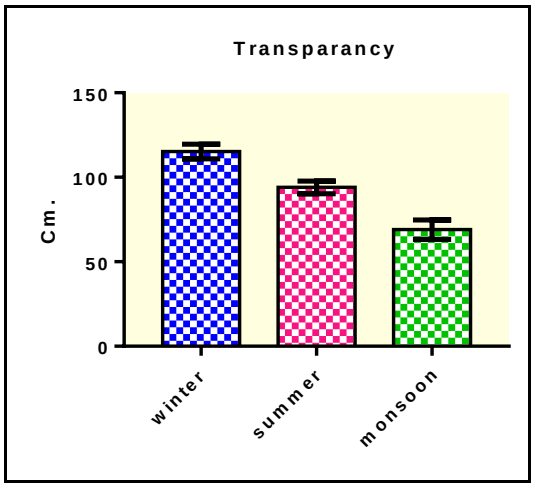
Fig. 3.2a Physicochemical Parameters of Baldane Reservoir during October 2011 – September 2013.



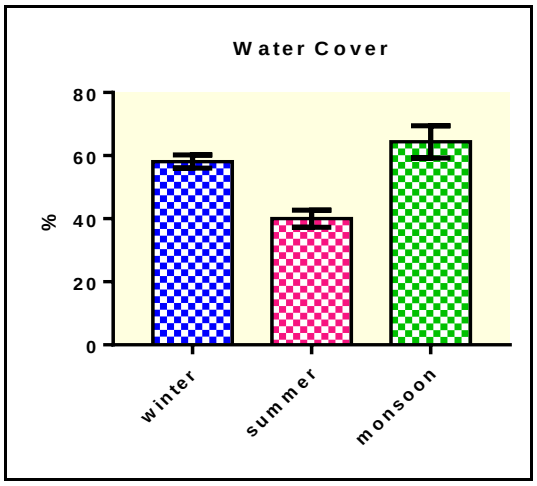
Graph 1:BR



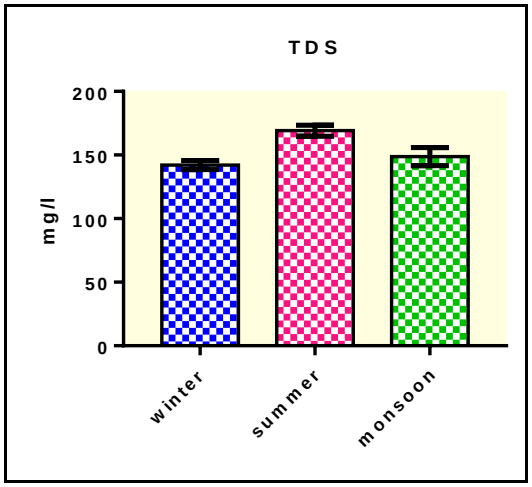
Graph 2:BR



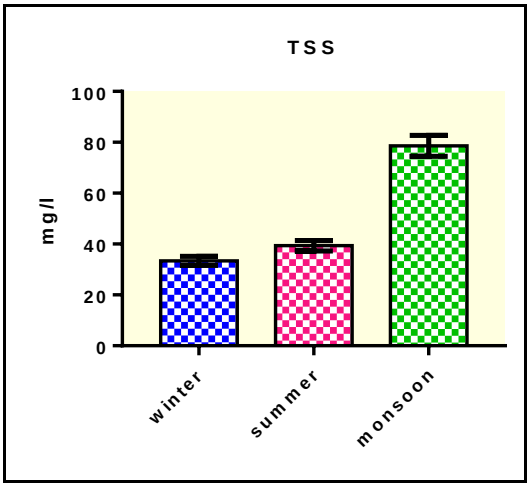
Graph 3:BR



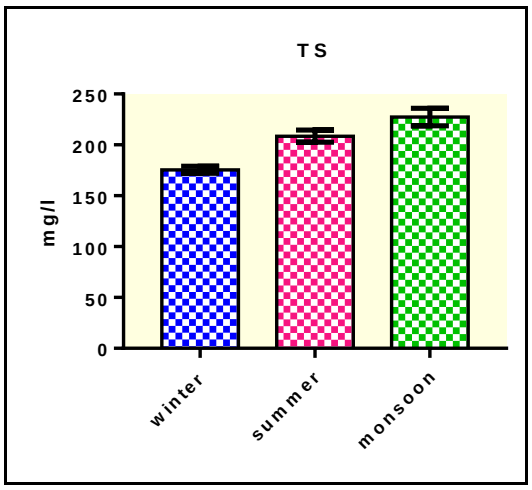
Graph 4:BR



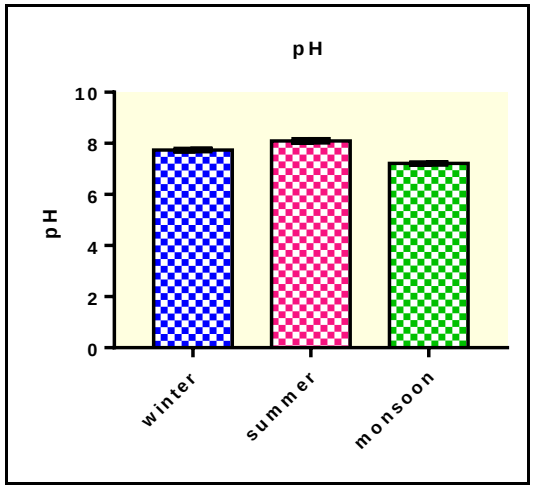
Graph 5:BR



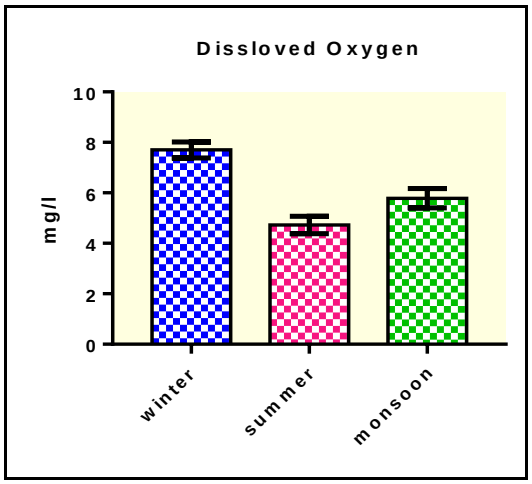
Graph 6:BR



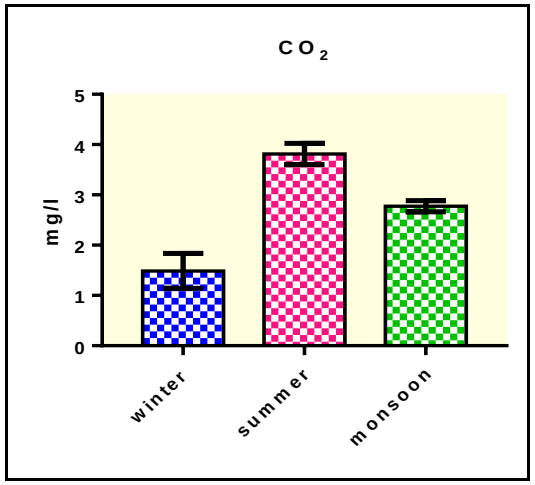
Graph 7:BR



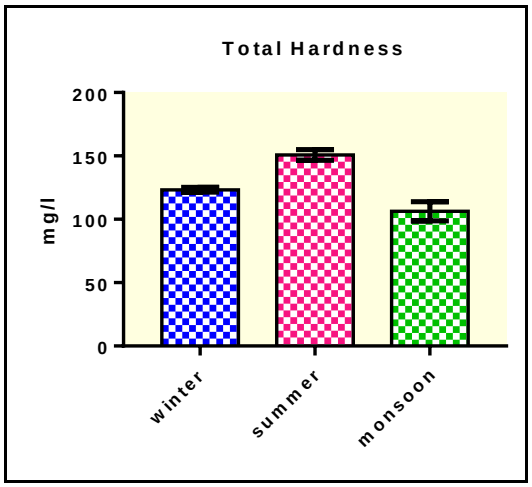
Graph 8:BR



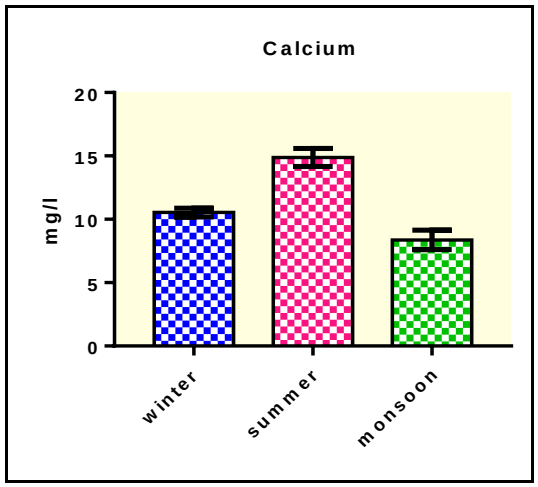
Graph 9:BR



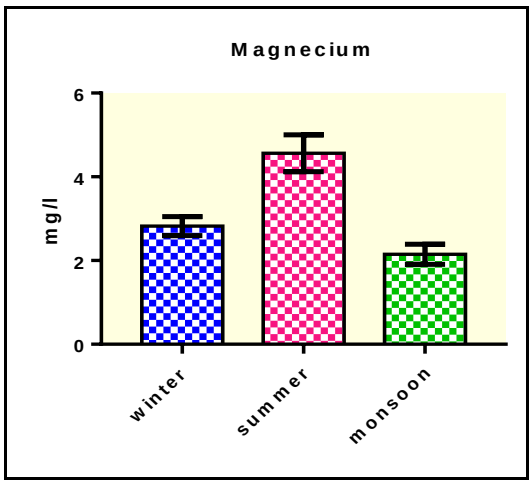
Graph 10:BR



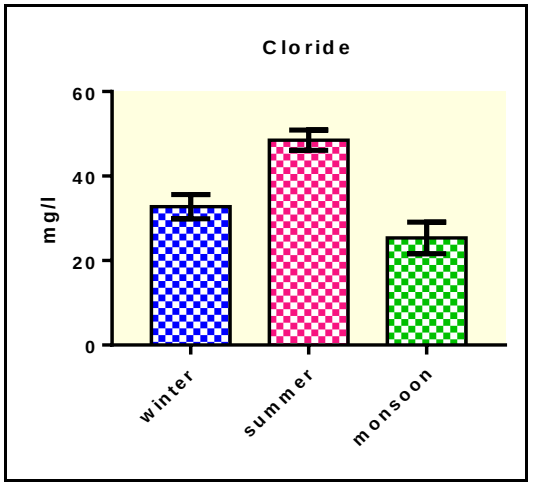
Graph 11:BR



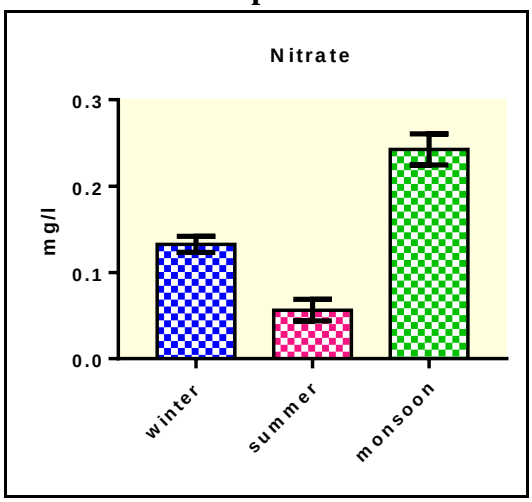
Graph 12:BR



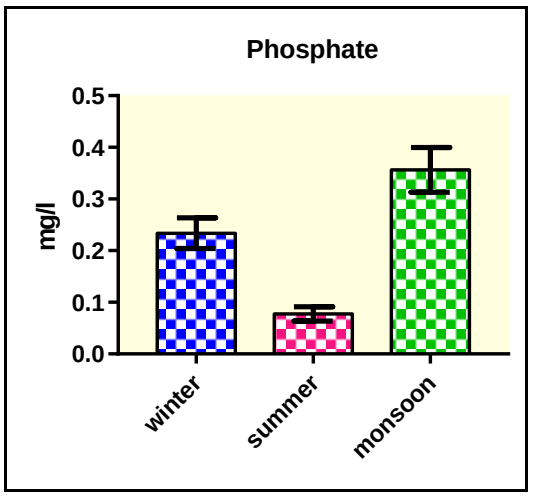
Graph 13:BR



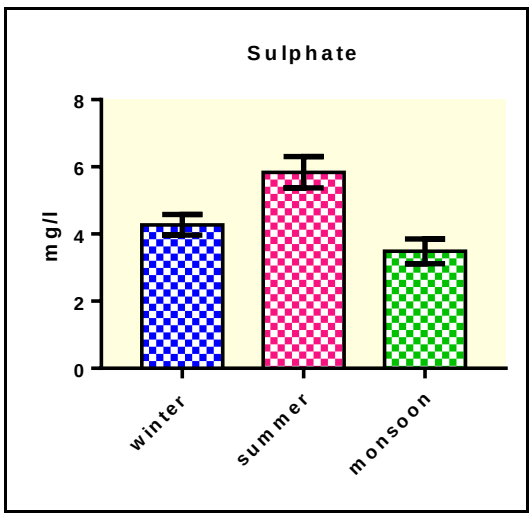
Graph 14:BR



Graph 15:BR

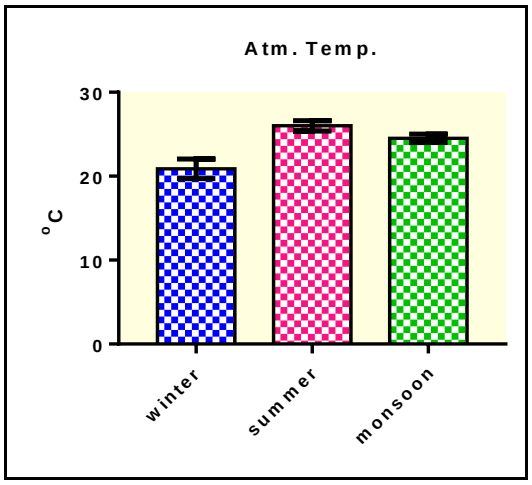


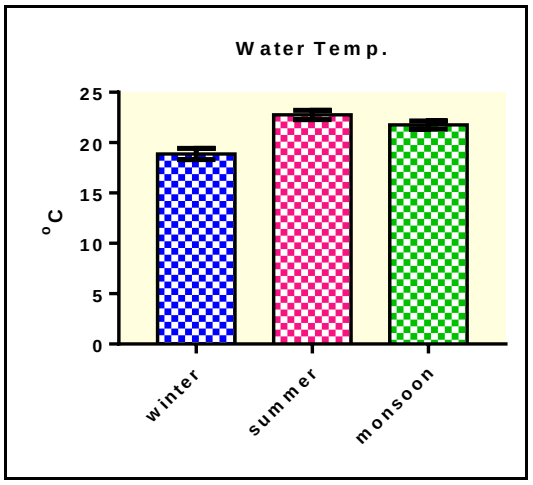
Graph 16:BR



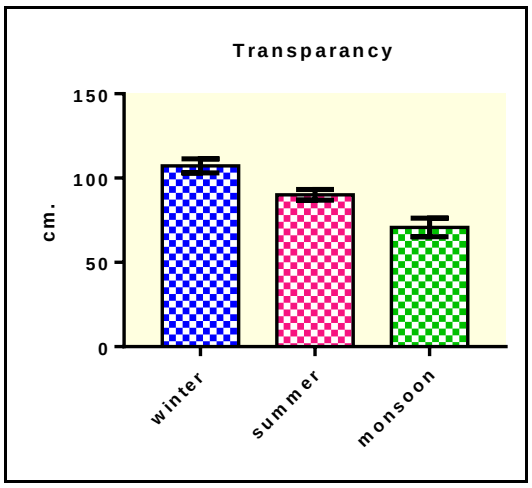
Graph 17:BR

Fig.3.3 Physcochemical Parameters of Krishna Park during October 2011 – September 2013.

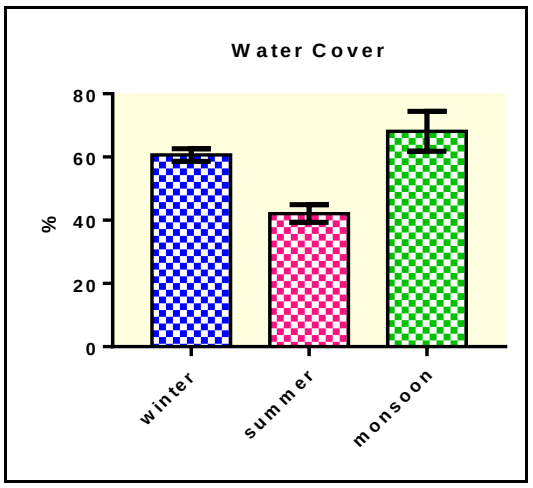




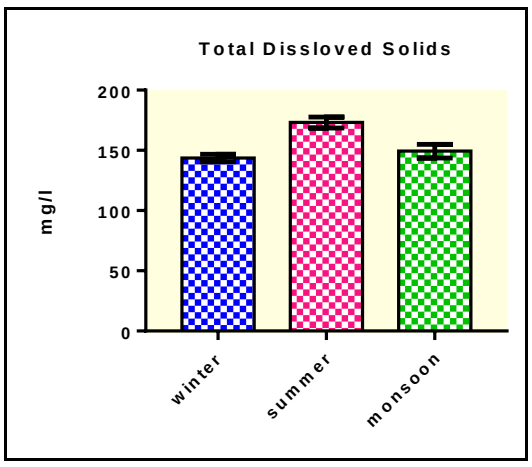
Graph 1: KPGraph 2: KP



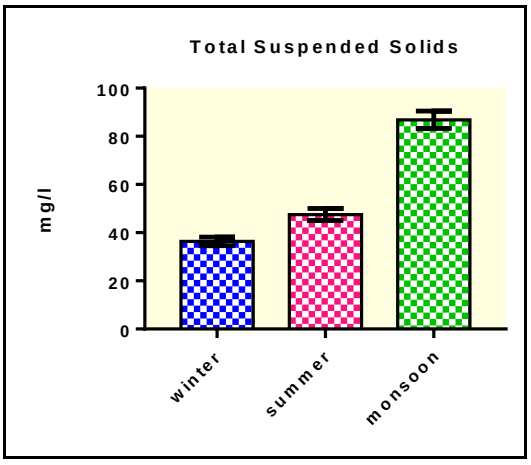
Graph 3: KP



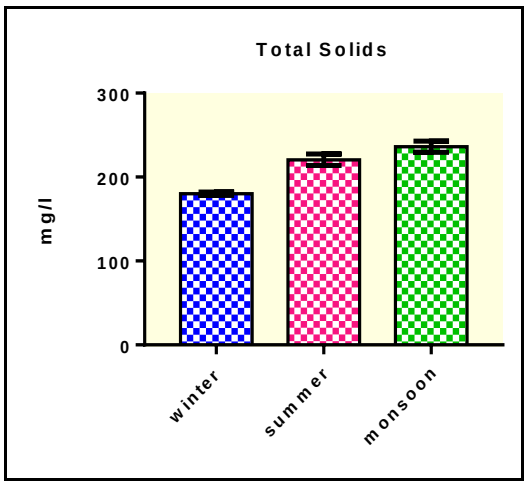
Graph 4: KP



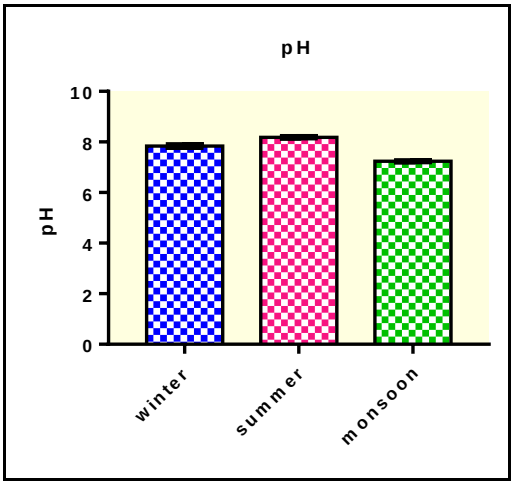
Graph 5: KP



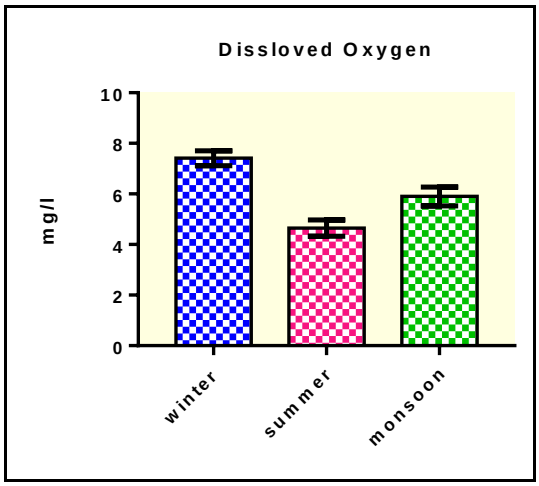
Graph 6: KP



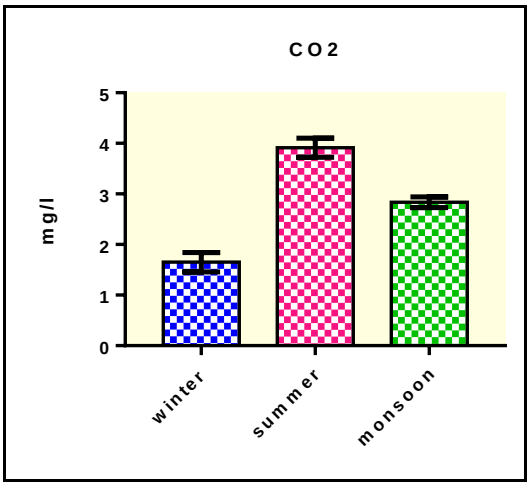
Graph 7: KP



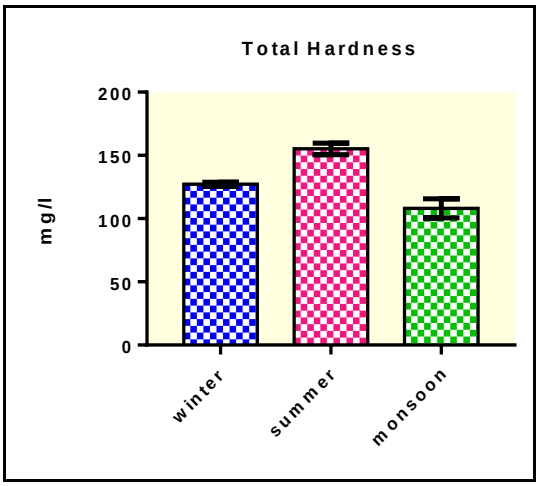
Graph 8: KP



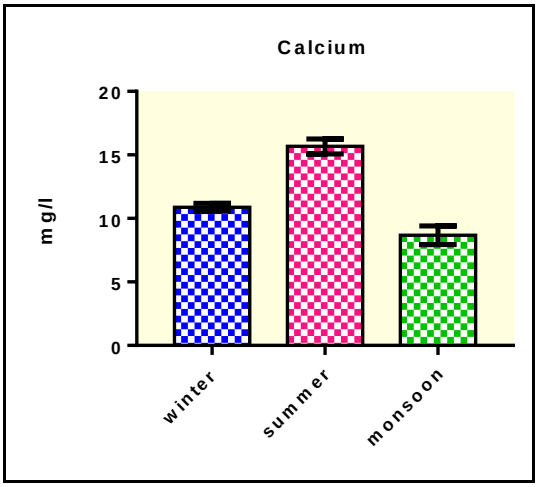
Graph 9: KP



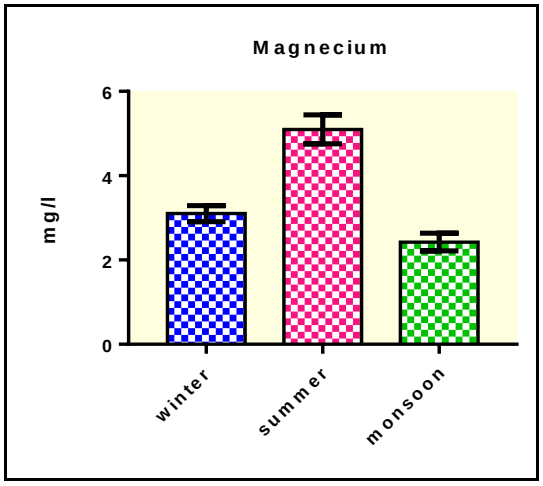
Graph 10: KP



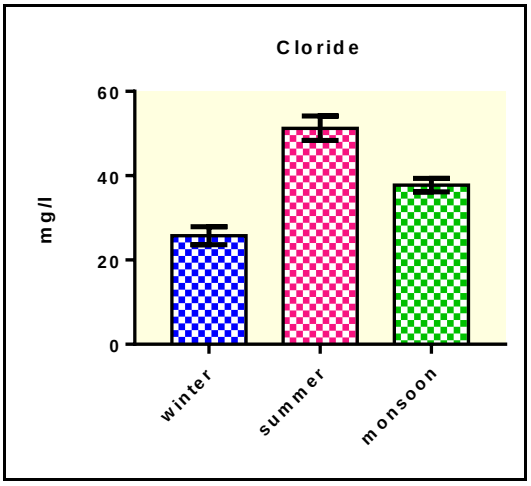
Graph 11: KP



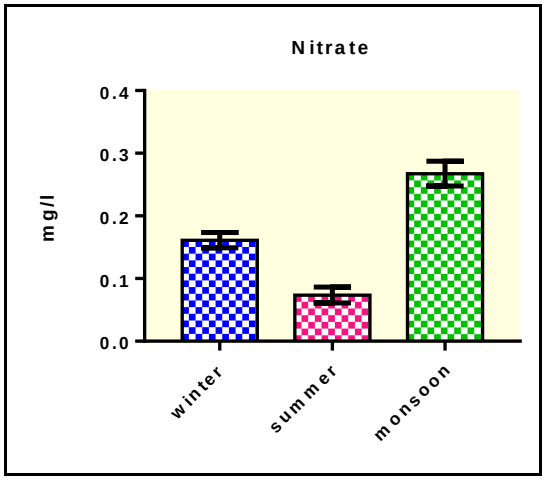
Graph 12: KP



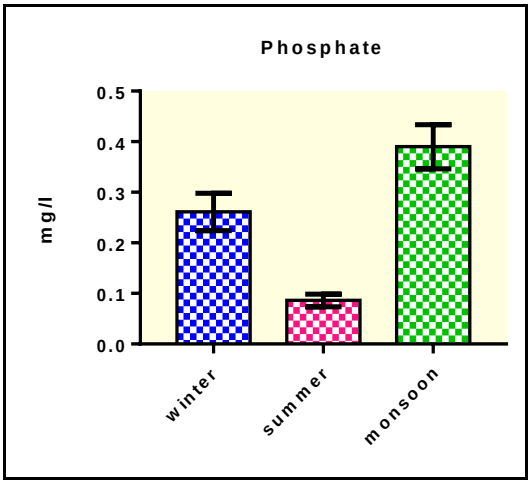
Graph 13: KP



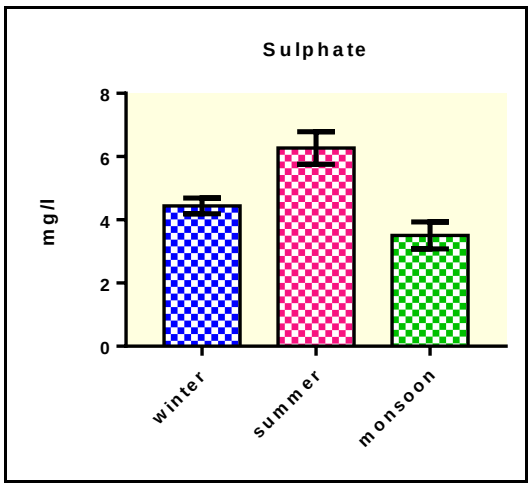
Graph 14: KP



Graph 15: KP



Graph 16: KP



Graph 17: KP

Table 3.4 Pearson Correlation- Physicochemical Parameters of Malpur Dam Studied during October 2011 - September 2013.

	AT	CA	CL	CO2	DO	MG	NO3	PH	PO4	SO4	TDS	TH	TRAN	TS	TSS	WC	WT
AT	**1.000**																
CA	**.481***	**1.000**															
CL	**.473***	**.914****	**1.000**														
CO2	**.907****	**.442***	**.459***	**1.000**													
DO	**-.786****	**-.517****	**-.554****	**-.894****	**1.000**												
MG	**.544****	**.870****	**.803****	**.516****	**-.599****	**1.000**											
NO3	**-.094**	**-.810****	**-.710****	**-.033**	**.147**	**-.679****	**1.000**										
PH	**.294**	**.874****	**.776****	**.236**	**-.297**	**.754****	**-.852****	**1.000**									
PO4	**-.318**	**-.810****	**-.915****	**-.287**	**.413***	**-.689****	**.725****	**-.795****	**1.000**								
SO4	**.603****	**.713****	**.599****	**.481***	**-.431***	**.655****	**-.587****	**.784****	**-.556****	**1.000**							
TDS	**.481***	**.853****	**.859****	**.435***	**-.514***	**.787****	**-.672****	**.746****	**-.834****	**.573****	**1.000**						
TH	**.492***	**.916****	**.863****	**.433***	**-.482***	**.777****	**-.805****	**.906****	**-.836****	**.744****	**.871****	**1.000**					
TRAN	**-.444***	**.268**	**.178**	**-.540****	**.479***	**.015**	**-.535****	**.508***	**-.296**	**.189**	**.222**	**.350**	**1.000**				
TS	**.597****	**.008**	**.167**	**.678****	**-.631****	**.171**	**.416***	**-.297**	**-.034**	**-.092**	**.208**	**-.044**	**-.822****	**1.000**			
TSS	**.199**	**-.576****	**-.440***	**.303**	**-.207**	**-.387**	**.829****	**-.773****	**.540****	**-.474***	**-.500***	**-.635****	**-.880****	**.743****	**1.000**		
WC	**-.505***	**-.756****	**-.870****	**-.460***	**.602****	**-.698****	**.564****	**-.638****	**.914****	**-.548****	**-.809****	**-.763****	**-.035**	**-.274**	**.311**	**1.000**	
WT	**.905****	**.458***	**.503***	**.880****	**-.835****	**.587****	**-.036**	**.236**	**-.318**	**.473***	**.494***	**.452***	**-.507***	**.687****	**.271**	**-.521****	**1.000**

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

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

Table 3.5 Pearson Correlation- Physicochemical Parameters of Baldane Reservoir studied during October 2011 - September 2013.

	AT	CA	CL	CO2	DO	MG	NO3	PH	PO4	TDS	TH	TRAN	TS	TSS	WC	WT
AT	1.000															
CA	-.030	1.000														
CL	.223	.030	1.000													
CO2	.806**	.001	.375	1.000												
DO	-.779**	.293	-.502*	-.834**	1.000											
MG	.337	.048	.881**	.458*	-.498*	1.000										
NO3	-.164	-.084	-.279	-.112	.167	-.380	1.000									
PH	.149	.213	.798**	.333	-.242	.802**	-.348	1.000								
PO4	-.132	-.037	-.945**	-.328	.441*	-.853**	.242	-.837**	1.000							
SO4	.451*	.120	.680**	.510*	-.557**	.737**	-.380	.699**	-.701**							
TDS	.365	-.028	.783**	.604**	-.737**	.693**	-.141	.499*	-.771**	1.000						
TH	.414*	.189	.889**	.514*	-.535**	.888**	-.302	.838**	-.880**	.720**	1.000					
TRAN	-.480*	.355	.257	-.490*	.545**	.236	-.132	.522**	-.365	-.191	.312	1.000				
TS	.447*	-.173	.130	.562**	-.689**	.086	.079	-.287	-.032	.619**	.045	-.826**	1.000			
TSS	.260	-.197	-.495*	.205	-.254	-.475*	.220	-.785**	.609**	-.056	-.550**	-.889**	.749**	1.000		
WC	-.324	-.062	-.946**	-.468*	.613**	-.858**	.251	-.744**	.944**	-.833**	-.901**	-.158	-.231	.408*	1.000	
WT	.936**	-.055	.277	.882**	-.830**	.360	-.216	.192	-.207	.431*	.468*	-.445*	.453*	.212	-.372	1.000

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

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

Table 3.6 Pearson Correlation- Physicochemical Parameters of Krishna Park during October 2011 - September 2013.

	AT	CA	CL	CO2	DO	MG	NO3	PH	PO4	SO4	TDS	TH	TRAN	TS	TSS	WC	WT
AT	1.000																
CA	.378	1.000															
CL	.763**	.549**	1.000														
CO2	.844**	.595**	.920**	1.000													
DO	-.825**	-.609**	-.795**	-.902**	1.000												
MG	.351	.927**	.595**	.616**	-.586**	1.000											
NO3	-.130	-.309	-.200	-.110	.199	-.442*	1.000										
PH	.039	.861**	.325	.278	-.237	.832**	-.314	1.000									
PO4	-.120	-.924**	-.329	-.399	.464*	-.882**	.284	-.863**	1.000								
SO4	.401	.765**	.483*	.542**	-.542**	.846**	-.424*	.679**	-.755**	1.000							
TDS	.439*	.766**	.648**	.699**	-.722**	.772**	-.226	.534**	-.762**	.723**	1.000						
TH	.373	.958**	.447*	.531**	-.598**	.909**	-.341	.820**	-.905**	.821**	.743**	1.000					
TRAN	-.471*	.255	-.494*	-.497*	.457*	.199	-.133	.535**	-.371	.152	-.210	.287	1.000				
TS	.555**	.054	.606**	.644**	-.618**	.122	.074	-.307	.023	.115	.578**	.025	-.841**	1.000			
TSS	.341	-.525**	.242	.248	-.199	-.446*	.265	-.787**	.615**	-.417*	-.065	-.542**	-.867**	.777**	1.000		
WC	-.266	-.834**	-.444*	-.522**	.602**	-.810**	.262	-.688**	.882**	-.822**	-.879**	-.872**	-.051	-.244	.379	1.000	
WT	.934**	.434*	.774**	.877**	-.855**	.462*	-.201	.081	-.240	.446*	.519**	.415*	-.478*	.620**	.358	-.329	1.000

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

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

Disscussion

Temperature:

Atmosphere temperature and water temperature are two important environmental factors that go hand in hand (Macan, 1958) and changes in the atmospheric temperature show a close proportional influence to that of water (Kaul *et al*., 1980). Hence simultaneous fluctuations in response to change in season are noted over the seasons at the three reservoir. However, the highest mean atmospheric temperatures were recorded at the larger reservoir Malpur dam and lower at Krishna park surrounded by vegetation as part of recreation centre. Similar temperature ranges have been recorded by many people from different parts of India, (Wankhede *et.al*., 2012) in Maharashtra as well as Deshkar (2008) in central Gujarat. The temperature range has also been corroborated by Wankhede *et al*. (2012); Patil *et al*., 2012; Harney *et al.* (2013); Patil *et al.* (2013), in different parts of Maharashtra and Mohamed, *et al*. (2009), Deshkar, (2011), Qureshimatva *et al.* (2015) from Gujarat and Mathur *et al*. (2010), Thirupathaian *et al*. (2012), Prabhakaran *et al*. (2013) from rest of India. Water temperature in Nassar lake in Africa (Mohamed, *et al*., 2009) ranged between 19.8 – 21.2 ^{0}C and 21 -31^{0}C during winter and summer respectively. But Kotut *et al*. (1999) reported irregular seasonal trends with mean monthly temperature from 25.96^{0}C to 31.96^{0}C in Turkewl George reservoir, in North Korea. The higher solar radiation affect both ambient as well as water temperatures and lower radiation decreases the temperature. The productivity and internal metabolism of fresh waters are driven and controlled by energy derived directly from the solar energy utilized in photosynthesis. However, Hardikar and Acharya (2013) reported quite higher temperature 28.3^{0}C , to 31.75^{0}C in mosoon too, 21.75 ^{0}C and 27.25^{0}C for winter season and 28.75^{0}C- 28.5^{0}C for summer season in two freshwater bodies at Ahemadabad. The summer maxima and winter maxima temperature trends have also been reported by Sharma *et al*. (1984), Tidame and Shinde, (2012), Abdar, (2013) in different water bodies in India.

According to Dart and Stretton, (1977) Fluctuations in water temperature may also occur due to change in ionization and increased solubility and precipitation of bottom sediment deposits increasing rate of decomposition of oxidizable organic matter after the rains. Temperature is biologically an important factor which plays a vital role in proper functioning of all living things. Aquatic organisms often have narrow range of

temperature tolerance (Chaudhari *et. al*., 2011) hence even moderate change in water temperature can influence an aquatic life.

Water Cover:

As is expected maximum water cover in the three monsoon dependent reservoirs occurred in monsoon, and minimum in summer due to evaporation. The precipitation in month of July, August, September, during Indian South-West monsoon brings in fresh water via the tributaries increasing the water cover. Significantly positive correlation of water cover with DO, PO_4, NO_3 indicates increase in nutrients brought with rain waters from neighbouring agriculture fields, increasing photosynthetic activities which in turn increases DO while negative correlation of water cover with Cl, CO_2, Mg hardness, pH, SO_4, TDS are indicators of dilution and concentration depending on seasonal variation in atmospheric temperature. The Malpur dam is constructed at the conflux of Amrawati and Nair rivers while Baldane dam and Krishna park are having elevated lands surrounding them collecting water in the depressions. The seasonal variations in the percentage of water cover with the contour of water body determines the littoral (relating to or near the coast or costal or shore) formation, is an indicator of protective nature of the lakes and reservoirs of India (Sugunan, 2000). An irregular shoreline encompasses more littoral formation over water cover. The space essential for colonization clearly affects the composite production of periphytic communities (Wetzel, 2006). Greater surface area provides more opportunities for colonization in lakes which are typical repositories of the great numbers of species. They contain a greater variety of microhabitats and their internal environment conditions are more stable as compared to small water bodies (Pip, 1987).

Total Solids (TS):

Solids refers to the suspend and dissolved matter together in water or waste water and useful parameter describing the chemical constituents of water and can be considered important for the productivity within water body (Goher, 2002). The total solids in water occur due to presence of inorganic substances, organic matter, suspended particles, slit, clay and plankton. Overall high TS is observed in monsoon which brings in organic matter, silt, clay inorganic substances there from neighboring areas with rain water runoff. The highest TS observed at smallest of the three reservoirs are probably due to use of the smaller one for various tourism activities, continuously disturbing the water and not allowing solids to settle down. Solids may affect water

effluent quality adversely in number of ways. However comparatively higher values of total solids have been recorded in the month of May and lowest in the month of December at Vishnupuri reservoir in Maharashtra (Pawale, 2014). Further, Manikandan *et al*. (2016) also reported higher values of total solids in Ukka dam lake during summer but attributed this to the dumping a lots of suspended solid wastes containing effluents received from textile and dyeing industries. However, Abdo (2005) has reported higher values of total solids and total dissolved solids in summer relating this to the elevation of the water temperature which leads to increase in evaporation rate and the accumulation of the dissolved salts in water and lower values in winter period was mainly due to the decrease in temperature that consequently reduces the evaporation rate.

Higher values of total solids in rainy months (Agarwal and Rajwar, 2010) at Tehri dam reservoir, in Garhwal Himalaya have been reported due to the gradual disturbances in sedimentation in solids as well as dust particles deposited along with runoff rainwater, affecting the quality of running water. Bhadja and Vaghela (2013) have also reported higher values of total solids from freshwater reservoir of Saurashtra, Gujarat in monsoon season due to runoff water which carries dissolved solids and organic wastes from garbage dumping, contributing to higher total solids. However, comparatively higher level during summer may be due to concentration due to evaporation too. Similar finding are reported by Deshkar, (2008) and Rathod (2009) in semiarid zone of central Gujarat, Ekhande (2010) and Patil (2011) at Yashwant lake and Lotus lake respectively at Toranmal.

Maximum total solids in monsoon reflects the input of rain water which brings large amount of dissolved solids and suspended solids with it as well as agitation of reservoir due to water current. After rainy season the solids settle down, minimizing their level by the end of winter.

Total Suspended solids: (TSS)

Total suspended solids refer to matter suspended in water or waste water. Waters high in suspended solids may be aesthetically unsatisfactory especially for purposes of bathing. Natural water contains a variety of solid particles in water column. The suspended solids determination is also used to evaluate the strength of domestic waste waters and efficiency of treatment units. Suspended solids are objectionable in aquatic ecosystems for many reasons (Sharifinia *et al*., 2013) as they contain much organic

matter that may cause difficulty in purification and consequently the waterbody may be devoid of dissolved oxygen.

As noted for TS maximum TSS are recorded in monsoon and minimum in winter during study period at all the three water bodies within standard limits. Higher and beyond standard range could be as a result of regular discharge of effluents from industries (Andem *et al*., 2012). (Agarwal and Rajurar, 2010) have reported maximum suspended solids which may be present in the form of coarse, floating fine or colloidal particles as a floating film occur in monsoon due to increased runoff from nearby catchments. Most of the Indian reservoirs show a similar tendency with respect to fluctuations of suspended solids. But contrastingly higher values have been recorded in summer and lower values in rainy season in three lakes of Udaipur city in Rajasthan (Chittora *et al*., 2017). During the present study total suspended solids showed positive significant correlation with phosphate, total solids and negative significant correlation with calcium, magnesium, pH, total dissolved solid, total hardness and nitrogen at Krishna Park reservoir the more disturbed and small reservoir, but positive significant correlation with Nitrate, phosphate, total solids while negative correlation with chloride, pH, Sulphate, total dissolved solid, total solids and transparency at Malpur dam the less disturbed and larger reservoir. Present results were also advocated by Shinde *et al*. (2011) at Harsool-Savangi dam, Aurangabad due to siltation, deterioration, heavy precipitation and mixing runoff from rain water which carried mud, sand etc. mixed in the dam water, (Ekhande, 2010 and Patil, 2011) at higher altitude Yashwant lake and Lotus lake respectively of North Maharashtra.

Total dissolved solids (TDS) :

The total dissolved solids composed mainly of carbonate, bicarbonate, chlorides, sulphate, phosphate, nitrate, calcium, magnesium, sodium, iron, manganese etc. It increasing in concentration beyond the normal limits make the water polluted (Pawale, 2014). Total dissolved solid is a direct measure of all these dissolved substances, both organic and inorganic, in waters. It is the sum of cations and anions concentration expressed in mg/l and increases the density of water influencing osmoregulation. In freshwater organisms, it also reduces solubility of gases like oxygen, utility of water for drinking purpose and also enhances eutrophication of the aquatic ecosystems (Mathur *et al*., 2008).

During present study maximum total dissolved solids were recorded to be high during summer while minimum during winter. Similar seasonal variations have also been reported with minimum TDS in winter and maximum in summer at Sarkari Talab in Gondia in North Eastern part of Maharashtra (Budhe, 2014). The water containing more than 500 mg/l of TDS does not qualify for drinking purpose hence below the 500 mg/l is desirable limit and 1500 mg/l is maximum possible limit for domestic use (ICMR, 1975). The TDS of water at all the three reservoirs studied remained below desirable limit all throughout the year indicating them to qualify for drinking water purpose. The results are also corroborated by Hulyal and Kaliwal, (2011) with higher TDS in summer and lower TDS in winter at Almatti reservoir of Bijapur in Karnataka state. Contrasting results were depicted in the region which is receiving maximum rainfall in world both during Indian South-West as well as North-East monsoons. with highest value of total dissolved solids during October and lowest in June in fish ponds of Lumbding town of Assam (Gupta and Dey, 2013). The dissolved solids are very important parameter describing the chemical nature of the water and can be considered as edaphically relate and contribute to productivity within the water body (Gohar, 2002). At chandolia lake, Ahmedabad, Gujarat the total dissolved solids ranged from 1008 to 1224 mg/l with highest reported during summer due to the addition of organic matter and solid waste into the lake (Qureshimatva *et al*., 2015). While highest total dissolved solids have been reported in rainy season and minimum in winter indicating total dissolved materials were of allochthonous origin have been reported by Singh *et al*., 2013. Seasonal variations showed maximum values in summer followed by rainy season and minimum during winter (Yadav *et al*., 2013).

Transparency

Water transparency is an important measure of light penetration, which is crucial to hydrobiology of all aquatic ecosystems. The different seasonal values of Secchi depth at different seasons during the two year study are related to suspended materials in water that produces turbidity and reduces light penetration. Highest transparency observed during winter while lowest during monsoon supports the values in TS, TSS and TDS indicating mixing of water in monsoon and settling down of particles in winter. Transparency is a characteristic of water that varies with the combine effect of colour and turbidity, which measures the light penetrating capacity through the water body (Ramachandra and Solanki, 2007). However, low transparency during summer season due to high plankton population has also been recorded (Budhe, 2014). Many

workers have reported similar results (Harney *et al.*, 2013; Patil *et al*., 2013; Sawant and Chauvan, 2013). Transparency showed significant positive correlation with DO, pH, TSS and WT while negative significant correlation with AT, CO_2 and NO_3.

pH (Potentia hydrogeni)

pH is the measure of the intensity of acidity and alkalinity and measures the concentration of hydrogen ions in water. Higher pH values recorded during summer while minimum values in monsoon with similar trends at all the three water bodies may be attributed to increase in alkalinity of water due to take up of CO_2 renders acidity to water. Fresh waters with pH range 6.0 to 9.0 have been noted to be productive and thus recommended for fish culture (Adeniji, 1986).

Above results are also advocated by many workers. Shinde *et al*. (2011) also reported maximum higher pH values in summer and minimum in winter at Harsool-Savangi dam of Aurangabad; Abdo. (2005) recorded higher values of pH during hot period (8.34 to 8.46) and lower pH values during cold period at Abu Za'ball pond in Egypt mainly related to the high carbonate content, while the uptake of CO_2 by phytoplankton decreasing as a result of increase in the concentration of HCO_3^- (El-Wakeel and Wahby, 1970; Abdel–Satar, 2005); Govindswami and Viji, (2012) also recorded higher values (7.44) during the month of May coinciding with high productivity of phytoplankton with removal of carbon dioxide by photosynthesis. Similar pH range was recorded (7.60 to 8.90) at Anasagar Lake due to the presence of carbonates and bicarbonates (Mathur *et al*., 2010). The pH remaining above 7.0 makes water alkaline.

During present study all the water bodies showed pH between 7.00 to 8.3 which was within the standard recommended range by Ministry of Environment Forest and climate change. The mean pH between different water bodies during the study showed no significant difference and this could suggests that water bodies were homogenous in terms of pH, indicative of solubility at all water bodies. Similar results have been reported Abdo, (2005). The reduced rate of photosynthetic activities reduces the assimilation/absorption of carbon dioxide and bicarbonates, which are ultimately responsible for increase in pH Khan and Siddiqui (1977). During the present study significant seasonal fluctuations in pH were recorded. Maximum pH value (8.8) in the month of May (summer) and minimum (7.3) in the month of September (monsoon) (Manjare *et al*., 2010), low pH values (5.5) during the first fourtnight of June and the highest (8.4) during the first fortnight of January at Hiran-

Minar water Tank of Sheikhupura, Pakisthan (Jabeen, 2000). The seasonal fluctuations in pH are related with the effect of photosynthetic activity of phytoplankton and other higher aquatic plants (Khand and Siddiqui, 1978). Mild acidic pH (6.1) to near neutral (7.1) water with an average of 6.56 ±0.30 and reported from Beepar Beel (wetland) at Dharampur near to Khonajan, with maximum in summer and minimum in winter (Nazir and Deka, 2016). The higher concentration of pH during summer season could be attributed to decrease in water level, high temperature, enhanced rate of evaporation and decreased photosynthesis (Sebastian, 2012). Due to diurnal changes in temperature of an aquatic ecosystem, pH of water body is diurnally variable property (Ojha and Mandloi, 2004). pH of water is important for the biotic communities as most of the plant and animal species can survive in narrow range of pH from slight acidic to slightly alkaline (Qureshimatva *et al*., 2015).

pH showed positive significant correlation with Mg Hardness, Sulfet, TDS, TH and Transparency supporting the idea about increasing Mg hardness increases TH which in turn with sulfates and TDS increases the pH. Probably photosynthetic activities decrease with increase in pH, reducing plankton density and increasing transparency.

Dissolved Oxygen (DO):

Oxygen the most fundamental parameter of Lakes and streams, beside water itself (Wetzel, 2006) when dissolved in water is obviously essential to the metabolism of all aerobic aquatic organisms. The high oxygen recorded during winter may be due to high solubility of oxygen at low temperatures and degradation of organic substances. Similar findings were recorded in the present study with maximum dissolved oxygen recorded in the month of December during cold climate when temperature is low. Minimum dissolved oxygen recorded in the month of May is the result of DO due decrease in the solubility as the temperature increases (Wetzel, 2006). Oxygen distribution is important for the direct needs of many organisms and affect the solubility and availability of many nutrients and therefore the productivity of aquatic ecosystems. The long days and bright sunlight during hot days accelerating the photosynthesis by utilizing carbon dioxide and gives off oxygen (Manjare *et al*., 2010). Broad range (3.6 to 10.5) may be due to combined effect of variations of phytoplankton density, submerged vegetation density, temperature of water and organic load of water (Nazir and Deka, 2016). Significant seasonal variations were reported during study period contrasting with low level of DO reported from August

to October due to higher temperature and low photosynthetic activity and from March to May, due to high organic load coming from surface water from nearby dumping areas (Nazir and Deka, 2016). Sharifinia *et al.*, (2013) reported DO of the Zarivar lake with lowest and highest values of 2.65 – 11.193 mg/l. Dissolved oxygen is essential for water quality, ecological status, productivity and health of a lake. Photosynthesis releases oxygen in the day light hours and the consumption of oxygen during the night results in lower pre-dawn levels. Dissolved oxygen is concerned with water quality and distribution and abundance of species in variety of wetland ecosystems (Priyatharsini and Dhanalakshmi, 2016). Minimum DO during summer season followed by postmonsoon, pre-monsoon and monsoon season, where, the minimum concentration of DO at Theroor wetland may be attributed to addition of effluents containing oxidizable organic matter, decay of vegetation at higher temperature and consumption of O_2 from water by producers and consumers. DO showed Significant positive correlations with PO_4, transparency and water cover while the significant negative correlation with AT, Cl, CO_2, Mg, SO_4, TDS, TH, TS and WT.

Free Carbon dioxide

Carbon dioxide is also the most important greenhouse gas, fluctuates across the air-water or sediment water interface and as a measure of net ecosystem metabolism of the aquatic system. The total carbon dioxide concentration influences pH too (Hutchinson, 1957) which is governed by the buffering effect of carbonic acid, carbonate and bicarbonate.

Although CO_2, is a minor component of air, it is abundant in water because of its solubility which is 30 times more than that of oxygen. The amount of CO_2 in water usually shares an inverse relationship with oxygen (Radhika *et al*., 2004). Free CO_2 dissolved in water is the only source of carbon that can be administered and incorporated in the skeleton of living organisms of aquatic autotrophs (Pir *et al*., 2012). It is directly proportional to the bicarbonates while inversely proportional to carbonates. Most of the carbon in fresh water ecosystem occurres as equilibrium products of carbon dioxide and is added to aquatic ecosystem by other factors like rainwater, inflow of ground water and respiration of aquatic flora and fauna (Harney *et al*., 2013).

In present study maximum carbon dioxide values were recorded during summer. The free carbon dioxide values were seen inversely proportional to the values of dissolved oxygen. Free carbon dioxide in waters accumulates due to microbial activity and

respiration of organisms. Free CO_2 reacts with sodium carbonate and sodium hydroxide to form sodfium bicarbonate. (Ramachandran *et al*., 2006). Hulyal and Kaliwal, (2009); Ayoade *et al.*, (2009). Absence of CO_2 has been related to non-polluted water of the Almatti reservoir throughout the study period due to higher photosynthetic activity and higher pH, which probably results in the conversion of CO_2 into HCO_3 and CO_3. The fluctuations in free CO_2 values corresponds directly with standing crop of phytoplankton as the number of phytoplankton increase throughout the winter and summer months, the free CO_2 disappears due to greater utilization of free CO_2 for photosynthetic activity (Kant *et al*., 1990).

Highest values of free carbon dioxide in the month of May at Ado Ekti reservoirin Nigeria (Idowu *et al*., 2012) and also at Lotus lake Maharashtra, India (Patil *et al*.,2013) have been reported during their studies period and seem to fluctuating throughout the year. Kudari *et al*., 2006 reported high CO_2 in different tanks of Haveri district, due to the presence of large number of *Daphnia carinata* species and rotifers and macro zooplankton. Free CO_2 present in water is mainly originated from the respiration of aquatic biota, decomposition of organic matter and infiltration through the soil (Singh *et al*., 2013; Ayyanna and Narayudu, 2013) and as an input parameter of the buffer system which influences the concentration of carbonates, bicarbonates, pH and total hardness in water. When oxygen content is increases, the carbon dioxide content decreases and vice versa. Similar observations have been recorded in present study at all the three reservoirs. Ayyanna and Narayudu, 2013 attributed this to photosynthetic activities of phytoplankton and oxygen consumption during respiratory activity of aquatic organisms. The maximum free carbon dioxide in summer (Harney *et al*., 2013) may also be due to the decomposition of organic matter, to the sequence of processes like uptake from autotrophs, assimilation by algae and decay of aerobic bacteria(Uchchariaya, 2012). Low photosynthetic activity and low precipitation of free CO_2 as carbonates is corroborated in the present study at all the three water bodies. However, highest free CO_2 in winter have been reported at Vishnupuri reservoir in Nanded, Maharashtra (Pawale, 2014), where free CO_2 and water temperature varied independently with low value of free CO_2 when aquatic vegetation was more abundant and high value of free carbon dioxide when water inflow to the reservoir was greatest.

Total Hardness

Hardness of water is the traditional measure of capacity of water to react with soap, hard water requiring a considerable amount soap to leather. Hardness in water due to the calcium and magnesium cations called temporary hardness reflects the sum total of alkaline metal cations present in it. Whereas sulphates and chlorides of calcium and magnesium cause permanent hardness. Hardness plays an important role in the distribution of the aquatic biota and many species are identified as indicator for hard and soft waters (Ramachandra *et al*., 2006). Total hardness share significant positive correlation with calcium hardness, carbon dioxide, magnesium hardness, pH, sulphate, total dissolved solids while negative significant correlation with dissolved oxygen, phosphate, total suspended solids and water cover during present study. Hardness increases in water in presence of aquatic plants (macrophytes). Shinde, (2011) has recorded highly significant positive relationship with turbidity, electric conductivity, total solids, total dissolved solids and total suspended solids, whereas significant negative relationship with transparency. The higher total hardness during summer has been considered due to reduction in water volume and increase in evaporation of water (Priyadharsini and Dhanalakshmi, 2016), whereas lower values in monsoon due to dissolved minerals from sedimentary rocks, run-off detergents and soaps (Palungandi, 2014). Manjare, *et al*. (2010); Harney *et al*. (2013); Priyatharsini and Dhanalakshmi, (2016) have also reported higher total hardness due to reduction in water volume and increase in evaporation. Contents released from dead molluscans shell are also expected to increase the concentration of total hardness in summer (Khan and Chaudhari, 1994). The lower values of total hardness have also been recorded in monsoon at all the three reservoirs due to rain water diluting the hardness (Chittora *et al*., 2017; Patil *et al*., 2013). According to Jhingran (1988) and Sugunan (1990), the hardness above 70 ppm is an indicator of the good productivity. The desirable limit of total hardness for drinking water specified by BIS (1991) is 300 mg/l and maximum permissible limit of 600 mg/l. According to Sharma (2014) at high temperature evaporation of water, weathering of rocks and addition of calcium and magnesium salts by means of plants and living organisms were found to be contributing factor for the increase in hardness of lakes in Kumaun region of Himalaya (Bohra and Bhargava, 1977). Minimum hardness in all the water bodies recorded during study period is also advocated by Sebastian (2012). The total hardness values during study period remained within the limits of BIS and WHO

(2001). Contrasting results have been recorded at Harsool dam of Aurangabad, India where maximum hardness was reported in monsoon probably due to calcium and magnesium brought to the waters by leaching from rocks in the catchments (Shinde *et al*., 2011).

Calcium Hardness (Ca)

Calcium is one of the most abundant substances in natural water and the quantity of calcium in water generally varies from 10 – 100 mg/l depending upon the type of rock (Trivedy and Goel, 1986). Therefore, Ca in natural waters differ according to difference in geographic regions or anthropogenic impacts. Calcium influence growth and population dynamics of freshwater flora and fauna both directly and indirectly (Wetzel, 2006) and is the essential micronutrient. Calcium is essential for maintenance of the structural and functional integrity of cell membranes.

The presence of higher levels of calcium in drinking water can lower cardiovascular disease mortality (Shahid *et al*., 2015). According to Indian standard for drinking water the values of calcium reported from Malpur dam were below the minimum range (6.2 – 16.4 mg/l) and remained in almost same range at other two water bodies during the study period with mild seasonal fluctuations.

Calcium is an essential and important nutrient for aquatic organisms being a cell wall constituent and regulatory factor for physiological function. Calcium as such has no hazardous effect on human health.

Highest amount of calcium recorded in monsoon (94 mg/l) is attributed to addition with rainwater runoff and lowest amount of calcium in winter to absorption of calcium by large number of organisms for shell construction, bone building and plant precipitation of lime (Solanki, 2012). Contrastingly decrease in calcium values has also been attributed to calcium being absorbed by living aquatic organisms in winter, while the amount of Ca increases during monsoon due to rapid oxidation of organic matter (Pulugandi, 2014). The high calcium (104 mg/l) has also been reported during summer in Duhok lake and lowest (30.6 mg/l) during spring in Dokan lake of Kurdistan region of Iraq (Toma, 2013). These variations in calcium hardness may be related to the geography of area, climate and seasonal variations, different biological activities in the water ecosystem, human activities, uses and due to addition of surface run off from agricultural and other catchment areas (Kumar *et al*., 2006). But contrasting results have been depicted by Yadav *et al.*, (2013) with higher values of calcium hardness in winter and lower in summer, whereas Hulyal and Kaliwal, (2009)

reported higher values in summer and lower in monsoon as is reported in present study at all the three reservoirs. Pandey *et al*., (2012) also reported maximum value of calcium hardness in May and minimum in August at Loharpur reservoir of Bhopal (M.P.) India.

Most calcium in surface water comes from streams flowing over limestone, $CaCO_3$, gypsum, $CaSO_4.2H_2O$ and other calcium containing rocks and minerals. The minimum values of calcium ion concentration during rainy season might be due to leaching to underground aquifers even higher concentrations of calcium ions from rocks and soils. Calcium carbonate is relatively insoluble in water, but dissolves more radially in water containing significant levels of dissolved carbon dioxide (Patil *et al*., 2013). Water bodies have been classified as, on the basis of calcium level poor (10.0 mg/l), medium (10.0 – 25.0 mg/l) and rich (> 25.0 mg/l) (Ohle, 1934). The order of the major cations in water is generally in a progression of Ca> Mg > Na > K (Rhode, 1949).

The weathering of rocks, surface run offs from surrounding water having high amount of calcium cation and less utilization of calcium by plankton and other aquatic organisms for their activity have also been attributed to contribute to higher calcium level during monsoon (Uchchariya, 2012). However high production rate and physiological activity of plankton are at their peak in winter and utilization of the calcium by them makes the lower calcium at its lower amounts. Higher calcium was also reported during summer due to the effect of bacterial decompositions of organic matter in the reservoirs (Harney *et al*., 2013).

Magnesium Hardness (Mg)

The general acceptable limit of Mg in fresh water is usually 50 mg/l whereas its maximum permissible limit is 100 mg/l (FCMR, 1975). Magnesium is found in various salts and minerals, frequently in association with iron compound and is vital micronutrient for both plants and animals. Dagaonkar and Saksena (1992) suggested that the magnesium is essential for synthesis of chlorophyll and acts as a limiting factor for growth of phytoplankton.

During present study maximum values of magnesium were recorded in summer at all three water bodies may be related to the uptake by macrophytes and algae in the formation of chlorophyll-magnesium–porphyrin–metal complex and also used in enzymatic transformation, especially in trans-phosphorylation by algae, fungi and bacteria as described by Wetzel, (2006). Magnesium hardness in water always

remains lower than that of calcium hardness. The magnesium appears as a carrier of phosphorus (Welch, 1952).

The maximum values of magnesium hardness recorded in summer may also be due to low water level and bacterial decomposition of the organic matter (Harney *et al*., 2013) whereas low level during monsoon may be attributed to distribution due to higher water level as compared to summer (Pandey *et al*., 2012; Toma, 2013). But contrasting results have been reported with highest amount of magnesium during monsoon, as associated with calcium (Qureshimtva *et al*., 2015) and lowest value during summer due to essentiality of magnesium for chlorophyll bearing plants for photosynthesis (Pawar and Pule, 2005).

Maximum seasonal average of magnesium hardness was recorded at Malpur dam and similar trends were observed in remaining two water bodies as was also reported in Periyar lake of Kerala(Krishnan, 2008). Because of the solubility characteristics of magnesium and its minor biotic demand, concentration of magnesium are relatively unchanging and fluctuate little in hard water streams (Wetzel and Qtsuki, 2006). In Pichola lake of Udaipur city of Rajasthan, the magnesium and calcium hardness recorded were higher in the month of March-April and lower in June–Aug (Chittora *et al*., 2017) as is also reported in the present study at all the three water bodies. The chemical denudation due to dilution from heavy rains coupled with reservoir circulation and weathering from rock and run-off from surrounding water shed might be contributing to the availability of calcium and magnesium ions. Maximum concentration of magnesium reported in summer (Lokhande, 2013). However, variation in magnesium during monsoon and winter period was negligible.

Chloride (Cl^-)

Chloride in the form of chloride ion, is one of the major anions in water and wastewater (APHA, 2012). The chloride concentration is higher in wastewater than in raw water because sodium chloride (NaCl) is a common article of diet and passes unchanged throughout the digestive system. Chlorides occur naturally in fresh waters as man and other domestic animals excrete chloride together with nitrogenous compounds.

Maximum permissible limit of Cl content in natural waters is 200 mg/l (WHO, 1965; TOMR, 1975; ISI, 1991). The most important source of chloride in the natural waters is the discharge of sewage and at very high concentration it gives a salty taste to the water. The concentration of salts in solution is critical to proper plant growth and it

affects taste and general suitability of drinking water (Hulyal and Kaliwal, 2011). High content of chloride in water may be because of pollution from chloride effluent of sewage and municipal waste (Gupta *et al*., 2009). High concentration of chloride is also considered to be the indicator of pollution due to organic waste of animal or industrial origin (Arya *et al*., 2013). These results of present study are corroborated with several studies with maximum amount during summer due to high temperature and high evaporation rate while lower concentration in monsoon due to dilution (Makode, 2012; Wankhede *et al*., 2012; Sawant and Chauvan, 2013; Toma, 2013; Qureshimatva *et al*., 2015). The presence of chloride, where it does not occur naturally, indicates possible water pollution (Munawar, 1970; Swarup and Singh, 1970).

Other contrasting results have been depicted by Yadav *et al*. (2013) where chloride content being maximum during rainy season is attributed to increase in the organic waste of human origin with rain runoff and minimum during winter.

The maximum chlorides recorded at Krishna park among the three reservoirs indicate more input of human origin due to tourism activities as the place is extensively used by picnickers and also smaller among the three reservoirs studied. The concentration of chlorides here are very low as compared to 250 – 1000 mg/l (ISI, 2012) desirable limits prescribed by WHO. Chloride concentrations are also considered as one of the basic parameters for classifying lakes polluted by sewage into different categories (Zafar, 1964). The higher chloride contents may be attributed to the presence of large amount of organic matter of both allocthonous and autocthonous origin (Pandit, 1999). Chloride is usually not dominant in open lake ecosystems (Wetzel, 2006) however, pollution sources of chlorides can modify natural concentrations greatly. During present study, seasonal fluctuations in chloride were recorded at all the three water bodies with significant positive correlation with AT, CO_2, Mg, pH and TDS while significant negative correlation with dissolved oxygen, NO_3, PO_4, TSS and water cover.

Nitrate ($NO3^-$)

Nitrate ($NO3^-$) is the common form of inorganic nitrogen entering fresh waters from the drainage basin in surface waters, ground water and precipitation (Wetzel, 2006). Human activities related to agriculture are the major cause of presence of nitrates and nitrites in surface water and also are responsible for environmental and health problems (Hamaidi-Chergui *et al*., 2013). The main source of nitrate in natural water

is the degradation and oxidation of nitrogenous organic matter. The presence of nitrate in freshwater bodies depends mostly upon the activity of nitrifying bacteria, domestic and agricultural sources (Murtuzasab *et al*., 2010).

During present study higher values were reported in monsoon at Krishna park reservoir probably due to influx of nitrogen rich flood water brings large amount of sewage as is also reported by Yadav *et al*., (2013). Hulyal and Kaliwal, (2004) reported low concentration of nitrate but with better concentration during post monsoon. The higher concentration of nitrate pose less serious environmental problem since it is relatively non-toxic to aquatic organisms (Prabhakaran *et al*., 2013). However, excess concentration of nitrate leads to eutrophication. Their presence can also be explained by an incomplete oxidation of the ammonia in water or a nitrate reduction reaction. The pollution due to nitrate can be caused by intense agricultural activity and misuse of chemical fertilizers (Hamaidi-Chergui *et al*., 2013; Elnagar and 51). Affy, (2016) also observed higher values of nitrates in Lissa El-Gamalia drain and attribute it to agricultural runoff in the drain. The nitrate concentration remained lower during the study period at three reservoirs. These lower nitrate concentration reported during present study indicate that water in the reservoir is not polluted as per WHO, 2011 and BIS 105000 standards.

In Idukki reservoir, nitrate values recorded were very low with comparatively higher (0.11 mg/l) during summer (Sebastean, 2012). The nitrate content ranging from 0.27 mg/l – 0.06 mg/l may be due to discharge of waste containing nitrate through runoff where higher values were recorded during rainy season (Lalparmawii, 2012). Whereas, contrasting results have been depicted with highest mean values during monsoon and lowest during summer and overall low level of nitrates due to utilization of nitrates by phytoplankton and macrophytes (Hulyal and Kaliwal, 2009). High concentration of nitrates during rainy season might be due to influx of nitrogen rich flood water at Mahagaon reservoir from Gadhinglaj, Maharashtra (Sawant and Chavan, 2013). The concentration and rate of supply of nitrate is intimately connected with the land use practices of surrounding watershed. Quite higher nitrates were recorded from Pandu lake in Andhra Pradesh leading to eutrophication where maximum value were recorded in June and lowest value in the month of August in contrast to present findings. The non-polluted tropical waters are generally deficient in nitrates, but the factors like discharge of sewage, runoff and nitrogen fixation may increase nitrogen concentration in water bodies (Ganapathi, 1960). Nitrogen in Indian

reservoirs is mostly in traces and seldom exceeds 0.5 mg/l Sugunan,(2000). The water with 0.2 – 0.5 mg/l of nitrates is of high productive nature, upto 0.2 mg/l of medium productive nature and in low concentration low productive nature (Jhingran and Sugunan, 1990). In any water body, the proportion of different forms of nitrogen is determined by the forms introduced and the balance between assimilation, mineralization, nitrification, denitrification and nitrogen fixation (Solanki, 2010). Usually fertilizers, municipal and industrial waste waters, agricultural wastes are the major sources of nitrogen in aquatic ecosystem. Meera *et al*., (2015) reported highest nitrates in monsoon due to influx of water and greater surface runoff in premonsoon, followed by monsoon and monsoon and lowest in summer. In present study at Malpur dam, Nitrates showed significant positive correlation with PO_4, TS, TSS and water cover while negative significant correlations with Cl, Mg, pH, SO_4, TDS, TH and transparency. At Harsool-Savangi dam, Aurangabad from Marathwada region of Maharashtra many parameters shared similar correlations, where nitrate showed high significant positive relationship with turbidity, electrical conductivity, total solids, TDS, TSS and TH and significant negative relationships with transparency (Shinde *et al*, 2011).

Phosphates (PO_4^-)

Phosphates occur solely as phosphates in natural waters. All forms of phosphates such as orthophosphates, condensed phosphates and originally bound phosphates are found in waters. Phosphate is added to land and water through different ways as phosphate containing fertilizers, animal manures and waste products from animals supplemented with phosphate enriched feed.

During present study higher values were recorded during monsoon at all the three water bodies. These results are corroborated with highphosphate at Almatti reservoir during monsoon attributed to influx of rain water containing fertilizers from the fields which brings phosphate from catchment area (Hulyal and Kaliwal, 2009; Shinde *et al*., 2011). Higher values in monsoon and premonsoon reported due to inflow of phosphate content from surroundings through runoff (Murthuzasab *et al*., 2010). Low content of phosphate in summer have been attributed to utilization of phosphate and recomposition by phytoplankton (Lokhande, 2013). In natural waters phosphorus range from 0.005 mg/l to 0.020 mg/l. The source of phosphate depends on geochemical condition and surface runoff from surrounding fields (Mathur *et al*., 2010). High concentration of phosphate give rise to algal blooms, which brings

eutrophication. Effect of human activities on the reservoir and its watershed reflected much on the variations seen in concentrations of phosphates, nitrates and possibly sulphates (Mustapha, 2008).

In freshwater most of the phosphorus is in a particulate phase of living biota, primarily algae and higher aquatic plants, with part of the colloidal and particulate fraction being lost by the productive zone by sedimentation and partly being hydrolysed to soluble orthophosphate (Wetzel and Likens, 1991). Ouma and Mwamburi, (2014) have reported that phosphorus in its various forms may become increasingly assimilated by the ongoing metabolic processes thereby being removed from the water column. Forms of phosphorus that are biologically available for plant growth include total dissolved phosphorus, ortho-phosphorus and soluble reactive phosphorus and therefore are better indicators of trophic status within waterbody (Sharifinia *et al*., 2013).

Minimum amount of phosphate recorded during winter in Lahru pond and maximum during monsoon (Kumar *et al*., 2014; Uchchariya, 2012; Abdar 2013) corroborate the present study during rainy season from the surrounding agriculture land due to surface runoff.

During natural process of weathering, the rocks gradually release the phosphorus as phosphate ions which are soluble in water. They occur as detritus in the bodies of aquatic organisms. Higher concentration of inorganic phosphate during winter in Derbendikhan Lake of Iraque can be attributed to the weathering of rocks to soluble alkali metal phosphates Toma (2013). Superphosphates applied in the agricultural fields as fertilizers and alkyl phosphates used in households as detergents can also be regarded as additional sources of inorganic phosphates during the season, whereas low values in summer at may be attributed limited inflow of water, high salinity and utilization of phosphate by phytoplankton.

During present study phosphate showed significant positive correlation with dissolved oxygen, TSS and water cover, while negative significant correlation with CaH, Mg, pH, SO4, TDS, and TH at Krishna park reservoir. Almost similar correlations have been reported at Harsool-Savangi dam, Aurangabad, Maharashtra (Shinde *et al*., 2011).

Sulphates (SO_4^-)

Sulphur exists in a number of oxidation states from most oxdised sulphates to the most reduced sulphide. Sulphate plays important role in soft water systems where

complete metal ion prevents reaction with other substances (Wetzel, 2006). It is present in fertilizers which contribute to water pollution and ultimately increase sulphate concentration in water body. Sulphate are also contributed from surface runoff water, which contains relatively large quantities of organic and mineral sulphate compounds (Shinde *et al*., 2011). Sulphate ions in surface water under natural conditions are due to the reactions of water with sulphate containing rock and with the biochemical and partly chemical oxidation of sulphates and other compounds of sulphur.

In present study, higher sulphate values recorded in summer season and lower in monsoon at Baldane reservoir are corroborated by Hulyal and Kaliwal, (2011) at Almatti reservoir of Karnataka. These highest values of sulphate at Almatti reservoir are expected to be due to sulphate release by decomposition of organic matter sulphate content ecorded during monsoon and postmonsoon, attributed to the dilution (Sebastian, 2012). Sulphate occurs in natural waters at a concentrations upto 400 mg/l to 1000 mg/l and causes water hardening in excess level (Darshini *et al*., 2018). During the study period sulphates exhibited prominent peak during summer at all the three water bodies as is also reported by Deka and Goswami, (2011); Deka, (2012); Meera *et al*., (2015); Nazir and Deka, (2016). Significant seasonal variations of sulphate content are reported at waste water during spring to 837.8 mg/l during summer, with an annual average of 586.5 mg/l at Mariout Lake, Egypt. However, contrasting results with higher concentration of sulphate could have come from leaching and runoff of nitro-phosphate and sulphate fertilizers from nearby farmlands.

In this drought prone area of North Maharashtra, presence of any waterbody have its own significance. Maximum physicochemical parameters assessed were under the permissible limits given by different agencies. Hence, the waterbodies are still not under any stress of pollution. But care should be taken to conserve these scarce waterbodies for future use.